V. Materials Processing and Metastable Materials Technology

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V-01
Solidification modeling for coupling prediction of porosity and segregation
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A theoretical model for simultaneously predicking the porosity and segregation in the structure solidified with a columnar dendritic interface is proposed, by analysing the redistribution behaviours of both gas element and the alloying elements during solidification process. To examine the validity of the model, numerical calculation is implemented for the cases of Al-4.5 wt.% Cu alloy with various initial gas concentrations. First, porosity formation is theoretically predicted, and the numerical calculation results are compared with Poirier’s. The present result is a bit smaller with a peak amount at late stage of solidification. Besides, the effect of different pressure contributions on gas bubbles formation is also calculated numerically. It is found that the depression driven by solidification shrinkage is minor compared with the contribution of surface tension. Then, a model for element segregation is derived with consideration of porosity formation, by substituting the feeding velocity of interdendritic liquid into the local solute redistribution model. Porosity formation in mush zone may reduce the suction of interdendric liquid, which is rich in solute, thus the segregation is relieved slightly. Finally, a method for theoretical coupling prediction of porosity and segregation is proposed.

V-02
A study on the escaping of entrapped gas from semi-solid metal
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Semi-solid die casting technology has great advantages at defects control and has been successfully used to produce high quality aluminum alloy components for several years. In this process, semi-solid metal is used which has higher apparent viscosity than liquid metal during flowing. Moreover, a low plunger velocity is used to avoid turbulence which is the main source of entrapped gas in conventional casting processes. But, entrapped gas is still a serious issue in semi-solid die casting process because gas may be entrapped in other ways, such as melting, turbulence in slurry preparation process, and confluence weld of slurry. The entrapped gas may retain in the semi-solid metal and lead to gas holes in casting, which is severely harmful to the strength of products. In this study, the escaping of entrapped gas from semi-solid metal was theoretically explored. The results showed that the entrapped gas cannot get away from semi-solid metal with high solid fraction. An experiment was designed to contrast the quantity of gas holes in melt before and after thixocasting process. The experiment results showed that a high level of gas holes in raw material led to a high level of gas holes in castings, which confirmed the theoretically explored results. This paper explained the importance of removing entrapped gas in pre-processes in high-solid fraction semi-solid die casting process and some advice was given at last.

V-03
Preparation and characterization of continuous through-porous pure aluminum flat pipes by depoling continuous casting
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1
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Through-porous pure aluminum flat pipes were fabricated continuously with a self-developed depoling continuous casting technology. An online measurement and control of mold temperature at free end of graphite core rods was realized, which was critical for the fabrication. The quality of flat pipes was characterized. The results show that the flat pipes can be successfully fabricated with the following process parameters: the melt temperature is 750 °C, cooling water temperature and flow volume are 20 °C and 400 L/h, heat insulating mattress thickness is 2 mm, mold temperature is 655~635 °C and drawing speed is 1~5 mm·min⁻¹. They have cross-section dimensions of 14×5 mm², aligned unidirectional pores diameter of 3 mm, pores number of 3 and internal and external smooth surface. The smaller the roughness of graphite core rods, the smoother is the surface of pores for the flat pipes. When the roughness of graphite core rods is 0.531 μm and 0.124 μm, the corresponding roughness of the surface of pores is 0.581 μm and 0.184 μm, respectively. The mold temperature at the free end of graphite core rods is kept at a low thermal temperature range which is 5~25 °C lower than the melting point of pure aluminum, which is necessary for stably depoling continuous casting.

V-04
Liquid phase separation and concurrent rapid solidification of immiscible Fe-Sn alloys
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Phase separation takes place in various immiscible condensed matter systems such as polymers, inorganic materials and metallic alloys, leading to the formation of either homogeneous dispersions or segregated microstructures. Among the numerous macrosegregation patterns evolving from phase separation, the core-shell and dispersed structures have attracted great research interest owing to their potential applications. Since the microgravity condition facilitates the establishment of spatially symmetrical temperature and concentration fields, the ground simulated space environment like the freely falling experiments inside drop tube is often applied to investigate the evolution process of core-shell structures. Meanwhile, the phase field theory provides an effective method to simulate the dynamic mechanisms of core-shell formation through the migration and coagulation of small globules produced by phase separation. Because the Stokes motion driven by the density difference of separated phase is suppressed to a considerable extent, the Marangoni migration of globules driven by the temperature and concentration gradients becomes a dominant factor for the phase separation process under microgravity state. The objective of this work is to investigate the rapid solidification mechanisms of immiscible alloys under the microgravity condition within drop tube. In addition to a systematic study by experiments, three dimensional phase field simulations are also carried out to visualize the dynamic process of liquid phase separation. In the meanwhile, fluid dynamics effects are taken into account to shed further light on the rapid solidification kinetics.

The experiments were performed in a 3 m drop tube, which provided a reduced gravity state for 0.78 s. The alloy was prepared from high purity elements of 99.99%Fe and 99.999%Sn in a high vacuum arc-melting furnace. Each sample had the mass of 4 g and was placed in a 13 mm ID15 mm OD160 mm quartz tube, which had a small orifice about 0.3 mm in diameter at the bottom and was installed on the top of drop tube. The drop tube was then evacuated to 2×10⁻⁴ Pa and backfilled with a gas mixture of He (99.995%) and Ar (99.999%) to 1×10⁵ Pa. The superheating to 100–150 K above the liquidus temperature was accomplished by induction
heating. After that, the bulk sample was dispersed into small droplets by high pressure Ar jetting gas, which fell down freely. The finally solidified samples were polished and etched with a solution of 1ml HF+1ml HNO₃+20ml CH₃CH₂OH+2ml H₂O₂ for 30s. Their solidification structures and solute distribution profiles were investigated with FEI Sirion electron microscope and INCA Energy 300 energy dispersive spectrometer.

The containerless rapid solidification of liquid Fe-Sn alloys were accomplished under free fall condition, and the process of phase separation and fluid microgravity dynamics analysis were investigated by modified Model H which was coupled with Marangoni migration velocity. The EDS analyses were also carried out to reveal the microstructures and solutal distribution characteristics:

The containerless microgravity solidification of Fe₅₀Sn₅₀ alloy results in three types of microstructures: homogeneous dendrites, uniform dispersions and multilayer core-shells. SEM analyses indicate that two to five layers core-shell structures are the dominant morphologies. Dendritic microstructures were formed only when the undercooling and cooling rate are high enough to suppress liquid phase separation. The 3-D dynamic phase field simulation demonstrates that the uniformly dispersive structure and the three to five layers core shells are all metastable transitional states of the liquid phase separation process. Whereas the two layer core-shell structure is the most stable morphology with the lowest chemical potential. Because Stokes motion is effectively prevented by the microgravity condition in drop tube, the two types of Marangoni migrations play the dominating role in the evolution of macrosegregated structures. In comparison, the solutal Marangoni migration velocity is always larger than the thermal Marangoni migration velocity. Thus the surface segregation and solutal Marangoni migration are the controlling factors for multilayer core-shell structures.

The liquid phase separation takes place for the liquid Fe₄₁.₅Sn₅₈.₅ alloy and results in the dispersed globues of Fe-rich phase distributed into the matrix of Sn-rich phase. EDS analysis demonstrates that significant solute trapping of α-Fe phase occurs during rapid solidification in the free fall condition. Meanwhile, the solubility of Fe in (Sn)₂ phase is larger than that in (Sn)₁ phase, which leads to the difference of the microstructural characteristics and growth modes during the rapid solidification. The phase field simulation illustrates that the homogeneous liquid phase experiences three evolution stages during the phase separation: nucleation, aggregation or coalescence, and Ostwald ripening, which is in accordance with the experimental results. The fluid dynamics analysis indicates that the solutal Marangoni migration velocity is always larger than the thermal Marangoni migration velocity, which drives the globules move rapidly outwards the droplet under the effect of the concentration field, and forms the large globules near the droplet surface.

V-05

Research on numerical simulation of die casting of copper rotor for high efficient electric motors
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For electric motors, copper rotors are significantly more efficient than aluminum ones. However, we should balance the properties of high efficiencies, low costs, small sizes and lower weights of the copper rotors. Die casting is always used in the manufacture of motor rotors, for its advantages of high production efficiency, high production quality and high precision. The two main challenges in copper rotor die-casting are the low tool life and the distribution of porosity. Numerical simulation is a cost-effective tool to visibly analyze the filling and solidification process. Through the study of numerical simulation, we can design a more reasonable die casting process, which can improve the casting quality and make the copper rotors a longer life and a higher stability. In this paper, we reported the results of an investigation of the effects of technological parameters including filling temperatures, die temperatures and pouring velocities on the copper rotors. The die-casting filling and
solidification processes for producing copper rotor in high-efficiency motor were studied by a fluid dynamics calculation software of FLOW-3D, which specializes in the accurate solution of transient, free-surface flows. The software is based on the finite volume method (FVM), which couples both the widely used Navier–Stokes and Fourier equations. As such, it is therefore believed to have a high accuracy by considering the heat loss during the filling stage.

Pure copper and H13 die steel were used in the simulation. The die casting parameters such as filling temperatures, die temperatures and pouring velocities were determined by using the orthogonal method. In the filling process, the fluid and temperature fields were analyzed, and the distribution of vol. fraction of entrained air and surface defect concentrations were also predicted in the simulation. The results can be used to indicate where the oxide film and the gas entrapment would appear in the castings. Simulating the solidification process can be also used to clearly predict where defects such as shrinkage and porosity may occur and then minimize them. The results will give effective guidelines to optimizing the processing parameters and selecting the die structures. Selected predictions from the simulation will be tested in a few experimental castings.

The numerical results show that the pouring velocity has the most significant influence on the filling time, the filling temperature less and the die temperature least. As for the filling properties, the effect of the pouring temperature is dominant. The pouring velocity is less significant for the solidification process in comparison with the filling temperature and the die temperature. By the analysis of the simulation results, the places of defect in the copper rotor were forecasted, and the reasons of the defect were well explained. Thus, the technological parameters can be improved in numerical simulation, and the simulation results will be validated further in practice.

V-06
Rapid solidification mechanism and microstructure evolution of Al-Fe-Si peritectic alloy under containerless processing condition
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Ternary Al_{42.23}Fe_{32.91}Si_{24.86} peritectic alloy was containerlessly solidified in a 3 m drop tube, the alloy droplets sized 110–975 mm were obtained. The dynamics mechanism of the alloy droplets during free fall were calculated based on Newton cooling model, the rapid solidification route, the microstructural evolution of the alloy droplets were revealed, and the micro hardness of them was measured. It is found that both the cooling rate and the undercooling of the alloy droplets increase with the decrease of their diameters, the maximum and minimum undercooling are 332 K and 56 K respectively. The solidification microstructure of the alloy droplets characterizes as different shapes of thin layer, there exist $\alpha$(Fe), $t_1$(AlFeSi), $t_2$(Al$_3$Fe$_3$Si$_2$) and $t_7$(Al$_{13}$Fe$_2$Si$_2$) phases, where $\alpha$(Fe) is the primary phase, $t_1$ and $t_7$ are the products of first and second peritectic transformation during the solidification. With the decrease of the droplets’ diameter, the spacing of the $t_1$ layer decreases, and its volume fraction sharply increases, while that of $\alpha$(Fe) obviously reduces. Also the solute contents of different phases are increasing with the undercooling, which means that there occurred obvious solute trapping effect during the rapid solidification under free fall condition. The micro hardness of the whole droplet and the peritectic phase are measured, it is found that they sharply increase as the droplets diameter decreases, which notes that the free fall condition can improve the mechanical property of the alloy.

V-07
The influence of processing parameters on surface quality of copper clad steel composite wires prepared
Copper clad steel (CCS) composite wires with the carbon steel core diameter of 8 mm and copper coating thickness of 1 mm were prepared by core-coating continuous casting method under argon protection. The effects of melt temperature, molten metal height and drawing velocity on the surface quality were investigated. The formation mechanisms of the surface defects were discussed. The results show that CCS wires with good surface quality can be continuously fabricated at a melt temperature of 1120 to 1200 °C, a molten metal height of 2 to 4 cm and a drawing velocity of 10 to 30 mm/min. Raising the melt temperature, increasing the molten metal height or decreasing the drawing velocity is in favor of improvements in the surface quality. Insufficient supplement of liquid copper during solidification shrinkage results in surface dimple, transverse hot cracking and exposed steel defect appear due to the frictional force between cladding metal and mold is larger than the tensile strength of cladding metal under high temperature.

V-08
The research on functionally graded carbide for metal cutting application
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Functionally graded carbides (FGCs) show significant potential for metal cutting applications. In this study, a brief summary will be made on the current FGC research. A special metastable FGC with fcc-rich surface layer (mainly Ti(CN) or TiN) is the research focus. This study shows that nitrogen plays the key role during sintering process. The functionally graded carbide of WC-TiC-Mo-Co prepared in this study show three-layer structure: the outer fcc-rich surface layer; the intermediate layer with abnormally large WC and high Co content; and the inner layer. TiC is the most critical component for the formation of fcc-rich surface layer. The higher content of TiC leads to the thicker fcc-rich outer layer, higher (Ti(CN) and/or TiN) content in the outer layer, and higher hardness of the fcc-rich outer layer. The formation mechanism for this fcc-rich surface layer is mainly the nitridation process between Ti and N. The three-layer structure has the combination of high wear resistance and high toughness, which is favorable for metal cutting applications.

V-09
Evidence for the transition from primary to peritectic phase growth during the solidification of undercooled Ni-Zr peritectic alloy
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The rapid solidification of undercooled Ni_{83.25}Zr_{16.75} peritectic alloy has been investigated by both electromagnetic levitation and drop tube processing methods. The maximum undercooling obtained by electromagnetic levitation method is up to 198 K and the measured dendritic growth velocity shows a steep acceleration at a critical undercooling of ΔT_{enθ}=124 K, which provides an evidence of the transition of the primary solidification mode from Ni_{7}Zr_{2} phase to peritectic phase Ni_{5}Zr. This is ascertained by combining the
temperature-time profile and the evolution of the solidified microstructures. Below the critical undercooling, the solidified microstructures are composed of coarse Ni$_7$Zr$_2$ dendrites, peritectic phase Ni$_5$Zr and eutectic structure. However, beyond the critical undercooling, only a few amount of Ni$_7$Zr$_2$ phase appears in the solidified microstructure. For large droplets solidified in the drop tube, the microstructures also consist of primary Ni$_7$Zr$_2$ phase, peritectic phase Ni$_5$Zr and eutectic structure. The competitive nucleation and growth between Ni$_7$Zr$_2$ and Ni$_5$Zr phases become intensive as droplet diameter decreases. The microstructures are composed of only peritectic phase Ni$_5$Zr once the droplet diameter is less than a critical value, $D_{\text{crit}}$, which is determined in the range of 226 to 67 $\mu$m. This indicates that Ni$_7$Zr$_2$ phase preferentially to nucleate and grows when the droplet diameter exceeds the critical value ($D_{\text{crit}}$). Once the droplet diameter is smaller than the critical value ($D_{\text{crit}}$), peritectic phase Ni$_5$Zr directly solidifies from the undercooled melt by completely suppressing the nucleation and growth of primary Ni$_7$Zr$_2$ phase, which is ascribed to high undercooling and cooling rate.

V-10

Microstructure design of high superelasticity and martensitic transformation critical stress in Cu-Al-Mn shape memory alloys

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Cu-Al-Mn shape memory alloys (CAM-SMAs) that exhibit excellent shape memory effect, superelasticity, capability of energy absorption, as well as low cost and good cold workability have wild potential applications in civil construction, micro-electromechanics systems, etc. The properties of CAM-SMAs strongly depend on its microstructure. For example, the superelasticity (SE) and the martensitic transformation critical stress (MTCS) of ordinary polycrystalline CAM-SMAs is only ~3% and not more than 400MPa. Although the superelasticity of CAM-SMA single crystal can reach to 10%, the MTCS is so low (~100 MPa) that seriously limits in many potential applications due to the low driving force can provide and fatigue strength. Therefore, it is very important to find out a way to develop a CAM-SMA with high SE and high MTCS based on microstructure design. In present paper, firstly, the effects of some essential microstructure factors such as grain orientation, grain size, morphology, type and distribution of grain boundaries on superelasticity were evaluated to propose the prior principles of microstructure design for high-superelastic CAM-SMAs. According to the prior principles, a columnar-grained CAM-SMA was prepared by unidirectional solidification technique. Some advantageous characteristics in the columnar-grained CAM-SMA such as strong orientation and straight low-energy grain boundaries assist in obtaining a high superelasticity of above 10% in the alloy. Secondly, the columnar-grained CAM-SMA was remarkably strengthened by bainite phase that was precipitated during a heat treatment at the temperature of 250–400 °C. At last, a high-performance CAM-SMA with high SE (5%–9%) and high MTCS (443–677 MPa) was obtained.

V-11

Four-phase dendritic model for macrosegregation, shrinkage cavity, and porosity prediction of a 55-ton ingot

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A four-phase dendritic model was extended from previous two-phase dendritic model for the better prediction of
macrosegregation, shrinkage cavity, and porosity during solidification, under the consideration of dendritic structure for equiaxed crystals, melt convection, crystals sedimentation, nucleation, growth, and shrinkage of solidified phase. With the contraction of solid phase, air was sucked into ingot and leading to shrinkage cavity after solidification. A modified criterion was established in such four-phase model to predict shrinkage porosity (microporosity) of a 55-ton industrial Fe-3.3 wt.% C ingot. The final macrosegregation pattern and shrinkage cavity shape were in good agreement with experimental results. The results indicated that the shrinkage cavity extensively affects the formation of positive segregation in hot top region which generally forms in the final solidification stage for ingot casting. The dendritic equiaxed grains play an important role on A-segregation. Moreover, a 3D case simulation was calculated revealing a 3D laminar structure of A-segregation in industrial ingot for the first time.

V-12
Thermophysical properties of highly undercooled liquid Ni7Zr2 alloy
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The thermophysical properties of alloys, especially in highly undercooled liquid state, are the indispensable parameters for composition design, modeling solidification process, controlling microstructure, and improving application performance. Electrostatic levitation technique was utilized to achieve high undercooling of Ni7Zr2 alloy. The thermophysical properties of liquid alloy can be precisely determined by contact-free photoelectric detection methods. The maximum undercooling 317 K (0.185\(T_L\)) of Ni7Zr2 alloy was achieved in experiments under the containerless condition. The density of superheated and undercooled liquid Ni7Zr2 alloy exhibits a linear increase with undercooling. The density at liquidus temperature and its temperature coefficient were determined to be 7.66 g\(\cdot\)cm\(^{-3}\) and 0.71\(\times\)10\(^{-3}\) g\(\cdot\)cm\(^{-3}\)\(\cdot\)K\(^{-1}\), respectively. According to the measured density, the volumetric expansion coefficient at \(T_L\) was obtained as 9.04\(\times\)10\(^{-5}\) K\(^{-1}\). The thermal expansion of liquid Ni7Zr2 alloy will be enhanced with the increase of undercooling. The specific heat to emissivity ratio displays a linear rise with the increase of temperature and decrease of undercooling. The value of ratio at \(T_L\) and temperature coefficient were measured to be 141.93 J\(\cdot\)mol\(^{-1}\)\(\cdot\)K\(^{-1}\) and 7.95\(\times\)10\(^{-3}\) J\(\cdot\)mol\(^{-1}\)\(\cdot\)K\(^{-2}\).

V-13
Droplets evolution in the immiscible gap of Zn-Bi immiscible alloys under high static magnetic fields
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In-situ solidification experiments of Zn-4wt.%Bi and Zn-6wt.%Bi immiscible alloys were carried out to investigate the droplets evolution under the effect of high static magnetic fields (HSMFs). Sample was put in the uniform heating region of electric resistance heating furnace which was inserted in the bore of HSMF facility. The heating temperature was 700 °C and held for 1 h. After the holding time, the melt was cooled down to the ambient temperature at different cooling rates without or with a vertical HSMF respectively. HSMF was switched on at the 30th minutes in the holding time and switched off after the quenching process. The experiments done under the HSMF of 6 T were carried out in a super conductive
magnet with an 80 mm room temperature bore in Shanghai University. The residual experiments were carried out in a Bitter resistance magnet with a 50 mm room temperature bore in LNCMI. For both Zn-4wt.%Bi and Zn-6wt.%Bi immiscible alloys, microstructure with extremely fine Bi-rich particles distributed in the matrix can be obtained under 29 T HSMF. The average diameter of Bi-rich phase was decreased with the increase of magnetic flux density. Stokes sedimentation disappeared when the HSMF was larger than 18 T. Bi-rich droplets grew as a way of pure diffusion in the liquid matrix when the HSMF started from 18 T. The microstructures were different for the different cooling rate in HSMF. The effects of HSMF on the solidification process of Zn-Bi immiscible alloys were investigated. The following conclusions can be obtained:

1. Zn-4wt.%Bi and Zn-6wt.%Bi immiscible alloys with extremely fine of Bi-rich particles (average diameter is about 3.8 μm) dispersed in the matrix was successfully obtained under 29 T HSMF.
2. The refinement of Bi-rich droplets was attributed to the additional magnetic Gibbs free energy when imposing 29 T HSMF.
3. Marangoni migration and especially Stokes sedimentation of Bi-rich droplets can be suppressed by superimposing HSMF. Stokes sedimentation disappeared when HSMF was larger than 18 T.

V-14
Preparation and mechanical properties of Ti3AlC2/Cu co-continuous composites by pressureless melt infiltration
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Metal-Ceramic interpenetrating composites consist of co-continuous matrices of discrete metal and ceramic phases. The goal is to develop superior multifunctional properties compared with traditional MMCs with a view to using these composites in applications including electrical contacts, electrical components and wear resistance in industries including aerospace, automotive and high-speed railway, amongst others. In this paper, a pressureless infiltration technique was used to produce co-continuous composites by infiltrating molten copper into a range of Ti3AlC2 foams in-situ produced from Ti, Al, Sn and TiC powders. Processing conditions for different material systems have been determined. The microstructure and mechanical properties of the composites are investigated. The results shows that, during the pressureless infiltration process, some Ti3AlC2 particles are decomposed into the TiC0.67 phase, while the additional Al atoms provided by Ti3AlC2 diffuse into the molten Cu matrix at high temperature, resulting in a strong interface of the composites. The co-continuous composites have good mechanical properties. The ultimate compressive strength of the composites reaches 1033 MPa and keeps a high plastic strain at fracture of 25.3%, the bending strength and fracture toughness KIC is of 810 MPa and15 MPa-m1/2, respectively.

V-15
Modeling and simulation of spray formed bimetallic gradient composite board by ANSYS
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In order to determine the spray forming process parameters of bimetallic gradient composite board using two gas atomizers, a shape model of the board has been established by use of the simulation calculation software ANSYS. The calculation of Si element distribution in the deposits has been incorporated into the shape model. The influence of deposition board shape and composition distribution by different tracking movement, forward speed, swing cycle and the spray center distance have been simulated using the APDL programming language. The results show that the surface of the board is smooth and uniform in a regular broken line mode. The shape of the deposition broad is varied from the flat platform to the stepped shape with the center distance of the atomization cone increasing from 0.02 m to 0.05 m. Meanwhile the thickness of the gradient distribution becomes more obvious and the width of the transition zone decreases gradually. The deposition broad is mainly influenced by the swing period. As the period of oscillation increases to 8 s, the composition distribution of each layer presents a jagged fluctuation. Both thickness of deposited board and width of the transition zone decreases as the forward speed increases, except the composition distribution. Finally, the modeling and simulation of the spray forming of bimetallic gradient composite board have been validated by experimental investigations and the simulation results are in good agreement with the actual results.

V-16
Combustion synthesis: A rapid way for preparing bulk Cu2SnSe3 thermoelectric materials
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Thermoelectric materials are attractive for solar thermal energy conversion and waste heat recovery. The existing methods for preparing thermoelectric materials involve multi-step processes with considerable time and energy consumption. Here we apply a direct and rapid way of gas pressure assisted combustion synthesis to produce thermoelectric materials. As an example, bulk samples of Cu2SnSe3 have been prepared and their thermoelectric properties are investigated. Thermal analysis indicates that the Cu2SnSe3 samples keep stable up to 850 K. The un-doped Cu2SnSe3 shows ZT of 0.51 at 773 K, and by doping with Ag and In the ZT can be much increased to 1.42 at 823 K. Our work offers an ultrafast, one-step, and furnace-free approach to the fabrication of thermoelectric materials, by which nearly full-dense thermoelectric materials can be produced in a few seconds and with less energy consumption.

V-17
Microstructure and mechanical properties of co-continuous TiCX/Ni composite by pressureless infiltration from Ti3AlC2 and Ni alloy
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Porous Ti3AlC2 MAX-ceramic preform containing continuous porosity about 5-50 μm in size was prepared by in-situ reaction method. As precursor, Ti3AlC2 decomposed into substoichiometric TiCx phase while melting Nickel-base alloy infiltrating into Ti3AlC2 ceramic. It was found that in the process of infiltration the Al atom was capable of dissociating from Ti3AlC2, and continued with further reaction with Nickel-base alloy, phases like Ni3(Al,Ti), Cr2Ni2Si, CrB, etc. were generated. The interfacial morphology was observed by SEM, and the phases produced were characterized by EDS and XRD. The hardness, yield stress σ0.2% and ultimate compressive strength of TiCx /Ni composite could reach 7.42 ± 0.16 GPa, 1.87 ± 0.15 GPa, 2.85 ± 0.13 GPa,
respectively. The enhanced mechanical properties profited from ceramic skeleton composed of TiC<sub>x</sub> particles and three-dimensional network structure filled with Nickel-base alloy.

V-18

Effective fabrication of novel metal matrix composites by friction stir processing

Bo-Lyu Xiao, Zhen-Yu Liu, Ding-Rui Ni, Zong-Yi Ma

Effective Fabrication of Novel Metal Matrix Composites by Friction Stir Processing

Friction stir processing (FSP) is a highly effective modification method for metals due to its complicated thermo-mechanical process. It has also been applied to fabricate metal matrix composites (MMC). FSP exhibited good capability for controlling interface reaction and distribution of reinforcing phases especially for nano scale reinforcements. Also, it is a short route and high effective method for MMC fabrication. Due to severe plastic deformation, FSP dispersed nano-scale reinforcements uniformly with high efficiency. For instance, carbon nanotube (CNT) was uniformly dispersed into Al matrix by several pass of FSP. A good combination of ultimate tensile strength of 600 MPa with high elongation of 10% was achieved in the FSP CNT/Al. Meanwhile, FSP could activate in-situ reaction, thereby producing dispersion strengthened Al composites with high content nano particles, such as Al<sub>3</sub>Ti/Al. Due to short thermal cycling, FSP could inhibit harmful interface reaction. A NiTi/Al was fabricated using FSP, which exhibited good shape memory effect. Compared to traditional powder metallurgy or stir casting techniques, FSP fulfilled high strengthening effect of reinforcements. It is hoped that FSP will be developed to be a future technique for MMC fabrication.

V-19

Ultrasonic processing and structural evolution of hypoeutectic Al-8%Si alloy

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Hypoeutectic Al-Si alloys are widely used aluminum alloys due to their good mechanical properties. The modification of both primary (Al) phase and (Al+Si) eutectic structure is of great interest since their refinement can significantly promote the strength and ductility. The application of power ultrasound to liquid or semi-liquid alloys is an effective way to improve the solidification microstructure. In present work, in order to investigate the effect of ultrasound on microstructural evolution of hypoeutectic Al-Si alloys, high intensity ultrasound is respectively introduced into the different solidification stages of solidifying Al-8%Si alloy.

When ultrasound is applied during the liquid cooling stage before nucleation, the primary (Al) phase grows into the equiaxed shape with an average size of 300 mm, which is almost ten times finer than those coarse dendrites during static solidification. This indicates that the power ultrasound results in more potential nucleation sites and consequently contributes to the refinement of primary (Al) phase. Once the ultrasound is employed during the nucleation and growth process of primary (Al) phase, globular (Al) grains with an average diameter of 35 mm are formed. This suggests that the cavitation-enhanced nucleation mechanism due to the high undercooling caused by the collapse of tiny cavities is the major reason for refining. In contrast, if the ultrasound is introduced only during the eutectic transformation, the resultant primary (Al) phase is characterized by coarse (Al) dendrites, and some dendritic fragmentation is observed, implying that the cavitation-induced dendritic fragmentation also plays some role in refining primary (Al) phase.

The (Al+Si) eutectic structure during static solidification is featured by very coarse (Si) plates distributed on (Al) matrix. When ultrasound is introduced into the eutectic growth process, divorced (Al+Si) eutectic structure is
formed at the alloy sample top, in which small globular (Al) phase and blocky (Si) phase grow individually. This is because the local high undercooling induced by cavitation promotes the two eutectic phases to nucleate independently, and the strong micro-jet efficiently suppresses their coupled growth. In the lower part where the cavitation is not so intensive as the sample top, (Al+Si) eutectic cells are found to originate from the center and grow epitaxially into a flower-like shape. The acoustic streaming ensures the radial symmetry of both the local concentration and temperature fields, and thus the solid-liquid interface is locally symmetric in three dimensions. Both the eutectic spacing and the size of eutectic (Si) phase are much smaller than those under static condition, indicating that power ultrasound also brings about remarkable refinement effect on Al-Si eutectic growth.

V-20

New insights into the mechanism of austenite decomposition into ferrite and bainite in low alloy steels
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This work aims to shed new light on alloying element effects on the migrating interfaces during the austenite to ferrite and bainite transformations in low alloy steels. For this purpose, a cyclic partial phase transformation approach has been designed to reveal the redistribution character of alloying elements and its effect on the austenite-ferrite transformation kinetics in a serials of Fe-C-M alloys (M= Mn, Ni, Co, et.al). During the cyclic partial transformations two special stages are observed: (i) Stagnant stage, in which the degree of transformation does not vary while the temperature changes; (ii) Growth retardation. The interface migration temporarily slows down at a particular stage of the final cooling after the cyclic phase transformations, and it eventually reaches a normal transformation stage due to an increase in undercooling. The new experimental results have been compared with the predictions of the classical paraequilibrium (PE) and local equilibrium (LE) models, and it allows a clear discrimination between the correctness of these two models.

A so called Gibbs Energy Balance (GEB) model, in which the dissipation of Gibbs energy due to diffusion inside the interface and interface friction is assumed to be equal to the available chemical driving force, is proposed to describe the kinetics of the austenite to ferrite and bainite transformations. The GEB model is a general model, of which the PE and LE models are two extreme cases. The GEB model has been successfully applied to predicting the transformation stasis phenomenon (Incomplete transformation phenomenon) during both the austenite to ferrite and bainite transformations in a serials of low alloy steels.

V-21

Solidification velocity scope for coupled growth of solid and gas phases during Gasar solidification
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In Gasar solidification, there exists an appropriate solidification velocity scope for the coupled growth of solid and gas phases, otherwise we can’t obtain ideal Gasar porous structure. In this presentation, we will introduce the theory and method to establish the solidification velocity scope for the coupled growth. In addition, the effects of the processing parameters and the thermophysical parameters will be analyzed. The differences of the solute distribution coefficient ($k_0$), diffusion coefficient ($D_L$) and the constant of solubility of hydrogen ($\xi(T_m)$) in the melt are regarded as the main reasons of the big discrepancy of solidification velocity between different
Dendrites are the most frequently observed evolution morphology of solid-liquid interface during solidification of metallic alloys. Understanding the mechanism of dendritic growth has aroused extensive research interest in both materials and physics fields. Many researchers carried out solidification experiments to investigate dendritic morphology stability and microstructure transition. The dendritic growth theoretical models and simulation methods has also been developed systematically near equilibrium conditions. However, the large deviations from thermodynamic equilibrium induced by rapid solidification significantly modified the solidification processes compared to those obtained at or near the equilibrium conditions. The resulting final mechanical properties can be modified strikingly by the refinement of microstructure and the extension of solubility. Such rapidly solidified microstructures often lead to improved properties such as higher hardness, better fatigue resistance or improved corrosion resistance. However, the relationship between high undercooling, rapid dendritic growth, solute content variation and microhardness is still unclear to us.

Here, ternary Ni-5%Cu-5%Sn and Ni-10%Cu-10%Sn alloys are taken as the model compositions, to investigate the variation of solidification kinetics and mechanical properties with the melt undercooling. The Cu and Sn alloying elements are selected to investigate the influence of solute content on the dendritic growth mechanism and mechanical property of Ni-based alloys. In order to achieve rapid solidification and high undercooling, glass fluxing technique is utilized to explore the relationship between dendritic growth characteristics, microhardness, solute content and bulk undercooling. Netzsch 404C DSC, Rigaku D/max2500 XRD and FEI Sirion 200 SEM, and HXP-1000TM microhardness tester are used to investigate the related properties.

At the experimental maximum undercoolings of 304K (0.18TL) and 286K (0.17TL) in ternary Ni-5%Cu-5%Sn and Ni-10%Cu-10%Sn alloys, the dendritic growth velocity attains 39.8 and 25.1 m/s, respectively. Large undercooling arouses the morphology transition from coarse dendrite into equiaxed dendrite and the lattice distortion from a small lattice constant to a larger one. With the increase of undercooling, the grain size of α(Ni) phase decreases remarkably from about two thousands of microns to twenty microns. At the maximum undercooling of 304 and 286 K, the microhardness of α(Ni) phase attains 142 and 173 HV, respectively. The rise of Cu and Sn solute contents reduces the dendritic growth velocity, but enhances the microhardness of α(Ni) phase. The variation of microhardness is mainly caused by the solute strengthening and lattice reinforcement.

High undercooling is achieved in ternary Ni-5%Cu-5%Sn and Ni-10%Cu-10%Sn alloys by glass fluxing methods. High undercooling arouses the rapid growth of α(Ni) phase in these two alloys. However, the further increase of the solute content suppresses the α(Ni) dendritic growth. Both the high undercooling and solute strengthening have a comparable effect in the microhardness enhancement of ternary Ni-Cu-Sn alloys.

Compared with the common electrical steel, the high silicon electrical steel (Fe-6.5wt.%Si alloy) exhibits
excellent soft magnetic properties and a wide application prospect in high frequency electromagnetic fields. However, the inadequate ductility and limited formability are the two well-known bottlenecks that severely limit the widespread engineering application of Fe-6.5wt.%Si alloy.

In the process of cold rolling, Fe-6.5wt.%Si alloy shows serious edge crack phenomenon, which seriously affects its process of industrialization. In this study, composite slabs of the warm rolled Fe-6.5wt.%Si alloy with 304 stainless steel at both edges were welded by YLS-6000 IPG fiber laser. The composite slab could be cold rolled to a thickness of 0.05 mm without obvious edge crack. A new technical prototype for selecting edge materials was proposed to the wide use of edge welding method.

V-24  
Studies on localized material properties in low transformation temperature weld
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The low transformation temperature (LTT) phenomenon is exploited for the reduction of harmful residual stresses in high-strength low-carbon steel weld. In this study, we focus on localized material properties in fusion zone (FZ) and heat affected zone (HAZ), where complex thermal-mechanical cycles in multi-pass welding process undergo, and those in the base metal (BM).

Methods: Two butt-welded plates are prepared by automatic submerge arc welding method. The first plate is a conventional weld (CW) with 7 welding passes and the second plate has 2 basal conventional welding passes followed by 9 subsequent LTT welding passes. At first, optical microscopy (OM) and scanning electron microscopy (SEM) observations are employed to reveal microstructural variations in different locations. Energy dispersive spectroscopy (EDS) inspection is also performed to examine constituent evolution along transition areas. Besides, tensile tests are conducted on samples extracted from each region and micro-hardness mapping is performed on the weld cross-section with a load of 0.3 kg for 10 s.

Evolution of grain size due to thermal history varying from FZ to BM is well confirmed on both plates. A ferrite phase is found in all areas in the first plate, whereas both martensite phase and retained austenite phase are found in FZ of the LTT weld in second plate due to the martensitic transformation during cooling. The main findings are the tensile results. It shows that the yield strength (YS) and ultimate tensile strength (UTS) are 540 and 665 MPa respectively at the last welding pass area of the first plate. Meanwhile, it is significantly enhanced to 1000 and 1280 MPa respectively for the second plate. Note that HAZ is strengthened in first plate, but in contrast it is weakened in the second plate. In addition, the transition area of the second plate is very brittle due to discontinuous microstructure. Chemical composition changes, hardness variations, and microstructural details will be presented.

Characterization of localized material property highlights significant difference between LTT and conventional welds. Using LTT weld, martensitic transformation can be beneficial for reducing harmful residual stress and for providing strengthened material, while there exists discontinuous microstructure and material properties in different regions, resulting in brittleness, which might arise as a potential threat.

V-25
Pitting corrosion behavior of friction stir welded joint of high nitrogen stainless steel
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High nitrogen stainless steel (HNS), as a relatively new kind of engineering material, has gained more and more attention, due to the favorable mechanical and corrosion properties. The wide application of HNS in industrial fields requires effective and reliable joining methods. However, the high nitrogen content brings some difficulties in the welding of HNS.

Friction stir welding (FSW) may become one of the promising joining methods of HNS due to its distinct advantages, which could achieved a well joints with high strength. Although the HNS joints with good mechanical properties can be achieved via FSW, the studies on the corrosion properties of the FSW HNS joints are relatively limited. In this study, the microstructure and pitting corrosion resistance of FSW HNS joints are investigated.

1.8 mm thick hot-rolled HNS plates were used in this study. FSW was performed at a welding speed of 50 mm/min and a tool rotating speed of 500 rpm, using a W-Re alloy tool with an 11-mm-dia shoulder and 5.7-mm-dia cylindrical pin. An argon gas shield was employed during the welding process to prevent the oxidation of the joint. The microstructure were analyzed by SEM, EBSD and TEM. Ferric chloride pitting test was used to evaluate the corrosion resistance of the welded joint, following Method A in ASTM G48 standard. The quantity and size distribution densities were statistically analyzed based on OM observation. Electrochemical tests were carried out using a three-electrode electrochemical cell, i.e. saturated calomel reference electrode (SCE), a planar Pt counter electrode and the sample as a working electrode.

No drastic decrease in breakdown potentials was observed in the heat affected zones with number and size distribution densities of pits being similar to that in the base metal. The nugget zone exhibited a relatively good pitting corrosion resistance, mainly attributing to the breakup of coarse inclusions and grain refinement during welding. The δ-ferrite bands and tool wear exerted no obvious effects on the corrosion behavior of the welded joint due to the lack of Cr diffusion. The welded joint shows relatively high corrosion resistance.

V-26
Quantification of microstructure in two-phase zone continuous casting Cu–Sn alloy and a model for quantitative relation between microstructure and processing parameters
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Based on orthogonal tests, Cu–4.7 wt%Sn alloy with diameter of 10 mm was prepared by two-phase zone continuous casting (TZCC) with the following processing parameters: melt temperature of 1080–1200 °C, mold temperature of 1005–1050 °C, continuous casting speed of 5–35 mm/min, cooling water temperature of 15–30 °C and cooling distance of 5–20 mm. It is characterized that the as-cast microstructure mainly contains large columnar grains, some of which contain small grains, resulting in the so-called “grains-covered grains”. The microstructure is quantified comprehensively from the following aspects: the sizes of columnar and small grains, the numbers of columnar grains with or without small grains, the numbers of small grains at columnar grain boundaries or at alloy surface, and the maximum and the minimum numbers of small grains in a columnar grain.
A model constructed by BP artificial neural network is developed to output the above aspects of microstructure with TZCC processing parameters as inputs, which yields high precision. The ways of the model construction and the microstructural quantification can be applied to other studies concerning about a quantified relationship between microstructure and processing parameters of continuous casting, which lays foundation for precise microstructure controlling.

V-27
Morphological control of Mg$_2$Si phase in Al alloys
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Primary Mg$_2$Si crystals in cast Al alloys display various geometric shapes, such as octahedron, hopper, truncated octahedron, cube and enormous dendrite. The morphology of Mg$_2$Si is related to the properties of Al alloys. So in the present paper, the morphological evolution and the growth mechanism of Mg$_2$Si in Al alloys were studied in terms of basic crystal growth theories and detailed observation of three-dimensional morphology of the Mg$_2$Si phase. Mg$_2$Si tends to form faceted octahedron (equilibrium shape) with minimized total surface free energy. However, the growth velocities of the and directions can be manipulated by means of external growth conditions, which are responsible for the evolution of Mg$_2$Si crystals into other morphologies. The result is useful for realizing the artificial manipulation of the solidification process and morphological evolution of Mg$_2$Si.

V-28
Thermodynamic database of the Al-Mg-Si-Sc quaternary system and its application to design novel A356 alloys with low Sc addition
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Based on the available experimental phase equilibria in the literature, a thermodynamic database of the Al-Si-Mg-Sc quaternary system was established by using the CALPHAD technique. The reliability of the established thermodynamic database was further validated in two self-designed Al-Si-Mg-Sc quaternary cast alloys, Al-7Si-0.6Mg-0.4Sc and Al-7Si-0.6Mg-1.2Sc (wt.%), based on their experimental microstructure information and phase transition temperatures.

With the aid of the Gulliver-Scheil solidification simulations, the influence of Sc levels on the solidification behavior in A356 cast aluminum alloys was comprehensively analyzed. By mapping the A356 alloys with Sc addition up to 1.0 wt.%, it was found that the cast A356 alloy with around 0.54% Sc addition owns the optimal microstructure and mechanical properties. The further experimental microstructural characterizations and mechanical property measurements confirmed the theoretical design, and indicated that the optimal additional amount of Sc into the cast A356 alloys is 0.52–0.54 wt.%.

V-29
Bimodal titanium alloys processed by semi-solid sintering: processing mechanism, microstructure and
mechanical behavior
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We report on a novel approach to fabricate TiNbCoCuAl alloys with a bimodal microstructure, using semi-solid sintering. In our work, the bimodal microstructure consists of a nanostructured matrix surrounding micron-sized CoTi2 twins. This bimodal architecture differs in fundamental ways from other bimodal microstructures reported thus far in the literature. Moreover, we report that the formation of this bimodal microstructure occurs in four related but distinct stages during sintering: 1) Spatial rearrangement of nano-composite powders; 2) nucleation and growth of β-Ti and CoTi2 phases; 3) formation of a semi-solid mixture containing molten CoTi2 and solid β-Ti phase; and 4) final evolution of a bimodal microstructure containing rapidly cooled nano-sized acicular α' martensite that precipitated from micron-grained β-Ti matrix and solidified micron-sized CoTi2 twins.

Interestingly, the yield stress, ultimate compression strength and plastic strain values corresponding to this bimodal structural alloy were 1611 MPa, 3139 MPa and 38.7%, respectively, which represent the highest values reported thus far in the literature. We discuss the mechanisms responsible for the high strength in terms of the presence of a nanostructured α' phase and the strengthening effect of micron-sized CoTi2 twins. Moreover, the high plasticity can be ascribed to a high density of slip bands in micron-grained β-Ti matrix and associated strength potency of the nano-sized α’ phase and the micron-grained CoTi2 twins. Our work provides fundamental insight into the challenges posed by the fabrication of novel structural materials with a high melting point for demanding structural applications.

V-30
Dendritic solidification in undercooled Au-9wt.%Ni melts
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In this work, the effect of melt undercooling on the solidification microstructure of Au-9wt.%Ni alloy is investigated using glass fluxing technique combining with cyclical superheating within the achievable undercooling range (0 to 130 K). The experimental results reveal that the dendritic morphology of Au-9wt.%Ni alloy is significantly associated with undercooling (ΔT). When ΔT is less than 20 K, the as-solidified morphologies are similar to conventional as-cast highly branched dendrites. In the undercooling range of 20 K to 70 K, the brittle fracture of dendrites occurs and results in the appearing of granular dendrite segments. When ΔT is larger than 70 K, largely developed fine dendritic morphologies are observed and the dendrite arm spacing decreases along with increasing undercooling. Notably, directional dendritic growth occurs when ΔT increases to 70 K, the brittle fracture of dendrites occurs and results in the appearing of granular dendrite segments. When ΔT is larger than 70 K, largely developed fine dendritic morphologies are observed and the dendrite arm spacing decreases along with increasing undercooling. Notably, directional dendritic growth occurs when ΔT increases to 130 K. Furthermore, the transition mechanisms of dendritic morphology are systematically discussed based on dendritic growth theories. Theoretic calculations show that constitutional undercooling plays a leading role in solidification when ΔT is less than 68 K. When ΔT is above 68 K, heat diffusion plays a primary role and solute trapping effect improves obviously as ΔT increases. The calculating results also reveal that the brittle fracture of dendrite takes place when the time required for dendrite break up is longer than that for post-recoalescence solidification.
Phase separation and designed metallic glasses

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Phase separation phenomena are very universal in some materials including metal/alloys, ceramics and polymers. The liquid-liquid phase separation into two immiscible liquids with different compositions and/or structures takes place when the melt is undercooled in the immiscibility gap. For some alloys, liquid immiscible systems present a unique opportunity in designing new metallic materials if we are able to understand the solidification process of the immiscible alloys. Here, I would talk about the liquid-liquid phase separation and the solute distribution in the two coexistent immiscible liquids. The solidification behavior and phase transformation of the two coexistent liquids have been discussed. Three examples are discussed how to design metallic glasses and their composites with different structures and properties using the liquid-liquid phase separation phenomena.

The first example. Al-Pb and Ni-Ag systems are typical immiscible systems. The liquid phase separation into Al-rich and Pb-rich liquids and into Ni-rich and Ag-rich liquids takes place for Al-Pb and Ni-Ag systems, respectively. Based on these binary systems, the multicomponent immiscible alloys were designed. The particle-type-structure composite with the spherical crystalline Pb-rich particles dispersed in the Al-rich amorphous metal matrix has been fabricated, and the Self-assembled double-layer-structure and sandwich-type-structure composites with crystalline Ag-rich and amorphous Ni-rich layers were developed. The structure among the particle-type, double-layer and sandwich-type structures is tunable by changing alloy compositions. Compared with the traditional fabrication of metallic glasses matrix composites, a new route utilizing liquid-liquid phase separation to design metallic glass matric composites has been proposed.

The second example. Development of the two-phase bulk metallic glasses (BMGs) is essentially retarded due to difficulties in finding of phase-separated (immiscible) alloys with high glass-forming ability (GFA) of coexistent phases. Referring to the concept of solute partitioning and minimization of free energy, we present an idea that a metallic liquid system containing two liquids with individual self-assembled eutectic composition may yield two-phase BMGs upon casting. The Zr–RE system is characterized by a miscibility gap and a monotectic reaction. It separates into Zr-rich and RE-rich liquids upon cooling through the gap. Based on this system, a new Zr–RE–Al–Co–Cu immiscible system was created to synthesize two-phase bulk metallic glasses by copper mold casting. The formation of the two-glass structure is discussed and a strategy of partial substitution of chemically similar elements for overcoming the drawback of low GFA is proposed. A family of two-phase Zr-RE based metallic glasses in bulk form is developed. The mechanical behavior of the two-phase BMGs with different ratio of Zr-rich to RE-rich glassy phase is studied for the first time. This work provides a new concept for fabrication of two-phase BMGs and reveals the role of constituent phases in determining the mechanical properties of the whole glass.

The third example. Bulk metallic glasses (BMGs) with a phase-separated and full glassy structure have recently been reported in several alloy systems. The occurrence of phase separation and thus induced structure are
mainly determined by the thermodynamic properties of the liquid solution of the corresponding alloy composition. Here, we designed new phase-separated Zr-based BMGs utilizing Cu/Fe immiscibility. The Zr-based BMGs contains 2–5 nm diameter glassy spheres with a population density and volume fraction of ~5.2×10^{24} \text{m}^{-3} and ~49.3%, respectively. The Zr-based BMGs dependent on alloy compositions exhibit remarkable plasticity at room temperature. It was found that the nanospheres inside the shear band dissolve through mechanical mixing driven by the sharp strain localization there, while those nearby in the matrix coarsen by Ostwald ripening due to the increased atomic mobility. This work presents direct visual evidences for deformation-related effects, in particular increased atomic mobility, in the region around shear bands.

V-32
The novel preparation of micro-hole with large aspect ratio
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It was difficult to prepare micro-hole with large aspect ratio by traditional processing technologies. In order to solve the problem, a novel preparation was proposed. It was carried out by casting method. In this process, carbon fiber and metal wire coated graphite paint were used as hole core respectively. And morphology and geometrical characteristic of micro-hole were observed and analyzed by scanning electron microscope and laser scanning confocal microscope, the results shown that average diameter and aspect ratio of micro-hole obtained by the group of carbon fiber hole core was about 0.2 mm and 1700~, and the other group was about 0.5 mm and 700~; and for shape factor, the micro-hole obtained by the metal wire coated graphite paint hole core was more close to circle, its shape factor was about 0.72; to roughness of micro-hole, its value obtained by carbon fiber hole core was smaller than that of the metal wire coated graphite paint, it was close to 3.2 μm.

V-33
Microstructure and properties of 5083/1060/AZ31 and 1060/AZ31/1060 composite plates fabricated by explosive welding
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5083/1060/AZ31 and 1060/AZ31/1060 composite plates were fabricated by explosive welding. The microstructure and properties of the bonding interface after explosive welding were investigated. The result shows that all bonding interface had a wavy morphology. With the increasing distance from the detonation point, the wavelength and the amplitude increased. The wavelength and amplitude of the upper bonding interface were less than that of the lower bonding interface. The evolution of microstructure in AZ31 were also investigated, it was found that severe plastic deformation has occurred in magnesium alloy AZ31. Adiabatic shear band and twin structure were observed in AZ31. Shear bond strength were determined by shear bond strength test, the results indicate that the bond strength increases when collision energy is raised in a certain range. The mechanism of wave formation was also discussed in this paper.

V-34
Pore structure analysis of large size gasar Cu ingot prepared by bridgman method
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Gasar Cu is a very promising material to be used as microchannel heat sink. However, large size Gasar Cu of high quality has been reported before. The Bridgman method was introduced to fabricate large size Gasar metal ingot. A high quality Gasar Cu cylinder sample of 150 mm in diameter and about 200 mm in height (weighing 20 kg) was obtained at a proper withdrawing velocity. Pore structure distribution at different heights and radii on the sample were measured and analyzed systematically. Except the pore aspect ratio, all the other pore structure parameters kept almost constant when the sample height was over 85 mm, while they all changed little along the radius. The uniformity of pore size declined when the pore size increased with the increase of sample height. Most of the pores were straight and round. The Bridgman Method is desirable for the fabrication of large size high quality Gasar metal ingots. This will promote the commercial application of Gasar metals, such as Gasar Cu for micro-channel heat sinks.

V-35
Thermophysical properties and solid microstructure characteristics of liquid Ni–Ti alloy investigated by electrostatic levitation
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The Ni-Ti alloy has attracted much research interest in recent years due to its superelasticity (SE) and shape-memory effect (SME) that make it apply widely. However, the thermophysical properties of the alloy in liquid state are not sufficiently studied, like the density and the constant pressure heat capacity, which are the fundamental properties for the process of solidification. We measured the density and ratio of specific heat to emissivity of liquid Ni-Ti alloy by electrostatic levitation technique. These properties of Ni-Ti alloy exhibit a nonlinear relationship with temperature from the superheated to undercooled state, and the achieved maximum undercooling is 376 K, which reaches up to 0.23T\textsubscript{m}. With the decrease of temperature, the volume of liquid Ni-Ti alloy shrinks more and more fast. Moreover, we analyzed the microstructures of the Ni\textsubscript{50.7}Ti\textsubscript{49.3} alloy. Under equilibrium solidification condition, the morphology is characterized by coarse dendrites. For the small undercooling of 31 K, the grain size becomes small and the morphology appears as the equiaxed grains. When the undercooling reaches 353 K, the microstructure seems to grow from a single nucleus.

V-36
Synthesis and characterization of copper–yttria composite by dry ball milling and spark plasma sintering
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Powders of oxide dispersion-strengthened metal matrix composites (ODSMMC) are always prepared by wet ball milling for avoiding oxygen pollution. A new method of synthesizing Cu-Y\textsubscript{2}O\textsubscript{3} composites was applied in the present work which is dry ball milling followed by spark plasma sintering (SPS). The study revealed that Cu-Y\textsubscript{2}O\textsubscript{3} composites by dry ball milled, in contrast with wet ball milled, exhibited a finer copper particle size after milling and more homogenous distribution microstructure. The dry ball milled composites also displayed higher densification, microhardness, ultimate tensile stress and electrical conductivity. The differences between these two methods are ascribed to formation of brittle oxide on copper particle surface during dry ball milling,
and coarseness of copper particles and aggregation of yttria particles for ethanol as progress control agent (PCA) during wet ball milling. By comparing with Cu-nanoAl2O3 composite, Cu-Y2O3 composite, with much higher volume fraction of yttria than the fraction of Cu-nanoAl2O3 composite, exhibited not only high microhardness but also high electrical conductivity. These advantages confirm the bright application prospect of more homogenous distribution Cu-nanoY2O3 composite in high strengthen and high electrical conductivity materials.

**V-37**

**Effect of prior martensite on the low temperature bainitic transformation**

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The effect of different volume fractions of prior martensite on the low temperature bainitic transformation and microstructures was quantitatively analysis by dilatometer, optical microscope and scanning electron microscope. The results showed that prior martensite transformation accelerated the subsequent low temperature bainitic transformation, and the incubation period and completion time of bainitic reaction were significantly shortened. This phenomenon was attributed to the increasing nucleation sites caused by the introduced dislocations in austenite due to the formation of prior martensite. However, it is noteworthy that, because of the increased bainitic plates adjacent to the prior martensitic plates, the probability of the impingement of bainitic plates during growth was increased, resulted in a decrease in the maximum attainable volume fraction of bainite.

**V-38**

**The research and application of continuous rheo-extrusion in preparation of high performance aluminum alloy**

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Continuous rheo-extrusion has the advantages of short process and high performance of the product, so it has been applied to prepare high performance aluminum alloy. Al-Ti-B grain refiner prepared by continuous rheo-extrusion has better grain refinement effect and lower cost than similar imported product. The tensile strength and conductivity of 6021 alloy conductor after T8 treatment are 326 MPa and 56.2% IACS, which are increased by 10.5% and 6% than that of JLHA2 aluminum alloy conductor in Chinese standard. A novel heat-resistant Al-Sc-Zr alloy conductor with the tensile strength of 223 MPa, elongation of 7.1%, and conductivity of 60.5% was also prepared, and its long-term working temperature can reach 230 ℃. The tensile strength, elongation and conductivity of the Al-Sc-Zr alloy conductor are improved by 39.4%, 255% and 0.83% than that of Japanese heat-resistant Al alloy conductor (IEC 62004-2007 AT1). Based on continuous rheo-extrusion, accumulative continuous extrusion forming (ACEF) has been developed and applied for preparing ultra-fine grain Al alloy, which has the advantages of continuous and high efficiency. The grain size of Al-Sc-Zr alloy wire was refined from 100 μm to 800 nm after one pass ACEF.

**V-39**

**Study on mechanism of oxidation on high temperature plasticity of Ti-6Al-4V alloy**

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The oxidation behavior and effects of oxidation on hot ductility of Ti-6Al-4V alloy were investigated by isothermal oxidation method and high temperature tensile test. The microstructure and morphology of fracture surface were analyzed, and an oxidation model for predicting the thickness of the alpha layer (oxidation diffusion layer) was established. The results show that the internal oxide is hard brittle alpha layer generated by the diffusion of oxygen dissolved in the matrix, whose oxidizing dynamics curves obey approximately parabolic law. The oxidation activity energy above and under the transformation point is 159 kJ/mol and 258 kJ/mol, separately. The tensile fracture surfaces has significant difference with the increase of oxidation time. The deterioration of high temperature plasticity of Ti-6Al-4V alloy under oxidizing condition is mainly due to the precipitations of alpha layer and microstructure changes.

### V-40
**Mechanical anisotropy and fracture behavior of columnar-grained \(<001>\)-orientated Cu-12wt.%Al alloy**
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Columnar-grained Cu-12wt.%Al (CG Cu-12Al) alloy prepared by unidirectional solidification process has high elasticity, high strength, high conductivity, high plasticity and other good comprehensive properties, which has a potential to develop into a high-performance elastic material as the alternative to beryllium bronze. Especially, the room temperature tensile elongation of the CG Cu-12Al alloy with high \(<001>\beta\) orientation along the axial direction exceeded 15%, which is 4~7 times more than that of the ordinary polycrystalline structure Cu-12Al alloy. Some previous researches have been indicated the mutual promoted effects between phase transformation and deformation of the strong texture Cu-12Al alloy determined its extraordinary plasticity. Meanwhile, CG Cu-12Al alloy have obviously anisotropy because of its special structure, which would be considered or used in the material design of its application. In this paper, the mechanical anisotropy and fracture behavior of the CG Cu-12Al alloy were investigated. The results showed an obvious anisotropy of the mechanical properties in CG Cu-12Al alloy sheets was observed. When the angle between the force direction and the growth direction of columnar grains ranged from 0° to 90° at the tensile tests, the plasticity of the samples changed in a “V” shape for tensile tests. The fracture strain decreased from 16% for 0° sample to 6% for 30° sample, then decreased to 12.8% ~ 10% for 60° ~ 90° samples. The crack propagation process of the pre-crack samples was observed using in-situ optical microscope. The results indicated that transgranular fracture occurred when the pre-crack was perpendicular to the grain boundaries of CG Cu-12Al alloy, while the crack propagated along the grain boundaries when the pre-crack was parallel to the grain boundaries. The mechanical anisotropy above was attributed to the combined effects of grain orientation and grain boundaries.

### V-41
**Microstructure evolution of an hot-extruded Cu-15Ni-8Sn alloy with different extrusion ratio**
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Cu-15Ni-8Sn alloy is a spinodal hardened alloy which possesses excellent combination of strength, elastic modulus, corrosion resistance and wear resistance. Much concern focuses on the final microstructures and properties of this wrought alloys after heat treatment. The microstructure feature of the alloy during hot plastic deformation processing is rarely declared. In this paper, the microstructure evolution of the hot-extruded Cu-15Ni-8Sn alloy with different extrusion ratio were investigated by optical microscope, scanning electronic microscope, electron backscattered diffraction. The results show that dynamic recrystallization occurs during hot extrusion at extrusion ratio ranging from 6 to 17. Moreover, the subgrain coalescence nucleation mechanism is involved in recrystallization process. With the increase of extrusion ratio, the fraction of recrystallized grain increases. However, the amount of discontinuous γ precipitates reduces. The cellular structure is observed to nucleate not only at grain boundaries but also in the coarsening annealing grains when the extrusion ratio is very low. When extrusion ratio is 17, the discontinuous γ precipitates and the residual annealing grains are suppressed and some recrystallized grains grow up.

V-42
Tailoring bimodal grain structures for optimized strength and ductility in Mg-Al-Sn-Zn alloys by hard-plate rolling (HPR)
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The development and optimization of processing techniques for hcp metals, for instance Mg, via tailoring microstructure and texture remains a challenge and critical to attain a simultaneous high strength and ductility. In the present work, a new hard-plate rolling (HPR) route, which achieves a large reduction during a single rolling pass, was applied to prepare Mg-Al-Sn-Zn alloy. HPR was demonstrated to be efficient in introducing micron-scale inhomogeneous deformation and hence facilitating the formation of a bimodal grain structure, and more importantly, gaining a simultaneous high strength and uniform ductility (~369 MPa and ~13.5%) in the Mg-Al-Sn-Zn alloys upon room temperature tension. The combination of high strength and uniform ductility of the HPRed Mg-Al-Sn-Zn alloy is much superior to their correspondents reported in the literature. To explore the effects of temperature and thickness reduction on the microstructure evolution and tensile properties of HPRed alloys, there temperatures, i.e., 300, 350 and 400 °C, as well as three thickness reductions, i.e., 60%, 70% and 80%, were chosen for the HPR experiments. When the thickness reduction kept constant, the strength increased first and then decreased, while the change in the uniform ductility behaved oppositely, with increasing HPR temperature. At each temperature, the strength of the alloy increased gradually while the uniform ductility decreased apparently with increasing thickness reduction. The optimized strength and uniform ductility, i.e., ~369 MPa and ~16.5%, was achieved when 60% reduction was adopted during 350 °C HPR.

Microstructure analyses by Electron backscattered diffraction (EBSD) revealed that the alloy always exhibit a bimodal grain structure after upon HPR with 60% reduction, despite the volume fractions and grain size distributions varied substantially depending on the applied HPR temperature. Specifically, ultrafine grains increase gradually in volume fraction with increasing temperature. Moreover, ultrafine grains in the 350 °C HPRed alloy had the smallest sizes, while those in the 400 °C HPRed alloy appeared apparently coarser. EBSD analysis revealed that the ultrafine/fine grains in the bimodal Mg-Al-Sn-Zn alloy formed via continual dynamic recrystallization (CDRX) and subsequent grain growth, which are quite sensitive to temperatures. The results
indicated that CDRX occur easily at grain boundaries and promote the formation of a considerable fraction of ultrafine grains upon HPR at 350 °C. In contrast, a lower temperature (300 °C) leads to limited CDRX and hence fewer recrystallized ultrafine grains while a higher temperature (400 °C) results in apparently growth of recrystallized grains. Moreover, pole figure suggested that the maximum intensity of basal texture decreases substantially from 15 to 10 and further to 8 with increasing HPR temperature from 300 to 350 further to 400 °C. Therefore, the superior combination of a high strength and uniform ductility of the alloy upon HPR at 350 °C alloy and 60% reduction has been attributed to the larger fraction of ultrafine grains formed via CDRX in the bimodal structure and the weaker basal texture. Our results demonstrated that a moderate temperature and proper thickness reduction during HPR promotes the optimized bimodal grain structure, i.e., more ultrafine grains, by facilitating CDRX meanwhile retaining fine recrystallized grains. The present work provides new insights into the production of bimodal Mg alloy with either strength or ductility or both. This work proposes a simple approach to design and fabricate bimodal metallic materials with a simultaneous high strength and ductility. Also, the simple HPR process can be easily adapted to current industrial process and, hence, has great potential for large-scale application of Mg alloy sheets.

V-43
Study on rotary swaging-drawing forming of gold cladding copper micro-wire and its properties
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Gold cladding copper micro-wire, which has advantages of gold's excellent oxidation resistance, corrosion resistance and copper's wonderful mechanical and electrical properties and low cost, is a kind of high-performance new type bonding material. In this paper, pure gold tube with an outer diameter of 10.6 mm and an inner diameter of 10.0 mm and Ph10.0 mm pure copper bar were used as raw materials, and the process of rotary forging-drawing-diffusion annealing-drawing was adopted, i.e., the rotary swaging and drawing were used to prepare the Ph3.5 mm wire, the combination of the diffusion annealing and drawing, including fine drawing and finish drawing, were then employed to produce the Ph60 μm gold cladding copper micro-wire. The surface of gold cladding copper micro-wire was smooth, with the good Au/Cu bonding interface, the average thickness of the gold layer was about 2.0 μm and cross section of cladding ratio was about 10.5%. The effects of annealing parameters on the microstructure, mechanical and electrical properties of the composite micro-wire were studied. The reasonable annealing parameters for the gold cladding copper micro-wires were the annealing temperature of 300 °C and the annealing time of 30min. The annealed composite micro-wire had the tensile strength of 254 MPa, the elongation to failure of 22.0% and electrical conductivity of 98.1% IACS. The process of rotary forging-drawing-diffusion annealing-drawing-annealing proposed in this paper can work as an effective method to produce the high-quality gold cladding copper micro-wire.

V-44
Drawing Fe-6.5wt.%Si wires with enhanced formability
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Fe-6.5wt.%Si alloy is hard to deform due to its low formability at room temperature. It hinders its industry application although the Fe-6.5wt.%Si alloy shows extremely low iron loss and much low noise when being
used as iron core in transformer or electrical engine. This embrittlement results from the appearance of ordered phases, like B2 and D03 structures. It has been discovered that the formability of the Fe-6.5wt.%Si alloy can be enhanced by heat treatment and thermal mechanical processing which reduced the content of the ordered phases. Thin sheet of 0.05-0.3 mm in thickness can be obtained by cold rolling. Some special treatments can also be employed to enhance the formability, including electroplastic effect by electro pulse, and the chemomechanical effect in an electrochemical environment. The electro-pulse passing a specimen during deformation results in a softening and ductilizing. The electrochemical environment accelerates the dislocation moving so that its workability is improved.

The technique was applied to drawing wires. Fe-6.5wt.%Si high silicon steel wires with a diameter of 0.5-2 mm are fabricated successfully by drawing. The as drawn wires show much better ductility than sheets. A tensile elongation above 4% was measured at the room temperature. The microstructure analyses show that the elongated grains after drawing and the disordering by deformation in the wires might contribute to its good ductility. Bs value of 1.437 T and Hc value of 16.96 A/m are obtained for the wire after proper heat treatment for the wires.

V-45
Size- and constituent-dependent deformation mechanisms and strain rate sensitivity in nanolaminated crystalline Cu/amorphous Cu–Zr films
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Hardness, tensile ductility and strain rate sensitivity of crystalline Cu/amorphous Cu-Zr nanolaminates (Cu/Cu-Zr C/A NLs) have been respectively measured as a function of modulation ratio ($\eta$). With reducing $\eta$, the tensile ductility is firstly decreased and subsequently increased, leaving a minimum value at $\eta \sim 1.0$. However, the strain rate sensitivity ($m$) is monotonically raised with reducing $\eta$ and spanned from negative at $\eta$ greater than about 1.0 to positive at $\eta$ lower than about 1.0, which indicates a tunability of the strain rate sensitivity engineered in the C/A NLs. Careful microstructural examinations reveal that deformation-induced devitrification (DID) in the amorphous nanolayers is the key factor responsible for the above experimental phenomena. The thinner is the amorphous nanolayer, the intenser is the DID. The size-dependent DID makes the pure Cu-Zr amorphous single layer films (i) exhibit thickness-dependence of tensile ductility opposite to that in pure Cu single layer films; and (ii) have a negative $m$ contrary to the positive $m$ in pure Cu counterparts. These results are rationalized by considering a competition between the two constituent nanolayers. In addition, strengthening mechanisms of the C/A NLs have been analyzed and the $\eta$-dependent hardness has been quantitatively described by using a modified mechanistic model.

V-46
Hot ductility of 20Cr13 steel at high temperature
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Hot ductility of 20Cr13 steel at high temperature was investigated. The steel selected for this investigation was obtained from a commercial hot-forged bar and has the chemical composition (wt.%) of 0.20 C, 0.60 Mn, 0.36 Si and 12.6 Cr. The area reduction ratio was measured through tensile test at 800, 850, 900, 950, 1000, 1050, 1100, 1150, 1200 and 1250 °C. In temperature range of 800-950 °C, the hot ductility was very low with area reduction ratio of 52-68 %. In temperature range of 1000-1200 °C, the hot ductility increased significantly, as the area reduction ratio increased to 82 % or more. However, as the temperature increase from 1200 to 1250 °C, the area reduction ratio suddenly decreased from 93 % to 83 %. The fracture morphology at different temperature was observed by scanning electron microscopy. The quasi-cleavage fracture happened at 800 °C and ductile fracture happened at other temperature. The dimples in the fracture became bigger and deeper with the temperature increased. Although nice ductile fracture happen at 1250 °C, but the displacement for fracture was much smaller than that at 1200 °C. In order to understand the mechanism of hot ductility changing, the main phases of the steel in temperature range of 600-1400 °C were calculated with thermodynamic software, and the microstructure near the fracture were observed by scanning electron microscopy. In temperature range of 800-950 °C, the M23C6 precipitated at the grain boundary of austenite, and it fractured in the tensile process. As a result, the micro-crack or micro-hole formed at the grain boundary of austenite and the hot ductility worsened. At 800 or 1250 °C, the ferrite precipitates and the micro-voids formed at the phase interface because of the deformation discordance of two phases, which was harmful to hot ductility. Moreover, quasi-cleavage fracture happened at 800 °C because of the ferrite cleavage, which further decreased hot ductility of the steel.

V-47

Effects of cold-rolling, solution and aging treatments on textures and superelasticity in FeNiCoAlTaB shape memory alloy

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Ferrous shape memory alloys enjoy wide application prospects owing to their advantages of low material cost, high cold workability and high strength. Especially the discovery of thermoelastic martensitic transformation in the FeNiCoAlTaB alloy with huge superelasticity has aroused profuse research. Recent studies on FeNiCoAlTaB shape memory alloys (SMAs) fabricated by rolling + recrystallizing have confirmed that a good superelastic performance can be obtained only with cold-rolling reduction above 98.5% followed by advisable solution and aging treatments, which indicates that rolling reduction and heat treatment conditions significantly influence the microstructure and superelasticity of the alloy. But the internal mechanisms of these phenomena are not clear at present. Therefore, revealing the improving mechanism on the superelastic properties of Fe-Ni-Co based alloys with severe rolling deformation, clarifying the rolling and recrystallization texture evolution in this alloy, and optimizing the cold-rolling + solution-aging fabrication method are fundamentally crucial. In the present study, the effects of various cold-rolling reductions, certain solution conditions and aging treatments on microstructure, texture and the superelastic response of FeNiCoAlTaB alloy were investigated. Fe-28Ni-17Co-11.5Al-2.5Ta-0.05B alloy ingot was first induction melted and casted in a vacuum furnace. The as-cast ingot was then homogenized and forged in the temperature range of 1100-1200 °C to both reduce the casting defects and improve the homogeneity of the microstructure. The 20 mm-thick as-forged specimens were cold-rolled with the reductions of 60%, 80%, 90%, 95% and 98.5%, subsequently, the cold-rolled sheets were solution-treated and aged with different conditions. The rolling and annealing textures were measured by X-ray
diffraction (XRD) method, and microstructure and grain boundary character distribution were examined by the electron backscatter diffraction (EBSD) method. Experimental results showed that the weaker Copper and S textures were formed in FeNiCoAlTaB alloy at relatively low rolling reductions (≤60%); the Copper rolling texture transformed into the Goss and Brass orientations through twinning and dislocation slipping with higher rolling reductions of 80-90%; the alloy with the rolling reductions over 98.5% was characterized by the highly enhanced dominant brass texture. Complete recrystallization occurred in 98.5% cold-rolled FeNiCoAlTaB alloy after solution treated at 1200-1300 °C for 1h, with the formation of strong (023)[100] and (032)[100] recrystallization textures which were benefit to the improvement of superelasticity of the alloy. The 98.5% cold-rolled FeNiCoAlTaB alloy after solution treatment at 1250 °C for 1h followed by aging for 72 h at 600 °C exhibited good mechanical properties of 1.6% in superelasticity, 0.7% in residual strain, and approximately 885 MPa in tensile strength.

V-48
The order structure decrease and ductility improvement of Fe–6.5wt.%Si alloy caused by rare earth elements doping
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Fe–6.5wt.%Si alloy serves as the key soft magnetic material in high frequency electrical equipment, energy-saving transformers and electric vehicles, etc. due to its excellent soft magnetic properties such as near zero magnetostriction, low iron loss and high permeability, etc. The brittle B2 (FeSi) and D0₃ (Fe₃Si) ordered structures are abound in Fe–6.5wt.%Si alloy, which is an important reason for the alloy's serious brittleness and restricts its fabrication and application seriously. To improve Fe–6.5wt.%Si alloy's ductility, current studies are focusing on hindering order–disorder transformations by quenching treatment and destroying ordered structures by deformation treatment. Studies suggested that rare earth (RE) elements doping can affect structures and phase transformations in some compounds due to the larger atomic radius and unique electron structure of RE elements, hence this work proposed the idea that changing ordered structures or phase transformations of B2 (FeSi) and D0₃ (Fe₃Si) phase by RE doping.

Fe–6.5wt.%Si ingots in 5 kg were prepared by a ZG-0.01 model vacuum medium frequency induction melting furnace, the doped RE content (Y, La, Ce, Gd) is ~0.01–0.04 wt.%, and the investigation and test specimens were sampled from same radius and height location of the casting ingots. The ordered structure investigations were conducted by X-ray diffraction (XRD) analyses, and the selected area electron diffraction (SAED) and morphologies investigations of ordered structures were carried out on a transmission electron microscope (TEM). The comparisons on mechanical properties between RE undoped and Ce doped specimens were given through 3-ponits bending tests at room temperature and tensile tests at 400 °C.

The obvious decrease of B2 and D0₃ ordered structure reflection peak intensity by RE doping was found in XRD patterns. The B2 and D0₃ ordered domains in RE undoped specimen are bright and with coarse sizes (~1 μm), and the anti-phase boundaries (APBs) of the domains are clear and discernible. Whereas, the domains in 0.021wt.% Ce doped specimen are of dispersive distribution and tiny sizes (~5 nm) and with a much weaker brightness. The average room temperature bending deflection increases to 0.77 mm from 0.62 mm and the average tensile elongation to failure at 400 °C increases to 23.0% from 7.3% by 0.021wt.% Ce doping.
The atomic radius difference between RE and iron is significant (the atomic radius of RE elements is ~50 % larger than of iron), hence RE atoms exist in the lattice only in the substitution form and the solubility is extremely low. And the electronegativity difference between RE and matrix elements (Fe, Si) is ~10 times as long as the difference (0.07) between silicon and iron. The great electronegativity difference will result in the silicon and iron atoms are much easier to attract electrons from RE atoms. Combined with the low solubility of RE atoms in the matrix, the electronegativity difference between RE and matrix elements will lead to the ordering combination tendency to RE–iron compounds and RE–silicon compounds formation, according to phase diagrams. The order–disorder transformations of A2–B2 and B2–D0₃ in Fe–6.5wt.%Si alloy are all second-order phase transformations, during which the long range ordered structures are formed by adjacent atoms rearrangement. The iron and silicon atoms will be dragged by RE atoms during the adjacent atoms rearrangement process due to the stronger ordering combination capability between RE and matrix atoms, which will weaken the combination capability between iron and silicon atoms during the B2 and D0₃ ordered phase formation process. Hence, the order–disorder transformations are hindered and the order degree is reduced significantly, which improves the alloy's ductility.

**V-49**

**Hot deformation and dynamic recrystallization behavior of 8Mn-6Al-0.2C steel**

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Medium-manganese steel exhibits excellent mechanical properties due to the TRIP effect of retained austenite, considered as a candidate for the third generation advanced high strength steel (AHSS) grades. The addition of light element such as Al brings it low density to reduce energy consumption and CO₂ emission and makes it a promising auto-body material. At present, many researches about medium-manganese steel containing aluminum have been done on component design, organizational performance and work hardening behavior while few are about the thermal deformation behavior and dynamic recrystallization (DRX). It is well known that the DRX is vital in microstructure control and mechanical properties during hot deformation, so it is necessary to study the deformation mechanism of medium-manganese steel containing aluminum.

In this study, the hot deformation and DRX behavior of medium-manganese steel containing aluminum were investigated by means of single-pass compression experiments. True stress-strain curve, DRX behavior under different deformation conditions, microstructure evolution and deformation constitutive equation were discussed, which may be a useful reference for hot rolling processing parameter design.

The steel ingot was smelted in a 20 kg vacuum induction melting furnaces with the measured composition of 8.00Mn, 6.00Al, 0.20C and Fe in balance (wt.%). The cast ingot was heated at 1180 °C for 2 h, hot forged between 1150 °C and 850 °C to slabs of section size of 35 mm×70 mm×100 mm, and then air cooled to room temperature. Samples of Φ8×15 mm were cut off from the forged billet and turning machined on the surface. Subsequently, Gleeble-3500 thermal simulated test machine was used for single-pass compression experiments at the temperature ranging from 1123 to 1423 K at an interval of 50 K and strain rate of 0.01, 0.1, 1, 10 s⁻¹ respectively. The samples were heated to 1200 °C at a speed of 10 °C/s and soaked for 120 s and then cooled to the deformation temperature at a speed of 5 °C/s. After that, the specimens were compressed until the total true strain reach to 0.9 followed by water quenching. Specimens were obtained for metallographic examination by sectioning at mid plane perpendicular to the compression axis, then polished and etched with 4% Nital. Microstructures were analyzed using the Leica DMR optical microscopy (OM).

The result shows that DRX microstructure is sensitive to deformation temperature and strain rate, which
consists of ferrite, martensite and austenite. Hot deformation conditions affect the volume fraction and morphology of each phase. With increasing deformation temperature at the same strain rate of 0.1 s\(^{-1}\), the volume fraction of ferrite had an obviously increase and the the original grains were replaced by DRX grains completely which is because the higher deformation temperature drives the dislocations to climb or slip on the grain boundary more powerfully. Comparing the microstructure at the strain rate of 0.1 s\(^{-1}\) and 0.01 s\(^{-1}\), the morphology of ferrite have changed from banded structure to equiaxed structure, and the grain size of the austenite increased significantly. It is attributed to the extension of the time of distortional strain energy’s acceleration and dislocation’s annihilation with the decrease of strain rate.

True stress-strain curves under different deformation conditions were investigated which were based on fitting analysis of experimental data. With the same strain rate, the flow stress increases rapidly with the increasing of deformation strain at the beginning of deformation due to the work hardening effect. When it increases to a critical strain, softening mechanism dominates the flow stress start to increase slowly and reach a peak. And then the curves present two different types according to the developing trend of flow stress. One is dynamic recovery curve, in which the flow stress is gradually tend to be stable. The other is dynamic recrystallization curve, in which the flow stress firstly has a gradual fall and then becomes stable in the end. It is observed that the higher temperature and the smaller strain rate correspond to the lower peak stress, which means softening mechanism is easier to occur. It can be seen that a similar yield platform exists in some of flow stress curves, named yield-point-elongation-like effect, which is attributed to the inhomogeneous strain between duplex structures inside the material at the stage of beginning deformation.

For the range of deformation conditions employed, the peak stress as a function of deformation temperature and the strain rate is analyzed through a hyperbolic-sine Arrhenius-type equation:

\[
\dot{\varepsilon} = A [\sinh(\alpha \sigma)]^n \exp\left(\frac{-Q}{RT}\right)
\]

where A (s\(^{-1}\)) and \(\alpha\) (MPa\(^{-1}\)) are material constants, \(n\) is a constant closely related to the strain rate, \(Q\) is the thermal activation energy of deformation (kJ/mol), \(R\) is the universal gas constant. Based on the peak stress, the value of \(\alpha\), \(n\), \(A\), and \(Q\) can be calculated after fitting analysis of experimental data: \(\alpha=0.013\)MPa\(^{-1}\), \(Q=335.024\) kJ/mol, \(A=1.69 \times 10^{13}\)s\(^{-1}\), \(n=3.8438\). Thus, the thermal deformation equation with the temperature range of 1123–1423K can be described by

\[
\dot{\varepsilon} = 1.69 \times 10^{13} [\sinh(0.013\sigma)]^{3.8438} \exp\left(\frac{-335024}{8.3147}\right) .
\]

Zener-Hollomon (Z) parameter is generally defined as the synthetic action of deformation temperature and the strain rate. It is usually used to predict the resistance of deformation at high temperature. In this paper, a new simplified stress function relation was used to express the correlation between the peak stress (\(\sigma_p\)) and Z: 

\[
Z = f(\sigma) = B \exp(\beta\sigma).
\]

As a result, the liner relation can be expressed by two stages responding to lnZ: 

\[
\sigma_p = 8.02\ln(e + 323177/T - 175.31), \ln Z \leq 30.09; \sigma_p = 22.77\ln(e + 917548/T - 618.86), \ln Z > 30.09.
\]

V-50

Calculation of Forming Limit Diagram of Aluminum and Magnesium alloy sheets by Using Polycrystal Plasticity Method

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Forming limit diagram (FLD) has become a useful tool for sheet-metal formability evaluation and widely applied in industries. However, it is time and labor consuming to obtain the FLD experimentally. Therefore,
prediction the formability of the material with numerical calculation is of great interest. For anisotropic metal sheet, the yield based, quadratic Hill function and the von Mises plasticity theory are frequently used to describe material constitutive behaviors. The crystal plasticity methods, capable of considering mesoscopic structure and texture evolution, provide an alternative approach to prediction of forming limit. Among those crystal plasticity methods, the visco-plastic self-consistent (VPSC) model is the most widely used ones. In this work, a method to integrate VPSC with M-K model is developed to calculate FLDs of AA 5182-O and AZ31B sheets. The influences of pre-strain, texture on the calculated FLDs are discussed.

V-51

Common defect and control of large section special steel forging
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The quality level of large section special steel forging in our country is lower than that of developed countries. One of the most serious problems was known as the low qualified ratio of flaw inspection. In order to figure out the defect in the forging and find the solution, systematic study was carried out on hundreds of large section special steel forgings in a domestic famous steel mill. The steel researched in this text: low-carbon steel Q345D/E, medium-carbon steel 27SiMn, high-carbon steel GCr15SiMn, stainless steel 20Cr13. Both the amount and type of all the defect in the above steel were calculated and analyzed.

The results show that the common defect of the steel were slags, inclusions, loose (cavity) and inner cracks. The composition of the slags and inclusions was detected by EDS (Energy Dispersive Spectrometer) and the source of them were analyzed. The abnormal microstructure near the cracks was detected by EDS, EPMA (Electron Probe Micro-analysis), OM (Optical Microscope) and SEM (scanning microscope). The orientation of grains on both sides of the cracks in Q345D/E, 27SiMn and 20Cr13 was investigated by EBSD (Electron Backscattered Diffraction). The evolution of the cavity in the ingot during forging process was simulated by a numerical simulation software Deform-3D. The genesis and formation time of the crack were determined. The slags and inclusions came from casting powder or pouring gate. The inner cracks in Q345D/E and 27SiMn initiated after A→F+P transformation, the cracks in GCr15SiMn formed after the precipitation of net-like proeutectoid carbides, the cracks in 20Cr13 formed after the precipitation of net-like carbides. The internal cause of the cracks was relevant to composition segregation and internal stress in the forging, the external cause was connected with effect of slow cooling.

Based on the above study, a set of new process was proposed and put into industrial application, with the result that the qualified ratio of flaw inspection in the above steel mill was improved from 20% to above 87%.

V-52

Influence of aluminum on microstructure, mechanical behavior and wear performance of ultra-high manganese cast steel
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The aims of the present work are to reveal the influence of Aluminum (6.6%) on microstructure, mechanical behavior and wear performance of ultra-high manganese cast steel under abrasive impact wear with different
heat-treatments. The abrasive wear mechanisms are also discussed. For this purpose, Al-free steel upon quenching (Q) and quenching (1050 °C) - aging (Q-A) at 500 °C for 2, 3 h, and Al-containing steel upon quenching (Q) and quenching (1050 °C) - aging (Q-A) at 550 °C for 1, 2, 3, 4 h were chosen to conduct impact abrasive wear tests. The chemical compositions of the steels were 1.30 C, 25.10 Mn, 6.60 Al, 0.45 Si, 0.0042B, 0.01 P, 0.013 S, the balance Fe in wt.% (Fe-25Mn-6.6Al-1.3C, Al-containing), and 1.31 C, 25.10 Mn, 0.48 Si,0.0045B, 0.01 P, 0.023 S, the balance Fe in wt.% (Fe-25Mn-1.3C, Al-free). The ultra-high manganese cast steels were prepared in a vacuum induction melting furnace (25 Kg). The impact wear tests were investigated by using MLD-10 abrasive wear testing machine, where the impact abrasive wear tests were performed under the low impact energy condition (0.5 J). The impact frequency was 200 times/min, impact angle was 90° and the overall impact time was 2h. The abrasive media was SiO2, with a size of 1.5 to 2.36 mm.

The microstructures of Al-free and Al-containing cast steels after quenching and quenching -aging were further analyzed with the help of optical microscope (OM), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD) and transmission electron microscope (TEM). The mechanical properties of the samples such as ultimate tensile strength, yield strength, total elongation, initial hardness, impact toughness (V-notch, ak) and wear resistance (was expressed by the reciprocal of the weight loss, $\varepsilon = 1/\omega$, $\omega$ is the abrasion loss of specimen in unit time) were tested.

The results show that the mechanical behavior and wear performance of the Al-free cast steel after quenching treatment: the ultimate tensile strength and yield strength are 856 MPa and 408 MPa, total elongation is 62%, initial hardness is 225 HB, impact toughness is 301 J/cm² and wear resistance is 1.375. The mechanical properties of 6.6 Al cast steel after quenching g treatment: ultimate tensile strength is 724 MPa and yield strength is 403 MPa, total elongation is 61%, initial hardness is 220 HB, impact toughness is 264 J/cm² and wear resistance is 1.076. As can be seen, the wear resistance of Al-containing cast steel is about 0.783 times of Al-free cast steel. It is noteworthy that the addition of Al decreases the ultimate tensile strength, the impact toughness and the wear resistance of Fe-25Mn-1.3C cast steel (as-quenched).

While, the mechanical behavior and wear performance of the Al-containing cast steel would be improved after aging at 550 °C due to the precipitation of nano-sized second phase (Fe, Mn)3AlC carbides within the austenite matrix. The mechanical behavior and wear performance after aging 1, 2, 3, 4 h at 550 °C: the tensile strength is 731, 751, 789, 785 MPa and the yield strength is 503, 581, 612, 630 MPa, and the elongation of the steel is 56%, 48%, 33%, 22%, initial hardness is 245, 252, 279, 296 HB, impact energy ( V-notch) ak is 180, 168, 75, 75 J/cm² and wear resistance is 1.184, 2.098, 1.938, 1.864 g⁻¹. However, the aging methods are not effective means to improve the yield strength, initial hardness and wear resistance for the Al-free steel. The mechanical behavior and wear performance of Al-free cast steel would be deteriorated after aging 1, 2, 3, 4 h at 500 °C: the tensile strength is 841, 705, 708, 676 MPa and the yield strength is 396, 407, 396, 413 MPa, and the elongation of the steel is 41%, 18%, 17%, 8%, initial hardness is 230, 226, 224, 226 HB, impact energy ( V-notch) ak is 149, 47, 25, 14 J/cm². The wear resistance after aging 2 h and 3 h at 500 °C is 1.343 and 1.025 g⁻¹ respectively.

It found that the wear resistance of Al-free steel decreased with the increase of aging time. It can be seen that the strength and wear resistance of the Al-containing steel after aging at 550 °C for 2 h reach the best match, and the wear resistance of Al-containing cast steel is about 1.526 times of Al-free cast steel.

The hardening mechanism of Al-free cast steel is twinning, and the subsurface microstructure of Al-containing cast steel shows Lomer-Cottrell locks, high density of dislocation tangles and dislocation walls, neither martensite nor mechanical twins were observed under the low impact energy condition for both heat treatment processes. Since the stacking fault energy (SFE) signifues the deformation mechanisms of ultra-high manganese steels. For this purpose, the SFE of Al-free and Al-containing also calculated to be 42.0 mJ/m² and 66.7 mJ/m² respectively. Therefore, the Additions of Al increase $\gamma_{\text{SFE}}$ therefore, strongly suppress the $\gamma\rightarrow\varepsilon$ and
twinning transformation. 
The preceding results indicate that the addition of Al reduces tensile strength, impact energy and wear resistance, but has no effect on the hardness and yield strength of ultra-high manganese cast steel after only quenching. The addition of Al suppresses the needle-like carbide precipitation in the process of aging, and the nano-sized carbides precipitates in the matrix, which play the main role in the increase of the hardness, ultimate tensile strength and yield strength. The fine nano-sized second phase \((\text{Fe, Mn})_3\text{AlC}\) carbides tend to precipitate coherently within the austenite matrix under the additional aging treatment, which can improve the initial hardness, strength and wear resistance. While, for longer aging time (4 h), coarse \((\text{Fe, Mn})_3\text{AlC}\) carbides would precipitate around the grain boundaries, which will deteriorate the performance of the steel.

V-53
Study on effect of La on microstructure and properties of H13 hot work die Steel
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As a high chromium content hardened hot work die steel with high-strength, high toughness, excellent thermal fatigue resistance, abrasion resistance and other characteristics in mesothermal conditions, H13 steel(4Cr5MoSiV1) is one of the most widely used hot work die steel. In recent years, along with the rapid development of large-scale aluminum extrusion product application, there have been a higher standard of comprehensive performance and life of die steel.

In order to develop the comprehensive mechanical properties, in this work, the effect of Rare Earth elements addition on microstructure and properties of H13 Steel were explored, and the influence of lanthanum element content brought to mechanical properties and fracture mechanism of cast and forging state H13 steel were studied. The result shows that for cast steel H13, as the lanthanum content increases, impact toughness(\(\alpha_k\)) , yield strength(\(\sigma_y\)) and tensile strength(\(\sigma_s\)) increase during the first period and then decrease. Compared with the original samples (RE 0wt.%), When the RE wt.% is 0.03 wt.% , \(\alpha_k\) increases 21.12\%, \(\sigma_y\) increases 3.78\%, \(\sigma_s\) increases 4.14\% , the elongation of fractured specimen increases 5.26\%; when the RE wt.% increases to 0.45wt.% , \(\alpha_k\) decreases 52.59\% , \(\sigma_y\) increases 3.70\% , \(\sigma_s\) increases 4.71\% , the elongation of fractured specimen decreases 63.2\%.

For the casted and forged H13 steel, H13 steel(RE 0wt.%) is composited by tempered sorbite and lanthanum-added steel structure is composited by tempered sorbite and tempered troostite after tempering. The tempering troostite is the strengthened phase, which increases the intensity of H13 steel. Compared with the original samples (RE 0wt.%), When the RE wt.% is 0.03 wt.% , \(\alpha_k\) increases 67.80\%, \(\sigma_y\) increases 5.02\% , \(\sigma_s\) increases 4.57\% , the elongation of fractured specimen decreases 13.64\%; when the RE wt.% increases to 0.15wt.% , \(\alpha_k\) decreases 72.53\% , \(\sigma_y\) decreases 0.13\% , \(\sigma_s\) increases 0.76\% , the elongation of fractured
specimen decreases 20.13%; when the RE wt.% increases to 0.45wt.%, $\alpha_d$ decreases 41.95%, $\sigma$ decreases 6.14%, $\sigma_s$ increases 7.34%, the elongation of fractured specimen (10.96%) remains stable.

The fracture analysis indicates that the fracture of casted H13 steel (RE 0wt.%) contains niobium spherical mouth, aluminum oxides, complex oxides such as $\text{MnO}$,$\text{Cr}_2\text{O}_3$, $\text{FeO}$,$\text{Cr}_2\text{O}_3$, cluster-like inclusions such as $\text{MnS}$ and $\text{FeS}$. The fracture of H13 steel (RE 0.15wt.%) contains oxide inclusions such as $\text{FeO}$,$\text{Cr}_2\text{O}_3$ and $\text{La}_2\text{O}_3$, most of the brittle sulfide such as $\text{MnS}$ and $\text{FeS}$ eliminate, which improves the impact toughness of H13 steel.

The fracture analysis shows that the forged steel quenching and tempering H13 has cup-cone fracture surface, the fracture of forged H13 steel (RE 0wt.%) contains the brittle sulfide such as $\text{MnS}$ and $\text{FeS}$, complex oxides such as $\text{FeO}$,$\text{Cr}_2\text{O}_3$ and $\text{FeO}$,$\text{Al}_2\text{O}_3$, the alloying elements V, Mn enrich in local precipitation; The fracture of H13 steel (RE 0.15wt.%) contains oxide inclusions such as $\text{FeO}$,$\text{SiO}_2$, $\text{La}_2\text{O}_3$ and $\text{SiO}_2$, most of the brittle sulfide such as $\text{MnS}$ and $\text{FeS}$ eliminate.

After being holding at $580^\circ$C for 20h, Hardness value of the H13 steel sample in forging state RE 0wt.% and RE 0.15wt.% are 31.5HRC, 38.8HRC (failure hardness 35HRC), which indicates that lanthanum improves high tempering stability of forging state H13 steel. As the amount of lanthanum increases, the fracture mechanism of casted H13 steel successively changes from the ductile fracture to prevail cleavage fracture and intergranular fracture. The fracture mechanism of forged H13 steel sequentially changes from intergranular fracture to quasi-cleavage fracture and fracture dimples. Considering the above results, the mechanical properties of H13 steel increases when RE wt.% is within the range of 0.03% to 0.15%.

V-54

**Giant elastocaloric effect in wide temperature range in columnar-grained Cu71.5Al17.5Mn11 shape memory alloy**

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Elastocaloric effect refers to the adiabatic temperature change under uniaxial stress, which is based on the entropy change associated with the reversible martensitic transformation in shape memory alloys, and it can be applied into the solid-state refrigeration due to the high coefficients of performance. In this paper, the elastocaloric effect in a columnar-grained Cu71.5Al17.5Mn11 shape memory alloy fabricated by directional solidification was investigated. The features of the columnar-grained Cu71.5Al17.5Mn11 alloy were characterized by electron backscatter diffraction (EBSD), differential scanning calorimeter (DSC) and cyclic tensile tests. The adiabatic temperature change corresponding to the elastocaloric effect was measured by fast unloading from martensite to austenite during the tensile tests. It is found that the columnar-grained Cu71.5Al17.5Mn11 alloy showed a reversible strain of 10%, and the corresponding stress-induced entropy change $\Delta S$ was determined to be 22.5 J/kg·K. The measured adiabatic temperature change reached as high as 12.8K, which is close to the maximum attainable value at an approaching level of 80%. Moreover, a wide operating temperature range...
window $W$ of more than 100K was identified, thus a strong refrigeration capability ($RC = \Delta S \times W$) of ~2300 J/kg was demonstrated. The outstanding elastocaloric refrigeration capability together with the low required force and uniform phase transformation, making the columnar-grained Cu-Al-Mn shape memory alloy a promising material for solid-state refrigeration.

V-55
Fe distribution through thickness of the twin roller cast 1235 aluminum billet and its effect on abnormal grain growth in the following annealing
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Twin roller cast is a novel technology which is often used to produce aluminum alloys in industries, for instance AA1235 aluminum alloys. The twin roller cast AA1235 aluminum billet has a special solidification microstructure. Whereas, the secondary Fe precipitates may have a great effects on the following microstructure evolution, which further affects the mechanical property of the alloy. Twin roller casting and a following annealing have been performed on the AA1235 aluminum alloy. The distribution of Fe precipitates through thickness of the twin roller cast or the annealed billet has been studied by Optical Microscopy, Scanning Electronic Microscopy and X-ray Energy dispersive spectrum analysis using a layer-by-layer dissolution method. It is found abnormal grain growth is of presence on the surface of the annealed billet. The effect of the evolution of these Fe precipitates on abnormal grain growth in the following annealing process has been analyzed.

V-56
Fabrication, mechanical properties and tribological behaviors of Ti2AlC and Ti2Al(Sn)0.2C
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Ternary compound ceramics of MAX phase with nanolamellar structure have gained more and more attention in recent years because they combine the excellent features of both metals and ceramics. Many studies have also been conducted to form solid solutions with A-sites to improve the mechanical and tribological properties of this compound. In this study, high pure and dense Ti2AlC and Ti2Al(Sn)0.2C bulks have been prepared with molar ration of 1:1:0.9 and 1:0.9:0:2:0.85, respectively, at 1450 °C with 2.8 MPa for 30 min in Ar atmosphere. The influences of mole ratios of raw materials, sintering temperature and holding time on the purity of these two kinds of materials have been discussed. The flexural strength of Ti2AlC and Ti2Al(Sn)0.2C have been measured to be 430 MPa and 410 MPa, respectively. The tribological behaviors have been investigated by dry sliding a low-carbon steel disk in the normal load range of 20~80 N, and the sliding speed range of 10~30 m/s. Both the bulks have good wear properties. Ti2AlC has a friction coefficient of 0.45~0.3 and a very low wear rate of $2.97 \times 10^{-6}$ mm$^3$/N·m, Ti2Al(Sn)0.2C has a friction coefficient of 0.35~0.25 and a wear rate of $2.1 \times 4.3 \times 10^{-6}$ mm$^3$/N·m. The influences of Sn incorporation on the microstructures and properties have also been discussed.

V-57
Relationship between microstructure and mechanical properties of 36MnVS4 steel for automobile engine
The relationship between microstructure and mechanical properties of 36MnVS4 steel was studied, which is a typical non-tempering steel and widely used for automobile engine connecting rod. The specimens were cut from a rolled bar with a diameter of 40mm and a chemical composition: C 0.36, Si 0.64, Mn 0.97, P 0.015, S 0.035, Cr 0.22, V 0.29 and Fe balance (in mass percent). In order to obtain specific microstructures, specimens were austenitized for 45min and later cooled. Different prior austenite grain sizes were obtained by austenitizing at 850, 950 and 1050 °C, and different ferrite contents were obtained by different cooling rates. The mechanical properties test results indicate that the strength and hardness are mainly decided by ferrite content which is governed by cooling rate and prior austenite grain size, while the impact properties are significant influenced by prior austenite grain size. The strength and hardness markedly decrease with the ferrite content increasing. The ferrite content gradually increases with the cooling rate decreasing. And the coarsening of prior austenite grains will increasing the stability of austenite and hider the formation of ferrite. While the coarsening of prior austenite grains will significantly decreasing the impact properties and improve the splitting property. Therefore, in order to improve the fracture splitting property of connecting rod, the prior austenite grains should be moderately coarsened. In addition, the influence mechanism of prior austenite grain size on fracture splitting property was also discussed. Due to the microstructure heredity, the sizes of ferrite and pearlite of the specimen with larger prior austenite grains are bigger after cooling, which means less boundaries. Generally, the boundaries can prevent the propagation of cracks, so the cracks always change its propagation direction or blunted into a ductile rupture void, each of them will absorb more energy and deteriorate the evenness of fracture.

V-58
Deformation induced lattice defects and their recovery in nanoscale carbon-rich ferrite lamellae of cold-drawn pearlitic steel wires
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Cold-drawn pearlitic steel wires belong to the most successful engineering materials. High density of lattice defects formed in ferrite lamellae during cold wire drawing is believed to play important roles in their outstanding mechanical properties. In this work, by a combination of X-ray line profile analysis and positron annihilation spectroscopy, densities of deformation-induced defects and their recovery in carbon-rich ferrite lamellae of cold-drawn pearlitic steel wires are characterized. It is shown that both the dislocation densities and the vacancy cluster concentrations increase continuously with increasing drawing strain; upon annealing treatment, the recovery of the lattice defects is dominated by the agglomeration and annihilation of vacancy-clusters at temperatures lower than 523 K, while the temperatures higher than 523 K the recovery process is controlled by the annihilation of dislocations. In the cold-drawn state, contributions of the defect hardening to the total tensile strength of the wires reach nearly 40%, which is mainly ascribed to the dislocation hardening. Upon annealing treatments, the strain aging hardening leads to a maximum strength at 473 K; above 523 K, the annihilation of vacancy clusters and dislocations in ferrite lamellae causes a continuous softening of the wires, where the decrease of dislocation density plays a major role.
Finite element simulation of chain-die forming U profiles with variable cross-section
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The traditional roll-forming has been widely used to manufacture constant cross-section products because of the high quality, efficiency and low cost. It is quite epidemic in producing AHSS automobile parts nowadays. However, with the development of the auto industry and diversity of the products, variable cross-section profiles have attracted more and more attention. The traditional roll-forming technique is difficult to meet the requirements. Chain-die Forming which was introduced in recent years makes it possible. Chain-die Forming is an extension of the roll-forming and its key characteristic is enlarging the rotation radii of the moulds, by which the deformation zone is extended. The study focuses on the finite element simulations of Chain-die forming U profiles with variable cross-section, including variable width and height. The feasibility of Chain-die Forming producing variable cross-section products is verified by the perfect simulation results. The advantage of Chain-die Forming is that there is no need to design the intermediate moulds except the finished-profile ones, which reduces the mould quantity immensely. Then the cost is lower.

Texture gradient enable ultra-strong and ductile alloys
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To engineer more advanced structures, e.g. lighter automobiles, higher buildings, more durable bridges or safer power plants, there is an everlasting need for superior metallic materials. For numerous components in such applications, metals are mankind’s only feasible materials choice, owing to their high strength and ductility. Yet, increasing the former of these properties, e.g. for light-weighting, leads to the decrease of the latter. The strength-ductility paradigm can be overcome by the use of expensive alloying elements such as Ni in steel or Y in Mg alloys, however, given the growing economical, ecological and energy-related concerns1, more efficient materials design solutions are needed.

Recently, using nature as a blueprint, alloys with grain size gradient, are revealed to have extraordinary mechanical properties, however, only at strong grain size gradient, after intensive surface treatment of the near-end product. Here, we discovered that coupling to the hitherto unheralded crystallographic texture gradient, weak grain size gradient (>200 times weaker than the above reported) produced by conventional bulk material process will also overcome the strength-ductility trade-off. Formation of such gradient microstructure is devised and triggered by only adding a weak temperature gradient before final hot working. With this, simultaneous increase of tensile ductility by 50% and tensile strength by 12% are achieved on a 1 GPa dual-phase automotive steel, distinguishing from other recently developed approaches. The texture gradient, which generates lateral strain gradient, optimizes the internal stress and stress state distribution against damage. The presented concept and approach are generic: they can be applied to other alloys as well using various thermo-mechanical treatment routes and offer their potential for large-scale industrial production at low cost.
Interaction of misfit accommodation and solid-state diffusional phase transformations
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During solid-state phase transformations, the specific volume of a new phase is often different from that of the matrix. In most instances, this intrinsic transformation misfit can be accommodated through the elastic/plastic deformation both in the matrix and in the new phase. However, phase transformation is a dynamic process. The generated strain energy due to misfit accommodation will vary with the transformation process and, simultaneously, as a part of thermodynamic driving force, can affect the overall transformation kinetics. This presentation is devoted to the interaction between the misfit accommodation and phase transformation. On the basis of spherical inclusion, infinitesimal deformation theory, and displacement continuity at interface, the interaction between misfit accommodation and interface-controlled transformation (without bulk diffusion of solutes) was analyzed in our previous work. It was found that the misfit accommodation counteracts the transformation at the initial stage but favors the transformation at the later stage. When phase transformations involves the long-range diffusion of solutes, however, growth may be controlled by both the interface migration and the solute diffusion. Due to misfit accommodation, there are inhomogeneous stress/strain field and solute diffusion field in the front of interface. A kinetic modeling for such solid-state diffusional phase transformation is presented, where the interactions of interface migration, solute diffusion and misfit accommodation are analyzed. A counterbalancing influence between mechanical and chemical driving forces is found.

Effect of aging treatment on microstructure and properties of V alloyed high manganese austenitic steel
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In this paper, the Fe-16Mn-1.3C-0.3V steel was prepared in a vacuum induction melting furnace. The furnace was charged with ingots (1.3% C, 16.5% Mn, 0.6% Si, 0.3% V, 0.0014% B all in wt.%) and was heated up to 1550 °C. After a series of heat treatment experimental processes, including solution treatment at 1080 °C for 1 h then aging treatment at 350 °C, 400 °C, 450 °C, 500 °C and 550 °C respectively for 1 h, the microstructure of these V alloyed high manganese austenitic steels was studied thoroughly using optical microscopy (OM), scanning electron microscopy (SEM), energy dispersive spectrometer (EDS), X-ray diffraction (XRD), and transmission electron microscopy (TEM). The steel’s toughness was tested by ZBC2452-B pendulum impact testing machine with 10 mm ×10 mm ×55 mm V-notch standard sample and its hardness was tested by XHB-3000 Brinell hardness machine.

After solution treatment at 1080 °C for 1 h, the steel showed the microstructural morphology of austenite matrix, tensile strength of over 800 MPa, elongation of 40.0%, impact toughness (V-notch) of 271.2 J/cm², hardness of 225 HB and yield strength of 389.7 MPa. During aging treatment, the tensile strength, elongation and impact toughness of experimental steel suffered a drop to various degrees. Instead, the hardness and yield strength have increased. However, when aging treated at 350 °C and 400 °C, hardness and yield strength of the experimental steel have no obvious promotion. After aging treated at 350 °C for 1 h, the hardness is 231 HB, tensile strength is 667 MPa, the yield strength is 400 MPa, impact toughness(V-notch )is 258 J/cm² and elongation is 26%. After
aging treated at 400 °C for 1 h, the hardness is 233 HB, tensile strength is 704 MPa, the yield strength is 405 MPa, impact toughness (V-notch) is 257 J/cm² and elongation is 31%. Using optical microscopy (OM) and scanning electron microscopy (SEM), a few fine precipitates were distributed dispersively in the austenite matrix.

Whereas aging treated at 450 °C, 500 °C and 550 °C, more and more precipitates were distributed in the austenitic matrix, and hardness and yield strength have been remarkably increased, which shows that addition of V enhances the hardness of the high manganese austenitic steel after aging treatment. After aging treated at 450 °C, 500 °C and 550 °C for 1 h respectively, the hardness are 249HB, 245HB, 241HB, and tensile strength are 707.3 MPa, 729 MPa, 540 MPa, and yield strength are 421 MPa, 427 MPa, 440 MPa, and impact toughness (V-notch) are 215 J/cm², 165.6 J/cm², 35.4 J/cm² and elongation are 31%, 30%, 3.4%. The result of mechanical properties shows that the experimental steel has the best comprehensive performance after aging treatment at 450 °C for 1 h. But after aging treatment at 550 °C for 1h, the elongation and impact toughness of experimental steel have dropped sharply to 3.4% and 35.4 J/cm². The bulky precipitates were seriously distributed at grain boundaries by using scanning electron microscopy (SEM).

In this paper, X-ray diffraction (XRD), energy dispersive spectrometer (EDS) and transmission electron microscopy (TEM) were used to study the deposition, morphology and composition of these precipitates. In the experimental steel, due to the presence of about 0.3 wt.% vanadium in the composition as one of the strongest carbide forming elements in steels compared to iron or manganese, vanadium reacts with the dissolved carbon of the molten steel leading to the formation of more stable vanadium carbid es instead of iron–manganese carbid es. With the temperature increases, the amount of needle-like precipitates at grain boundaries and the size of austenite grain have increased, which lead to the deterioration in impact toughness and elongation. With the best aging treatment process, fine vanadium carbid es were found to precipitate within the austenite matrix, which significantly enhanced the austenitic matrix and improved work-hardening ability. XRD pattern of the Fe-16Mn-1.3C-0.3V steel confirmed that vanadium carbid es exist as V₈C₇ in this type of steel. Meanwhile, a selected area diffraction pattern (SADP) demonstrated that the fine precipitates are vanadium carbid es. V₈C₇ particles of 10~100 nm have been observed in the austenite and the enhancement of hardness mainly depended on dispersed precipitated V₈C₇ particles. Those precipitated fine V₈C₇ particles have coherent orientation relationship with austenite. However, with growing up of the V₈C₇ particles, the orientation relationship disappears when the particles reach a certain degree size.

The preceding results indicate that vanadium carbid es in the Fe-16Mn-1.3C-0.3V steels are of the type V₈C₇. The addition of V enhances the hardness of the high manganese austenitic steel after aging treatment. With the increase of aging treatment temperature, more and more precipitates were distributed in the austenitic matrix. The result of mechanical properties shows that the experimental steel has the best comprehensive performance after aging treatment at 450 °C or 1 h. V₈C₇ particles of 10~100 nm have been observed in the austenite and the enhancement of hardness mainly depended on dispersed precipitated V₈C₇ particles. Those precipitated fine V₈C₇ particles have coherent orientation relationship with austenite.

V-63

Is twinning important for TWIP steels?

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Twinning-induced plasticity (TWIP) steels are well-known for their excellent combination of high strength and exceptional ductility. The excellent mechanical properties of TWIP steels are commonly attributed to deformation twins. This work intends to evaluate the role of twinning in the mechanical properties of TWIP
steels. Synchrotron X-ray diffraction experiments were carried out to measure the dislocation density that is used to evaluate the dislocation strengthening. It is found that the dislocation density in TWIP steels is very high and the corresponding dislocation strengthening accounts for ~90% of the flow stress increment after yielding. In comparison, deformation twins contribute to only 118 MPa at a true strain of 0.4, indicating that the hardening contribution of twins in terms of kinematic hardening to the flow stress should be insignificant. In other words, deformation twins only have minor effect on the flow stress, in contradiction to the current understandings in literature.

V-64
Influence of cooling rate and chemical composition on phase transformation and hardness of C70S6 steel
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The influence of cooling rate and chemical composition on phase transformation and hardness of C70S6 steel was studied, which is a typical kind of non-tempering steel and widely used for automobile engine connecting rod.

The specimens were cut from steels Nos.1-2 with different chemical composition. The chemical composition of steel No.1 was C 0.74, Si 0.2, Mn 0.64, P 0.019, S 0.062, Cr 0.14, Ni 0.06, V 0.045, Mo 0.01, Cu 0.13 and Fe (in mass percent). And the chemical composition of steel No.2 was C 0.69, Si 0.18, Mn 0.54, P 0.014, S 0.059, Cr 0.14, Ni 0.06, V 0.035, Mo 0.01, Cu 0.01 and Fe (in mass percent).

The law of phase transformation during continual cooling was researched by Gleeble-3800 thermal simulation testing machine. In order to obtain CCT curves and the effect of cooling rate and chemical composition on hardness, the specimens cut from steel No.1 and No.2 were heated for 30 s at 1120 °C and later cooled to the deformation temperature 950 °C, then compressed by a deformation of 45% with a strain rate of 3s⁻¹. The specimens were cooled to room temperature with different cooling rates after deformation. Furthermore, in order to provide theoretical basis for hardness controlled and carbon equivalent designed of rolling materials, the specimens cut from steel No.1 and No.2 were austenitized for 45 min at 950 °C and later cooled to room temperature with a cooling rate similar to the actual rolling production.

The results show that all the microstructures of two experimental steels are a matrix of ferrite, pearlite and sorbite under all cooling rate. The ferrite and pearlite contents gradually decrease with the cooling rate increasing, while the sorbite content increases. Both the pearlite transformation start temperature and end temperature decrease with the cooling rate increasing. Besides, the hardness increases with the cooling rate. Under same cooling rate, the pearlite content and phase transformation temperature of steel No.2 with a low carbon equivalent (Ceq=0.82%, which is calculated by the equation: \( Ceq = C + Mn/6 + (Cr+V+Mo)/5 + (Cu+Ni)/15 \)) are higher than those of steel No.1 with a high carbon equivalent (Ceq=0.9%). And the hardness of steel No.2 is lower than that of steel No.1. The mechanism of that was studied. The results show that the hardness of C70S6 is affected significantly by the ratio of pearlite and sorbite. The hardness obviously decreases with the pearlite content increasing. And the pearlite content gradually increases with the cooling rate decreasing. In addition, decreasing carbon equivalent can raise the phase transformation temperature and move up CCT curves. In other words, higher pearlite content or lower hardeness can be obtained by decreasing carbon equivalent.

The hardness of steel No.1 obtained by heating for 45 min at 950 °C and later cooling to room temperature with a cooling rate similar to the actual rolling production is much higher than the standard requirement of rolling
bars (below 260 HBW). According to the results of previous experiments, the hardness can be reduced by cooling rate decreasing. However, the hardness of steel No.1 is still very high (272.9 HBW) with the cooling rate decreasing to 0.1°C/s. And, during the actual rolling process, the cooling rate is difficult to be decreased to 0.1 °C/s. While the hardness of steel No.2 cooled with a cooling rate similar to the actual rolling production is 255.2 HBW, which is appropriate. Therefore, in order to obtain an appropriate hardness, the Ceq must be controlled. And a Ceq=0.83% is recommended.

V-65
Effect of alloy composition on mechanical properties and cold cracking during direct chill casting of 7*** aluminum alloys
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High strength 7*** series aluminum alloys have been extensively used in aerospace industries due to the excellent properties. However, cold cracking has been an increasingly severe challenge during direct chill casting of the alloys. In this research, a cold cracking index (CCI) was proposed by the author combining experimental results and FEM simulation. It was found that the cold cracking tendency is low above 250 °C during direct chill casting of the 7*** series alloys, and begins to increase rapidly when ingot temperature continue to decrease below 200 °C. The cold cracking tendency is basically consistent with the amount of nonequilibrium eutectics of these alloys under the same casting process. It is very likely that massive nonequilibrium eutectics located at grain boundaries greatly weaken the ductility of as-cast alloy, making the ingot prone to cracking due to stress concentration. It also revealed that the application of water wiper can effectively decrease the cold cracking tendency.

V-66
Novel superalloy strengthened synergistically by Suzuki segregation and gama prime phase
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The properties of superalloys are usually deteriorated by the coarsening of nano-sized γ' phase, which is the primary strengthening component at high temperature. Stabilizing the γ' phase represents one of the key challenges in developing next-generation superalloys. Here, we fabricate a cobalt-base superalloy with nanoscale coherent γ' phase (Ni,Co)3(Al,Ti,Nb), which is isolated by stacking-fault ribbons in the alloy matrix as a result of Suzuki segregation of alloying atoms, and demonstrate that this new nanostructure can slow down the coarsening of γ' phase at high temperature. As a result, the Co-Ni-base superalloy displays a considerably high tensile-yield point exceeding 1650 MPa at room temperature and 1250 MPa at 1073 K, which are markedly higher than those of the commonly used nickel- and cobalt-base superalloys, thereby paving a new way for developing superalloys with exceptional mechanical performances and thermal stability.

V-67
Effects of La microalloying on microstructure evolution of pure copper
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The absorptivity of La in pure copper and the effects of La microalloying on microstructure evolution of pure copper were studied by adding different La contents to pure copper under vacuum condition. The microstructure of copper ingots with different La contents were synthetically analyzed by means of optical microscope (OM) and scanning electron microscope (SEM), and the content of La in ingots was tested using inductively coupled plasma-atomic emission spectrometry (ICP-AES). The results show that the absorptivity of La in pure copper is more than 90% under vacuum condition and the burning rate is mainly due to autoxidation of La and the reaction with impurity elements in copper. The microstructure of copper ingot is refined with La addition. The columnar to equiaxed transition (CET) occurs with 0.14% La addition and the microstructure of copper ingot is full equiaxed grains when La content is 0.16%. The CET mechanism is that the constitutional supercooling degree and the number of heterogeneous nucleation particles in copper melt are increased with La addition.

V-68
Microstructure evolution and material flow behavior during thixoforging of M2 tool steel
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Thixoforging is an innovative technology in which the complex parts with good mechanical properties can be formed, usually in a one-step operation, by taking the advantage of the thixotropic properties of the semi-solid metallic slurries. The microstructure plays a crucial role for steel thixoforging process, since it determines the thixotropic flow behavior of materials in the semi-solid state. Therefore, it is necessary to well understand the microstructure evolution and flow behavior during forming. Thanks to the high content of alloying elements and their low diffusion rate, the microstructure of M2 tool steel grade in the semi-solid state could be preserved by quenching process which helps investigating the microstructure evolution and material flow behavior during thixoforging. The M2 samples with two different thermal histories (as-extruded, as-annealed) were investigated. Partial induction remelting was performed at the processing temperatures ranging from 1290 °C to 1340 °C, which corresponds to the liquid fraction range between ~10% and ~30%, according to the DSC analysis. An interconnected liquid network surrounding the globular solid grains was formed with increasing temperature. However, as compared to the as-extruded M2 samples, the as-annealed ones exhibited better microstructure for thixoforging: less liquid microsegregation, more spherical solid grains. In addition, the microstructure evolution of extruded M2 was also in situ observed by CLSM (Confocal Laser Scanning Microscope). The thixoforging experiments of M2 were performed using a mechanical press. Combining with the load-displacement curves and the microstructure of the thixoformed parts in different positions, the material flow behavior was investigated and discussed. Different mechanisms in various forming stages were proposed.

V-69
The Effect of Temperature on Deformation Behavior of Sintered Porous 2024 Aluminum Alloy during Semi-Solid Compression
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Temperature is a very important parameter during semi-solid processing, a promising manufacturing route which has recently gained wide use for dense materials. However, very few investigations on porous materials were reported. In order to investigate the influence of temperature on deformation behavior of sintered porous 2024 aluminum alloy during semi-solid compression, the samples were compressed uniaxially at a semi-solid state. The results show that liquid fraction of powders soaking at a semi-solid state increases with increasing temperature. DSC measurement is a suitable method to determine liquid fraction of powders in this study. As temperature increases, more powders of samples water-quenched after compression are broken up, which makes the microstructure more spherical and uniform. The relative density increases with the increase of temperature. Thus, the deformation resistance of sintered porous materials decreases, which makes true stress decrease with the increase of temperature. Therefore, the effect of temperature on deformation behavior of sintered porous materials at a semi-solid state is attributed to the liquid fraction, which significantly affects the breakup of solid skeleton or powders and the flowing of liquid.

Experimental and numerical studies on formability of 6016 aluminum alloy sheets
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In this study, experimental and numerical methods are used to study the forming properties of 6016-T4P aluminum alloy sheets at ambient temperature. Parameters of the mechanical properties are obtained by using uniaxial tensile tests. The tensile strength is approximately 260 MPa, and the elongation is about 26%. The forming limit diagram (FLD) for 6016-T4P aluminum alloy sheet is determined by die bulging test as well. A Johnson-Cook constitutive equation \( \sigma = 136.9 + 470.675e^{0.279} \) of 6016-T4P aluminum alloy is proposed based on the tensile tests of room temperature. On the other hand, simulations of die bulging test are performed by using ABAQUS 6.13 finite element (FE) software. The predicted FLD using the developed constitutive equation are compared with the experimental data. As a result, the simulation results show good agreement with the experimental curves. Meanwhile, it is observed that the optical microstructures of the 6016-T4P aluminum alloy are homogeneous with average grain size of 44μm. Three different phases of AlFeMnSi, AlCrFeMnSi and AlZn are identified in the microstructures by TEM and XRD investigating. The precipitated phases have great effect on the mechanical properties and formability of 6016-T4P aluminum alloy. Further, a numerical simulation and defect prediction of stamp forming for an automobile part (B-column) are investigated by using FE method. Consequently, an optimization scheme of the die structure is proposed.

Influence of precipitation hardening on the sliding wear behavior of a Cu–Zn–Al–Mn–Si based brass alloy

V-70

V-71
Special brasses containing Mn and Si possess high wear resistance due to the dispersion of hard Mn$_5$Si$_3$ particles. In this study the effect of precipitation hardening on the wear resistance of a Cu–30Zn–3Al–3Mn–1Si based brass alloy was investigated. Dry sliding wear test was conducted using a block-on-ring configuration. The results indicated that finely, nano-scale Mn$_5$Si$_3$ particles precipitate from the matrix after annealing at 800 °C for 4 h, resulting in the increase of hardness from 240 to 278 HV. Both the wear loss and friction coefficient greatly decreased, indicating the improvement of the wear resistance. From the examination of the worn surfaces, adhesive and abrasive wear were proved to be the major wear forms. The adhesion and abrasion decreased after the precipitation-hardening treatment.

V-72

A multiscale lamellar structured ferrite/cementite steel managing both high strength and stabilized uniform strain

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The aim of this research was to develop a ferrite/cementite steel with a structure entailing ameliorated ductility (stabilized uniform strain) and strength as high as ultrafine-grained (UFG) steels. The mechanisms inducing the good combination of mechanical properties in the multiscale lamellar structure was to be investigated. We used different thermal treatment to obtain two types of initial structures: a martensite (M) structure and a ferrite + pearlite (F+P) structure. Both steels were subjected to warm rolling up to a strain of 1.7. Transmission electron microscopy (TEM) and scanning electron microscopy (SEM) equipped with electron backscattering diffraction (EBSD) were used to investigate the microstructural characteristics. Uni-axial tensile test and nanoindentation were used to evaluate the mechanical properties. Homogeneous UFG structure was developed in the warm rolled M steel, giving a high yield strength of 1150 MPa but no uniform strain during tensile deformation. By contrast, a multiscale lamellar structure with a broad grain size distribution was obtained in the warm rolled F+P steel, which presented the same high yield strength as the M steel, as well as a relatively high uniform strain of 7.0 %. The good balance between strength and ductility was attributed to the lamellar structure with a gradient grain size distribution, which caused an enhanced strain hardening and stabilized the uniform deformation. Through designing a lamellar structure with multiscale grain size distribution, we obtained an appreciable property combination in ferrite/cementite steel. The strength was as high as the UFG steels, while the uniform strain was stabilized and improved owing to the enhanced strain hardening. The approach described here provide a new principle for designing plain carbon steels with superior performance.

V-73

Effect of precipitates on austenite grain growth behavior in a low-carbon Nb-V microalloyed steel

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The purpose of this study was to determine the most sensitive factor affecting grain growth between heating temperature, holding time and precipitates. Finally Arrhenius mathematical models of austenite grain growth...
were built, offering foundation for establishment and optimizing of Q345E billet heating schedule. The chemical composition (wt,%) of investigated steel is: C 0.15, Si 0.31, Mn 1.47, P 0.012, S 0.004, Nb 0.05, V 0.08, Ti 0.003, Als 0.018. The specimens were austenized at 850-1250 ºC in box electric resistance furnace held for 20, 40, 60, 120, 240, 360min and then quenched in water (25 ºC). Etching the quenched samples in saturated picric acid and hydrochloric acid solution revealed prior austenite grain boundaries (PAG). The PAG boundaries were observed through optical microscope (OM). Transmission electron microscope (TEM, JEM-2100) examination was performed on carbon extraction replicas to observe morphology of precipitates. The extraction replicas were taken out carefully on copper grid via deep etching. The precipitates were identified by selected area electron diffraction (SAED) and energy dispersive spectrometer (EDS) analysis. Because of pinning effect of NbC and/or VC on austenite grain boundaries, grains grow slowly at 850-1000 ºC. However, when temperature reaches 1050 ºC, abnormal grain growth is observed, which is attributed to dissolution of NbC particles. The NbC precipitates dissolves significantly at 1150 ºC. However, grain sizes are still very small. Thus, austenite grains grow rapidly at 1050-1150 ºC. The fully dissolution temperature of this steel is 1150-1250 ºC. Finally, the relationship between \( T_{GC} \) and \( T_{DISS} \) can be illustrated as follows: 100 ºC \( \leq T_{DISS} - T_{GC} \leq 200 ºC \). When heating temperatures are 850-1050 ºC and 1050-1250 ºC, grain growth activation energies (\( Q \)) are 59945 J/mol and 135813 J/mol, respectively. The different grain growth models are mainly caused by the gradual dissolution of NbC particles.

V-74

Simulation analysis of aluminum circular tube in a two-stage porthole dies extrusion process
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The single stage porthole die extrusion is largely applied in our research and industrial production. This paper adopts a new method of two stage porthole die for a hollow aluminum tube, which adds a pre-porthole die in front of the conventional porthole die that can slow down the metal deformation rate and control the metal flow uniformity. In this paper, we performed a simulation of hollow aluminum extrusion in single stage porthole die and two stage porthole die. Through a series of numerical simulation based on Forge software, the advantage of two-stage porthole die extrusion, such as the surface quality of extruded profile, extrusion force, welding quality and die stress, has been studied. The results showed that the pressure of welding and required extrusion force decreased and the surface quality of the extruded profile would be improved. Thus, we can prolong the work life of mandrel root by the means of this method.

V-75

Study on low temperature mechanical properties of power transmission tower steel
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The tensile and impact tests have been used to the study the mechanical properties under different temperatures of 300 mm large scale angle steel at different positions, especially the tensile strength, yield strength, total elongation and impact toughness in the range of -40 ºC to 0 ºC. The results showed that the microstructures and impact toughness at different positions were difference, the grain size of edges was smallest and the impact toughness was best. The low temperature impact toughness of heat affected zone was the worst due to the coarse grain. When the impact energy was 34 J, the ductile-brittle transition temperature of weld, center, vertex
and edge were -7.2 °C, -33.0 °C, -31.5 °C and much less than -40 °C, respectively. Meanwhile, because the banded structure was detrimental to the ductility, the elongation of rolling direction of rolling direction was lower than vertical direction. The strength of weld was higher than other locations, but the elongations was obviously decrease.

**Poster**

**V-P01**

**Electrochemical drawing Fe-6.5Si alloy wire**

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Fe-6.5Si alloy has excellent soft magnetic properties, especially in high frequency application. Due to the low ductility at room temperature, the Fe-6.5Si alloy is hard to be fabricated into thin sheet by cold rolling processes. Some literature show that the iron core can be made of silicon steel wire by winding copper body. The iron core made of this technique has many advantages. Moreover, the industrialized production process of wire material is simple and low cost. Therefore, the development of Fe-6.5Si alloy wire material has important practical significance.

Although the wire is easier to deform than the sheet, it can still not be realized to draw Fe-6.5Si alloy into the wire at room temperature because of its low ductility. In this paper, the electrochemical effect was introduced into drawing process. The electrochemical reaction on the surface of the wire material can reduce the degree of hardening of the surface, and promote the forming of the material. The drawing of Fe-6.5Si alloy wire at room temperature was realized, The reduction of area reached 86%. The wire shows good surface quality and excellent ductility.

**V-P02**

**Liquid phase separation of Cu75Fe25 melts in static magnetic field**

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Some binary systems such as Cu-Co and Cu-Fe show a metastable miscibility gap in the undercooled liquid [1]. When a homogenous liquid is undercooled to the bimodal of the metastable miscibility gap, it will be decomposed into two liquids of different compositions, which solidify separately later. This decomposition is usually termed liquid phase separation and in principle can produce a homogeneous dispersion of one liquid in the other liquid. But, it has proven difficult to obtain the homogenous dispersion by casting of phase-separated alloys on the Earth due to the presence of natural or artificial convection in liquid alloys [2]. Studies on Cu-Co alloys showed that the imposition of a static magnetic field on electromagnetically levitated samples can change a bimodal droplet size distribution into a quasi-singular one as a result of damping of forced convection [3]. However, such a magnetic field effect has not been validated for glass-fluxed samples, which can reach undercoolings as high as those of electromagnetically levitated samples [4].

In the present work, bulk Cu75Fe25 alloys were undercooled and solidified using the glass-fluxing technique with and without imposition of a static magnetic field of B = 2 T. The surface temperature of the samples during...
melting and solidification was measured using a single-color pyrometer. The solidification microstructure of phase-separated samples was examined using an optical microscope. The apparent sizes of Fe-rich droplets, which were frozen in during rapid solidification were measured with the aid of a CAD software. The results showed that the size distribution of Fe-rich droplets in the glass-fluxed samples is sensitive to the imposition of the static magnetic field. When no magnetic field is applied, the size distribution of the Fe-rich droplets shows a single peak only. When the magnetic field of 2 T is applied, the size distribution of the Fe-rich droplets will show more than one peaks. Additionally, the frequency of small-sized droplets is reduced, whereas the frequency of large-sized droplets is increased. These observations suggest that the imposition of the static magnetic field might have accelerated droplet coarsening in the glass-fluxed Cu-Fe samples by altering patterns of melt convection.

References

V-P03
Micro/nanowire arrays with largely tunable diameter and spacing for strong radiate sources
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With the recent advances in “fast ignition” of inertial confinement fusion (ICF) and the strong radiate sources of high differentiate in space-time, the interaction between high-power ultrashort pulse laser and materials become research focus recently. Compared to normal solid materials, the micro/nanowire arrays that look like “velvet” has a low average density and a high local density, which can produce higher efficiency of conversion to the X-ray pulse. Recent researches indicate that, X-ray generation from femtosecond-laser produced plasma has become an attractive way to obtain short pulse X-rays. However, for micro/nanowire arrays laser targets applications, one important challenge that needs to be overcome is obtaining accurate control of the diameter, length, location, and packing manner of the micro/nanowires. Metal-assisted chemical etching (MACE) is a simple and low-cost method for fabricating various Si micro/nanostructures with the ability to control various parameters, and Si structures will be an ideal template to electrodeposit metallic micro/nanostructures. Advantages of this method include the ability to etch a defined pattern specific to the application of interest including complex, curved, linear or non-linear patterns. It is also a simple fabrication method requiring only a single lithography step combined with a wet etch. A gold film with coded hole arrays was fabricated by electrodepositing in Si micro/nanostructures. The coded hole arrays gold film with largely tunable diameter (0.1~10 μm), length (1~100 μm), and spacing (0.1~30 μm) could be used to produce strong radiate sources in our lab.

V-P04
Numerical simulation of temperature field and microstructure of a wide copper plate during warm mold continuous casting
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Distribution of temperature field in continuous casting process is a key factor that affects the continuous casting progress and the quality of the plate. Revealing the plate temperature has guiding significance for mold design and development of process parameters, which reflects more obviously in continuous casting of wide plate. In this paper, warm mold continuous casting for wide copper plate (500mm×12mm) was taken as the object, and the finite element model was established based on the actual size and the numerical simulation for wide copper plate during warm mold continuous casting and the temperature field and microstructure were analyzed by ProCast software. The results show that: when the copper melt temperature is 1200 °C, the mold temperature is 800~1000 °C, casting speed is 60-100 mm/min, the temperature field in the horizontal direction of the wide surface of the copper plate is uniform, and the temperature between center and edge is less than 10 °C. The temperature in the vertical direction decreases, and the temperature between narrow face and wide surface is within 25 °C at the edge. Microstructure of plate appears “bamboo-like” grain along the direct of casting. Warm mold continuous casting technology can solve the cast zoning cooling problem happened in cold mold continuous casting of wide plate. Plate with microstructure of “bamboo-like” grain along the direct of casting which can provide good performance can be produced with the method, which shows good prospect in application.

V-P05
Fabrication of continuous Fe-6.5wt.%Si fibers by rotation water spinning method
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Fe-6.5wt.%Si alloy is one kind of soft magnetic materials with higher relative permeability, lower coercive force and nearly zero magnetostriction. Silicon steel wires can be wounded into transformers, inductors et al., suggesting another application shape rather than thin sheet for soft magnetic materials. Continuous Fe-6.5wt.%Si fibers through have wide application prospects.
In this paper, continuous fibers of Fe-6.5wt.%Si are prepared by rotation water spinning technology successfully by optimizing parameters such as injection diameter, pressure, distance, angle, temperature and rotating water speed. Diameter of the fibers are in the range of 100~140 μm, the length can reach 30 meters. The rapidly quenched fibers exhibit very high plasticity, up to 30% at room temperature. In addition to fast cooling condition, the excellent plasticity is believed to be related to its strong cubic texture {100} and gauss texture {011}.

V-P06
Deformation twinning in equiaxed-grained Fe-6.5wt.%Si alloy after rotary swaging at intermediate temperatures
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Fe-6.5wt.%Si alloy is a kind of soft magnetic materials with nearly zero magnetostriction, high relative
permeability, low coercive force and iron loss. However, Fe-6.5wt.%Si alloy is brittle at room temperature due to appearance of ordered phases like B2 and DO3. It is hard to be deformed in conventional rolling process. There are patents claiming the possibility of constructing transformers by coiling silicon steel wires around a copper conductor. This suggests that the wires of high silicon steel can be a good choice for industry application, besides silicon steel sheets. Previously, Fe-6.5wt.%Si alloy wires were prepared through die forging, hot rotary swaging and hot drawing process. The tensile ductility of Φ6mm hot rotary swaging bar is enhanced after heat treatment at intermediate temperatures. Deformation twinning is found in Fe-6.5wt.%Si alloy within equiaxed grains after hot rotary swaging. It is necessary to discuss the reason why deformation twinning takes place in rotary swaging bar at intermediate temperatures. The ductility of Φ6 mm hot rotary swaging bars are improved after various heat treatments. Deformation twins grow in the equiaxed grains at intermediate temperature tensile tests, and a large number of twins appear after heat treatment. More twins can be observed in necking area than the other places. Dislocation pile-up and tangling are observed in the necking area, leading to slipping more difficultly and then deformation twins appear. The higher temperatures, larger strain rates and more contents of ordered phases repress the deformation twinning. However, grain sizes have little effect on deformation twinning.

**V-P07**

**Dendritic tip velocities in undercooled melts of pure nickel under static magnetic fields**

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Effects of melt flow on dendritic growth have attracted attention in recent years. Magnetic fields are regarded as an effective tool to control melt flow in metallic melts. When a static magnetic field is applied to undercooling solidification, it will impose a Lorentz force onto thermoelectric currents which are created by a thermal or and a chemical gradient along primary tips and dendritic arms. The force stirs the melt and gives rise to the so-called thermoelectric magnetohydrodynamics (TEMHD) flow [1]. Numerical modeling predicted that the TEMHD flow can alter morphology and tip kinetics of growing dendrites [2]. To verify such predictions, it is necessary to perform direct measurements of tip velocities in solidifying melts under static magnetic fields. In the present work, a bulk sample of high-purity nickel was repeatedly melted and solidified in a flux of soda lime glass under static magnetic fields of intensities up to 6 T. The static magnetic fields were generated by a superconducting magnet which had a large bore and allowed a heating coil to be installed inside [3]. In each melting and solidification cycle, a pyrometer and a high-speed camera were used to monitor surface temperature and recrystallization of the undercooled sample, respectively. The recorded video images of the recrystallizing sample were analyzed using a software to determine tip velocities in the undercooled sample. The measured surface temperature of the sample was calibrated by considering a thermal gradient crossing the sample [4]. The results showed that under each static magnetic field, the measured dendritic tip velocities follow a power law with rising undercooling. To deduce the influence of the static magnetic fields, different power laws were fitted to the measured dendritic tip velocities, and the fitted tip velocities were then normalized with respect to those obtained without the static magnetic fields. The normalized tip velocities show a U-shaped dependence on the intensity of the static magnetic fields for undercoolings below DT = 120 K. Such a U-shaped dependence can be attributed to two kinds of magnetohydrodynamics, which compete with each other in the melts and slow down or speed up tip velocities depending on the intensity of the static magnetic fields [5].

References
Crystal growth velocities in undercooled hypoeutectic Co80Sn20 alloys
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Rapid solidification of undercooled melts can produce metastable microstructures. For example, an anomalous eutectic structure was often observed in rapidly solidified eutectic or near-eutectic alloys under high undercooling conditions. To understand such a metastable structure, it is necessary to perform in-situ studies of competitive growth kinetics of single-phase and eutectic dendrites in undercooled near-eutectic alloys. In the present work, we studied crystal growth velocities in undercooled hypoeutectic Co$_{80}$Sn$_{20}$ alloys with and without the imposition of a static magnetic field of 5 T. Master alloys were prepared by arc-melting high-purity elemental materials under protection of an argon atmosphere. Each of the alloys had a mass of about 1 g. The alloys were then put in a flux of soda lime glass and melted in an induction-melting furnace. The alloys were overheated to temperatures of 100 to 200 K above the liquidus temperature for achievement of large undercoolings during cooling. The static magnetic field of 5 T was offered by a superconducting magnet with a large bore. The temperature of the fluxed alloys was measured using a single-color pyrometer through the melting and solidification cycle of the alloys. The rapid solidification process, i.e. recalescence, of the alloys were monitored in-situ and recorded using a high-speed camera in real time. The crystal growth velocities were determined by analyzing the recorded video images with the aid of a computer software. We found that unlike previous observations on hypoeutectic Ni-Sn alloys [3], the measured crystal growth velocities in the hypoeutectic Co-Sn alloys show irregular variations with rising undercooling in the absence of the static magnetic field. However, the crystal growth velocities measured in the presence of the static magnetic field show clear dependences on undercooling. The crystal growth velocities increase with rising undercooling initially. After reaching a maximum at an undercooling of 60 K, the crystal growth velocities decline with rising undercooling. Possible reasons for the magnetic field-induced changes of the crystal growth velocities were discussed by considering thermodynamic and kinetics factors that may influence nucleation and crystal growth in undercooling melts.

Effect of Ce addition on the microstructure and properties of Cu-4Fe composites
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Increasing interests have been paid to the Cu–Fe alloys in recent years for its outstanding physical properties. In this paper, the rare earth of Ce, as a third element was added to the Cu-4Fe alloy to improve the comprehensive properties and the effects of its addition on the microstructure, and properties of as-cast and
deformation-processed Cu-4Fe composites were investigated. Results show that addition of Ce significantly decreases the average size of the as-cast Cu-Fe alloys and facilitates the precipitation of secondary Fe particles in the Cu matrix. The filamentary structure of Cu-4Fe with addition of Ce seems to more stable than that of Cu-4Fe during the subsequent annealing process. Moreover with the increase in annealing temperature, the strength and hardness of the composites decrease but the conductivity increases. As a result, an improvement in mechanical properties was achieved. In particular, a remarkable change in the conductivity of the composites appears with the variation of Ce content. Thus the mechanisms of facilitation of the precipitation of secondary Fe particles and improvements in properties by Ce alloying were analyzed.

V-P10
The crack formation mechanism of Si-bearing steel during the twin-roll strip casting process
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The Twin-roll strip casting technique is now being investigated world-wide due to the huge advantage of short process. A major negative drawback is that the control of surface quality closely associated with the properties of strip is very difficult, which acts as obstacle to develop the advanced technology. So the key issue related to the development of the technique is to study corresponding factors causing the cracks on the strip surfaces, and illuminates the crack formation mechanism.

High content of 6.5% Si-bearing steel were fabricated by twin-roll strip casting. The cracks on the surfaces of the processed strips were obtained and analyzed by digital camera after series of surface treatment. Optical microscopy (OM) and scanning electron microscopy (SEM) were used to observe and characterize the microstructure nearby crack and fracture surface along the normal direction, respectively, and the crack formation mechanism was further analyzed in conjunction with processing parameters utilized during twin-roll strip casting process.

The results indicated that larger amount of vertical cracks along the rolling direction were observed in comparison with transverse cracks along the transverse direction on the strip surfaces. Transgranular and intergranular fracture modes both worked during the formations of vertical and transverse cracks on the processed strips. The dominant factor causing the formation of crack on the surface of the processed strips was the inhomogeneous transfer of heat during casting and rolling. The inhomogeneous transfer of heat induced by atmosphere during casting and roughness of roller both resulted in variations of dendrite length and secondary dendrite spacing (SDAS). Meanwhile, the rolling force suffering at solidification end destroyed the dendrite tip, which further influenced the filling of liquid steel between dendrites, and the dent and shrinkage occurred. Then, the crack initiated under series effects as stated above.

The predominant methods to eliminate the cracks forming during the twin-roll strip casting process are listed as below: (a) Shielding gas atmosphere should be utilized during casting and rolling. (b) The roughness of roller should be controlled in a certain scale. (c) The kiss point during casting should be controlled precisely. d. Rolling force should be small enough.

V-P11
In-situ X-ray diffraction study of phase transformations of Au-20Sn solder alloys at elevated temperatures
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49
Au-20Sn alloys are an excellent lead-free solder material for high-reliability and high-temperature applications such as flip chips, MEMS, LEDs, laser diodes and radio frequency devices [1,2]. The as-cast Au-20Sn ingots consist of two ordered intermetallic compounds, Au₅Sn and AuSn, at room temperature and thus, is hard to be extruded into thin strips for commercial applications following any ordinary processing routes [3]. It was shown by one of the authors [4,5] that with a careful control of casting and annealing it is possible to deform bulk Au-20Sn ingots at elevated temperatures thus enabling fabrication of thin solder strips. However, the deformation mechanism in this material is unknown due to a lack of knowledge of structural changes of the Au-20Sn material at elevated temperatures. In the present work, an in-situ synchrotron X-ray diffraction experiment was performed to investigate phase transformations of Au-20Sn solder strips. The experiment was carried out using transmitted X-rays of a wavelength of 0.06678 nm at the beam line BL14B1 of Shanghai Synchrotron Radiation Facilities. The strip sample had a thickness of 33 mm, and was heated and cooled using a vacuum furnace at rates of 10–20 K/min. The results provides evidence for an order-disorder transition of the Au₅Sn compound during heating and cooling. But, the AuSn compound does not show any structural transition except for thermal expansion. In future, high-temperature X-ray diffraction experiments will be carried out on the bulk Au-20Sn material under a mechanical load using synchrotron radiation X-rays with higher energy.

References

Development of low cost Mg alloys with balanced performance
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Magnesium alloys have the advantages of high specific strength, high dimensional stability, good machinability and easy recovery. However, magnesium alloys have low corrosion resistance, weak flame retardant performance and poor formability, which make them limited to large-scalely apply in industry. Therefore, it is always an important topic to improve the processing properties, the corrosion resistance and flame retardant performance in the study of magnesium alloy.

Mg-Al-Ca alloys with high Ca/Al ratio haven’t been studied comprehensively because too much Ca addition would decrease the mechanical property of magnesium alloy. Our group systematically designed a series of Mg-Al-Ca alloys with high ratio of calcium and aluminum. Their reticular structure was fully broken into micron and submicron particles by direct water cooled semi continuous casting, rolling and extrusion processing, so that Mg-Al-Ca alloys can be seen as the composite materials of Mg (α-Mg)-Al₂Ca, which greatly improve the yield strength, elongation, flame retardant performance, corrosion resistance and processing properties.

The yield strength of Mg-5Al-5Ca can reach 310 MPa and its corrosion rate is 2.048×10⁻⁶ g·mm⁻²·h⁻¹, which is better than AZ31. Its ignition temperature (1071 °C) far exceeds the current magnesium alloys. The tensile
strength of Mg-3Al-3Ca is 200 MPa at 175 °C and 97 MPa at 250 °C, tensile strength of Mg-4Al-4Ca is 200 MPa at 175 °C, 113 MPa at 250 °C, and tensile strength of Mg-5Al-5Ca is 170 MPa at 175 °C, 95 MPa at 250 °C. So Mg-3Al-3Ca, Mg-4Al-4Ca and Mg-5Al-5Ca have good mechanical properties at high temperature.

The series of Mg-Al-Ca alloys we designed basically solve the key problems of magnesium alloys such as low corrosion resistance and weak flame retardant performance by direct water cooled semi continuous casting, rolling and extrusion processing. Also, element content of Mg, Al and Ca are abundant in the earth, which can reduce costs. They are low cost Mg alloys with balanced performance. All these make Mg-Al-Ca alloys with high Ca/Al ratio comprehensive potential in large-scale application.

V-P13

Material strength and plasticity of Lanthanum-doped Titanium-Zirconium- Molybdenum alloy

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Samples of Titanium-Zirconium -Molybdenum alloy and Lanthanum-doped Titanium-Zirconium-Molybdenum alloy were fabricated by using powder metallurgy and rolling technology. Material test results show that Lanthanum-doped Titanium-Zirconium -Molybdenum alloy has higher strength and plasticity than Titanium-Zirconium-Molybdenum alloy. Lanthanum oxide particles not only act as heterogeneous nucleation core, but also act as the second phase particles to hinder the grain growth during the sintering crystallization, and result in grain refinement. The mean grain size was reduced from 25.64 μm to 14.26 μm. The tensile strength and elongation of sintering billet increased 14.1% and 20.5%, respectively. When the Lanthanum-doped Titanium-Zirconium -Molybdenum alloy rolled to plate, the second phase particles pinned dislocation and made the dislocation tangles to produce the sub-grain. It made the dislocation multiplication and played a dispersion strengthening effect. The tensile strength and elongation of Lanthanum-doped Titanium-Zirconium-Molybdenum alloy was found to be 1295 MPa and 8.09 % respectively.

V-P14

The mechanism of lanthanum in arc erosion of titanium-zirconium-molybdenum alloy

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Titanium-Zirconium-Molybdenum alloy and Lanthanum-doped Titanium-Zirconium -Molybdenum alloy were fabricated by powder metallurgy method. The effect of lanthanum in arc erosion of titanium-zirconium-molybdenum alloy was investigated by SEM, arc erosion test system and the scale. The results show that lanthanum-doped Titanium-Zirconium -Molybdenum alloy has higher strength, density and lower electrical resistivity than Titanium-Zirconium -Molybdenum alloy. The average of arc energy and arc time decrease 17.9% and 20.9% respectively due to doping lanthanum can decrease the arc current by forming reverse current between the contacts. The mass loss decrease 32.5% and erosion area reduces 32.6%. The effect of lanthanum is that the lanthanum in the cathode has a good ability of electron emission.

V-P15

Properties of injection molded and sintered water-gas joint atomized 316L stainless steel powder

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Water atomized, water-gas joint atomized and gas atomized 316L stainless steel powder were injection molded and sintered. The flow properties, sintering densification and mechanical properties of three kinds of powders were discussed. The feasibility of water-gas joint atomized powder used in powder injection molding was also studied. The results show that the MFI (melting flow index) of water-gas joint atomized powder is 1108.5 g/10 min. It suggests that water-gas joint atomized powder has better liquidity than conventional water atomized powder in injection molding, which is approach to the liquidity of gas atomized powder. The sintering experiment results indicate that the sintering activity of water-gas joint atomized powder is much higher than conventional water atomized powder. The sintered density, tensile strength, yield strength, elongation and hardness of the water-gas joint atomized powder arrive at 98.13 %, 505 MPa, 193 MPa, 55% and HRB78 respectively, the values of which are also superior to the MPIF standard. The Metallographic structure of water-gas joint atomized powder is a typical austenitic structure. Comprehensively considering the properties and cost, water-gas joint atomized 316 stainless steel powder can be widely used in the actual production of the metal injection molding.

V-P16

Effect of solution treatment on microstructure and mechanical properties of hot-extruded Cu-15Ni-8Sn alloy

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The effects of solution treatment on the microstructure evolution of hot-extruded Cu-15Ni-8Sn alloy were investigated by optical microscope (OM), scanning electronic microscope (SEM), differential scanning calorimetry (DSC) and tensile testing, and the effects of solution temperature and time on the mechanical properties of the alloys were analyzed. The results indicate that, the gama-phases precipitated at first and then dissolved with the extension of the solution time during solutionizing at 800 °C, the volume fraction of the gama-phase reached its peak at about 1h. However when solutionizing at 860 °C, the gama-phase solely dissolved gradually with the extension of the solution time. In addition, a small amount of annealing twins appeared intragranular in the process of solution treatment. The gama-phase dissolution and the grain growth of aerfa(Cu) are the main softening factors of the alloy during the solution treatment. Through overall consideration, the optimum solution treatment is annealing at 820-840 °C for 1-2 h.

V-P17

Corrosion mechanism of Laser Beam Welded Joint of 2060 Aluminium-Lithium Alloy Filled with Al-5.6Cu Wire

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2060 alloy is a new generation of aluminum-lithium alloy with better strength properties and has got widely applications in aerospace industry. 2060 aluminum sheets with a thickness of 2 mm were welded by fiber laser with ER2319 (Al-5.6Cu) wire. The microstructure and corrosion resistance of the welded joints in 3.5 wt.%
NaCl solution was investigated, as well as their intergranular corrosion resistance. The results show that the grain of the weld is refined, and the microstructure of each region is uniform, including equiaxed fine grain zone, columnar grain zone and equiaxed dendrite grain zone. The weld zone is mainly composed of a large number of $\theta'$ ($\text{Al}_2\text{Cu}$) phase and a small amount of $R$ ($\text{Al}_5\text{Cu}_3\text{Li}_3$) phase, undissolved $\text{T}1$ ($\text{Al}_2\text{CuLi}$) phase, $\text{AlLi}$ phase, $\text{Al}_{11}\text{Cu}_5\text{Mn}_3$ and $\text{Al}_7\text{Cu}_2\text{Fe}$ compounds centrally distributed at the grain boundaries. During the initiation of corrosion when immersed in 3.5% NaCl solution, the base metal, heat affected zone and weld zone were mainly affected by pitting corrosion. With the prolongation of immersion time, the pitting corrosion gradually expanded, and the local areas are changed to intergranular corrosion and exfoliation corrosion. In the electrochemical corrosion test, the corrosion tendency of the base metal and heat affected zone was larger with the lower corrosion potential, but the corrosion current density of the weld is relatively larger because of the existence of porosities. The serious segregation of $\text{Cu}$, $\text{Mg}$, $\text{Ag}$, $\text{Si}$, $\text{Fe}$ and other elements in the grain boundary of the weld aggravate the occurrence of intergranular corrosion.

V-P18
Microstructural evolution and properties of Cu-1.5Ti alloy during aging
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The microstructural evolution in Cu-1.5 wt % Ti alloy aged at 400 °C was investigated using the hardness, electrical conductivity measurements, and high resolution electron microscopy. The electron metallography results show that the sequence of the decomposition in the studied Cu-1.5 wt.% Ti alloy can be summarized as follows: a modulated structure resulting from spinodal clustering $\rightarrow$ formation of clusters and then ordered fcc phase $\rightarrow$ formation of LRO $\text{β}'$-$\text{Cu}_4\text{Ti}$ which distributed periodically along the $\text{Cu}$ directions. The ordered fcc phase shows a cube-on-cube orientation relationship (OR) with matrix, while the LRO $\text{β}'$-$\text{Cu}_4\text{Ti}$ shows an OR of $[001]_{\text{Cu}}//[001]_{\text{β}'}$ and $(310)_{\text{Cu}}//(100)_{\text{β}'}$. After aging for 24 h, the hardness and electrical conductivity of this alloy reach 175 HV and 25.3 % IACS, respectively. The spinodal clustering is responsible for the hardening of the alloy during the initial 30 min aging. Hardening of the ordered fcc phase and $\text{β}'$-$\text{Cu}_4\text{Ti}$ phase makes a significant contribution to the strengthening during the advanced stage of aging.

V-P19
The research on mechanical properties and wear behavior at extremely low temperature of a 16Cr-6Ni austenitic steel
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The Cr16-Ni6 austenitic stainless steel, with excellent mechanical properties and corrosion resistance, is an important structural material used in aerospace industries. The mechanical, friction and impact behavior at extremely low temperatures, as well as the inherent relationship between these properties and the phase transformation of the alloy, is required for the applications in extreme environments. In this research, the tensile strength and plastic behavior of the Cr16Ni6 steel is investigated at room temperature and -196 °C. The results indicate that the yield strength and tensile strength of the alloy increase significantly with lower temperatures, from 990 MPa to 1350 MPa and from 1313 MPa to 1900 MPa, respectively. It is revealed from the microstructure observation conducted by scanning electron microscopy (SEM) and x-ray diffraction technique
(XRD) analysis that the face-centered cubic (fcc) structure of the matrix remains stable with no tangent phase transformation to martensite observed during the tensile tests at -196 °C. Thus, the similar crystallographic characteristics referred to plastic deformation of the fcc matrix such as multi crystal slip system and mechanical twinning between the specimens at room temperature and -196 °C is found, resulting in the slight reduction of elongation at lower temperature. The lattice constants of the matrix calculated based on XRD results according to Prague diffraction law, although without phase transformation, is found reduced apparently at -196 °C, suggesting that the metallic bonding strength between the atoms shall be improved subsequently. The improvement of strength is mainly attributed to the fact that it is more difficult for the dislocation slips along lattice planes at -196 °C than at room temperature, since the movement and diffusion abilities are significantly reduced. The impact energy remains almost the same value about 71-79 kJ during the decrease of temperatures, due to the stability of matrix and the similarity of plastic deformation behavior of the alloy. The friction coefficient, is found the be a little lower at -196 °C, which is in good agreement with the variation of mechanical properties.

V-P20
Combustion synthesis of β-SiAlON using 3D ball milling
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β-SiAlON, with the general formula β-Si_{6-z}Al_{z}O_{z}N_{8-z} (0 ~ 4.2), has been attracting a great deal of attention owing to its excellent mechanical and thermal properties, superior chemical stability, and notable thermal shock resistance. For combustion synthesis (CS) of β-SiAlON, using a large amount of diluent decreases the production efficiency, which is a problem particularly during industrial-scale production. Therefore, it is important to seek more efficient methods that utilize less diluent in obtaining the pure material. The aim of this paper is to investigate CS of β-SiAlON using a 3D ball mill, focusing on the effects of the 3D ball mill on the particle size of the raw materials and on the amount of unreacted Si in the final products.

The starting materials of silicon, aluminum, and silica were mixed using a 3D ball mill. The milling conditions were controlled in terms of vertical spin \( V_v \) and horizontal spin \( V_h \). Each milled mixture was combustion-synthesized at an initial N\(_2\) gas pressure. After CS, the products crystal phase was identified using X-ray diffraction (XRD), while the microstructure was examined using scanning electron microscopy (SEM).

The results show that the particle size distribution of the raw materials was significantly affected by the premixing conditions. Various particle sizes and particle size distributions can easily be obtained by using a 3D mill instead of a 2D mill due to the complex biaxial rotation movement of 3D milling. The particle size was more sensitive to the rotation ratio (vertical spin/horizontal spin, \( V_v/V_h \)) than the rotation rate when using 3D milling. Finally, β-SiAlON with less than 5 mass% unreacted Si was obtained using premix milling conditions of 135×200 [vertical spin (rpm) × horizontal spin (rpm)]. The grain shapes of the final products were clearly influenced by the particle size distribution of the raw mixtures. An appropriate particle size and particle size distribution can easily be obtained by using 3D milling instead of 2D milling; As the rotation ratio (vertical spin/horizontal spin, \( V_v/V_h \)) approaches 1.0 for 3D milling, the particle size decreases and the particle size distribution broadens; Larger raw particle sizes resulted in large and uniform rod-like grain shapes in products, while smaller ones led to small and non-uniform grain shapes, including some
whisker-like structures.

V-P21
Effect of bonding temperature on microstructure development during transient liquid phase bonding of Ti2AlNb alloy using Ti-Zr-Cu filler alloy
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Transient liquid phase (TLP) bonding of Ti2AlNb by making use of vacuum brazing furnace was carried out using Ti-Cu-Zr based foil as filler alloy at 950, 1000 and 1050 °C. The effect of bonding temperature on joint interface, phases constitutions and their distributions were investigated by taking advantage of OM, SEM, EDS and XRD analyses. The result reveals that the TLP joint consists of isothermally solidified zone and diffusion affected zone, and a non-isothermally solidified zone exists only when the bonding temperature was not high enough. The interface morphologies of the joints are found to be very sensitive to the bonding temperature, and with the increasing of the bonding temperature, the width of isothermally solidified zone decreased from 69 μm to 23 μm. When the bonding temperature is 1050 °C, the isothermally solidified zone disappears, meanwhile, more alloying elements of Cu and Zr diffused most adequately into the base material. Along with the increasing of bonding temperature, the secondary phase constitution of joint changed from Ti(Cu,Al)2+AlNb2+Ti solid solution to Ti solid solution+Nb(CuAl)+Al4Cu9+Al2Zr3. At the bonding temperature of 950 °C, 1000 °C and 1050 °C, the proportion of solid solution was 35.7%, 20.2%, 6.7%, respectively. When the bonding temperature is 1000 °C and the holding time is 2 h, the secondary phase content at isothermally solidified zone is the least, the main reason is high bonding temperature leading to the generation of secondary at the isothermally solidified zone in the cooling process when bonding temperature is 1050 °C. The morphology of base metal has changed because of the relatively high bonding temperature is higher than the a→β transition temperature of 980 °C.

V-P22
Tungsten inert gas-spot welding of oxygen free high conductivity copper sheets
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Spot welding of OFHC copper 1.2 mm thickness to make a nugget with low weight, high contact area when the next generation of electric car needs for joining copper sheets to transfer electric power from the source at the back of the car to the engine in front. However, many researchers suggested the addition of impurity to establish a nugget with the resistance spot welding of copper that need a lot of current to do. This process kept the high purity of joint while it is fluxless and free of additives. High purity copper sheets were used to be welded with different welding parameters. The peak current (150, 175, 200, 225, 250A DC), current pass time (3 s, 4 s, 5 s, and 6 s) and electrode tip angle (60, 90, 120) were investigated. The new nuggets are useful to transfer the electric power through the wide contact area where the joint has a good penetration and high shear strength.
The results imply that the increase of the current peak to 225 A and time 5 s increasing the shear strength; however the increasing of current to 250 A and 6 s decrease the shear strength while some of the copper metal sputtered out of the welded point. The increase of electrode tip angle increases the nugget size.

Spot welding of pure copper is not difficult anymore. The peak current, arc striking time, electrode tip angle of TIG-spot welding can be managed to establish a spot welded joint for OFHC copper. It provides an easy, cheap, efficient welded joint for electric connection points in environment electric friend cars.

V-P23
Electronic control of friction on a nanotextured surface by laser-processing
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In computing and MEMS (as areas of research), Ni-Co coating is widely applied to such devices as micro-forceps, micro-mirrors, micro-switches, etc. Ordinarily, these devices work under an external electric field; however, the effect of this external electric field on the friction performance of Ni-Co coatings is rarely studied. If the external electric field is able to affect the frictional properties of a surface, it can be used in the active control of the coefficient of friction or in maintaining its stability.

Through controlling the surface characteristics, an engineered surface can be made to deliver the desired functional performance. Improving the coating performances by laser-processing has been considered as an effective technique elsewhere. Many researchers have investigated the use of laser-processing techniques on alloy coatings to improve their surface performance. Nowadays, methods such as moulding, electrochemical deposition, and chemical vapour deposition are used to produce artificial surfaces with particular textures. However, all of these methods fail to produce controllable, textured, surfaces.

Here, the nanotextures on the Ni-Co alloy coating surface were fabricated by a laser-processing technique. The surface morphology and microstructure of the laser-processed region were characterized by SEM. Then, the nanotribological behavior of different nanotextured surfaces under an external electrical field was investigated by friction force microscopy (FFM) and AFM.

To ensure the composition of the bath was uniform throughout, the electrolyte was subject to magnetic stirring for 20 min before the deposition process started. A nickel sample, of commercial-purity grade, measuring 80 mm × 60 mm × 2 mm was used as the anode, and a type 316L stainless steel specimen, measuring 20 mm × 10 mm × 2 mm, was used as the cathode. The cathode was placed 30 mm from, and parallel to, the nickel when immersed in the bath. Before electroplating, the specimen was polished using 2000 grit and then degreased in acetone under ultrasonic vibration for 5 min, and then pre-treated in 1 mol/L HCL solution for 2 min at room temperature to remove the surface oxide scale. A type CHI660D electrochemical workstation was used to perform electroplating under direct current conditions, with the current density set to 25 mA/cm², and a total electroplating time of 20 min. The deposition thickness was 8 μm. The surface morphology and microstructure of the coating were characterized by SEM.

An ultraviolet laser (DSH-355-10, Photonics Industries, USA) with a working wavelength of 355 nm was used to process the specimen. The laser power ranged from 0 J/cm² to 2 J/cm² at a scan speed of 25.4 mm/s and line...
interval of 0.01 mm with a constant beam diameter of 1 mm. The SEM was used to analyze the effect of laser irradiation on the surface morphology and microstructure of the coating. The nanotribological behavior of the Ni-Co alloy coating in this electric field was measured by AFM/FFM in CAFM mode. In this manner, the varying load (0.1 to 1.0 V), and bias voltage (0.0 V, 0.5 V, 1.0 V, 1.5 V, and 2.0 V), were applied to the contact between the probe and the sample at a scanning rate of 1 Hz over a scanning length of 50.0 µm. The laser power was increased from 0 J/cm² to 0.22 J/cm². Through these experiments, it was concluded that the formation of regular nano-protrusions was dependent on the power of the ultraviolet laser. When the applied laser power was greater than 0.22 J/cm², the Ni-Co alloy coating underwent rapid fusion due to the extreme heat. Therefore, the surface morphology of the laser-processed area became smooth, and the nano-protrusions on the surface almost all vanished.

The different relationships between the frictional force and normal load were studied at bias voltages of 0 V, 0.5 V, 1.0 V, 1.5 V, and 2.0 V. It can be seen that the friction increased quasi-linearly with increasing normal load for the different Ni-Co alloy coating surfaces. It may be concluded that the bias voltage can be increased to reduce friction on the surface after laser-processing.

The influence of different applied laser power on the morphology of laser-induced nanotextures on a stainless steel-based Ni-Co alloy surface was investigated. The frictional force on such nanotextured surfaces can be controlled by an external electric field. The following conclusions were drawn: By adjusting the applied laser power, various nanotextures on the Ni-Co alloy coating were produced. At the same time, regular nano-protrusions can be produced by choosing certain laser-processing parameters. Laser irradiation under a forward bias voltage can affect the nanotribological properties of an Ni-Co alloy coating, and the frictional force can be actively controlled by an external electric field. Moreover, the changes seen after laser treatment showed that the frictional force initially decreased with increasing bias, and then increased after the bias voltage exceeded 1.0 V. Furthermore, with certain nanotextures and bias voltages, the frictional force could be maintained at a stable value.

V-P24

Synthesis of magnetic Fe₃O₄ nanoparticles via one-step reduction method

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A new method one-step reduction preparation of Fe₃O₄ nanoparticles was proposed. The iron nitrate and citric acid were prepared for the gel, and the gel powder was dried under a protective atmosphere via carbothermal reduction reaction to obtain the reaction product. The reaction products were characterized by X-ray diffraction (XRD), fourier transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM), vibrating sample magnetometer (VSM). The results showed that the Fe₃O₄ nanoparticles of pure phase, single-crystal, high crystallinity can be formed under the condition of ferric nitrate and citric acid molar ratio of 1:1 and carbon
thermal reduction temperature of 600 °C. The powders were so nearly spherical nanoparticles with the particle size of 10 nm. The one-step reduction method for Fe₃O₄ synthesis has the advantages of controllable, short process, large-scale production, and will be an important method of producing Fe₃O₄ nanoparticles.

V-P25

Synthesis of Fe nanoparticles via one-step reduction method

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The Fe nanoparticles were synthesized via a novel method one-step reduction method. The excessive citric acid helps to obtain pure and high crystallinity α-Fe and the appropriate temperature (at 620 °C). The Fe nanoparticles were carefully characterized by the X-ray diffraction, transmission electron microscopy (TEM) and vibrating sample magnetometer (VSM). The morphological characterization indicates that the Fe nanoparticles present spherical shape with diameter of 30 nm. The magnetization hysteresis loops reveal the high saturation magnetization (Ms=198.97 emu/g) and the good ferromagnetic behavior of the magnetic materials. The one-step reduction method for nanoparticles synthesis has the advantages of controllable, short process, large-scale production, and will be an important method of producing nanoparticles.

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The effect of air-gaps between casting/water-cooled mold interface on the interfacial heat transfer coefficient

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Combined water-cooled molding is a new way of the rapid solidification of large-sized castings which could reduce segregations and refine the microstructure of casting. So it has attracted the attention of many domestic and foreign enterprises. The cooling rate of castings is controlled by the heat exchange of the interface of the water-cooling mold/casting. With the cooling and solidifying, the casting would shrink, and the air gap would be generated between the casting and the interface. So, the air gap could impede the exchange of the casting and mold, and the interface heat transfer coefficient would drop rapidly. The purpose of this paper is to study the air gap width and the time of the air gap formed on the interface heat transfer coefficient.

In this paper, interface heat transfer coefficient of the casting/water-cooled mold is calculated by measuring the cooling curve of the casting in water-cooling mold, and then bringing it to inverse calculation in the ProCAST software.

The results show that: With the air gap width increased from 6mm to 30 mm, interface heat transfer coefficients are 185 W/(m²·K) down to 155 W/(m²·K). The Interface heat transfer coefficient decreases with the increase of the air gap width. With the time of air gap formed increased from 40 to 200, the interface heat transfer coefficients are 175 W/(m²·K) down to 55W/(m²·K). The interface heat transfer coefficient decreases with the increase of the time air gap formed.

The effect of residual stress and microstructures on 316 stainless steel treated by LSP

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In order to improve the stress corrosion resistance of 316 stainless steel, a new technology is proposed and studied in this paper. The 316 stainless steel sample was treated by laser shock processing (LSP). The residual stress and microstructures of 316 stainless steel with and without LSP were measured and compared by the methods of X-ray, transmission electron microscopy (TEM) and Electron Back-Scatter (EBSD). The strengthening mechanism was discussed. It showed that the high residual compressive stress introduced by laser shock processing was about -112 MPa, compared with tensile stress of samples without LSP. The TEM and EBSD results showed that severe plastic deformation and nanocrystals layer were formed by LSP, and the orientation of the grains has evident rotation in the process of plastic deformation. These help to enhance the stress corrosion resistance of 316 stainless steel.

The evolution of LPSO structure of Mg-11Gd-4Y-2Zn-0.5Zr alloy during hot compression deformation at different temperatures
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The deformation behavior and microstructure evolution of LPSO phase of Mg-11Gd-4Y-2Zn-0.5Zr magnesium alloy were investigated. This alloy deformed by hot compression using Gleeble 3500 thermal simulation machine at different temperatures, the microstructure analyzed by optical microscopy (OM), scanning electron microscopy (SEM) with spectroscopy (EDS) and XRD. The results showed that the kink bands of LPSO structure of Mg-11Gd-4Y-2Zn-0.5Zr alloy, after thermal compression processing, aggravate as temperature increasing. The fine lamellar LPSO phase can be observed in all the alloy. At 450 °C and 500 °C, some fine lamellar LPSO phase in the grain had been broken into short rod or small block forms, meanwhile, a new rod-like LPSO structure appeared along the grain boundary. Moreover, the decomposition of LPSO structure was more obvious with the increasing of temperature. During hot compression deformation, the segregation of Y, Zr had eliminated partially and the diffraction peaks of W-phase had disappeared. Moreover, there is an increase in hardness as the dispersion distribution of LPSO phase increase.

A Comparative Study on the Friction and Wear Properties of Three Different Copper Alloys
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A comparative study on the friction and wear properties of three kinds of copper alloys, including Cu-Ni, Cu-Al and Cu-Be alloys was carried out in this study. The friction pair was stainless steel, and both dry and MoS₂ lubrication friction experiments are investigated. During the experiments, different loads are chosen for different alloys. It was found that under dry friction condition, the friction coefficients of both Cu-Ni and Cu-Al alloys don’t change as the loads changes, whereas the friction coefficient of Cu-Be alloy increases as the loads increases. Under lubrication friction condition, the friction coefficients of all three alloys don’t change as the load changes. The results show that the dry friction coefficient of Cu-Ni is the largest (0.74), the Cu-Al alloy is the center (0.60), and the Cu-Be has the smallest dry friction coefficient (0.54). The lubrication friction coefficient of both Cu-Ni and Cu-Be is the smallest (0.12), and the Cu-Al alloy has a relative larger lubrication friction coefficient (0.27). The microstructure observations are consistent with the friction and wear performance, and the SEM results show that different wear mechanisms are dominated for different alloys.
**Research on cutting performance of coated cemented carbide end milling cutter**
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The cutting performance of three kinds of coated cemented carbide end milling cutter was researched systematically by the test of milling 420 die steel. The milling force was measured by the dynamometer. The tool surface cutting temperature was measured by the infrared thermometer. The radial wear (NB) of major cutting edge was measured by spiral micrometer. The average width (VB) of the major flank wear land of circumferential cutting edge was measured by 3D microscope of Zeiss. The surface morphology and chemical composition of wear failure areas was measured by 3D microscope of Zeiss and SEM&EDS. The surface machining quality of 420 was measured by surface profiler. The hardness change of the 420 was measured by Vickers hardness tester. The residual stress of 420 was measured by XRD. Through all of these, the cutting performance of three coated cemented carbide end mills with TiAlN coating, AlTiN/AlCrN coating and AlTiN/AlCrN composite coating was researched systematically. Under the same cutting parameters and a milling distance 8000 m of major cutting edge, AlTiN/AlCrN composite coating end milling cutter had plenty of burrs, AlTiN/AlCrN coating end milling cutter had a few burrs and TiAlN coating end milling cutter had no burr. Under the same cutting parameters and a milling distance 10000 m of circumferential cutting edge, it had the same results. If the wear rate of coated tool is faster, the tool life will be shorter and the surface quality will become poorer. The cutting performance of coated tools depends on the coating quality. It is not only related to the type of coating, but also related to the binding force of the coating.

**Constitutive equations for 6061 aluminum alloy at elevated temperature**
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6061 aluminum alloy is used to make many automobile parts, such as car wheel, control arm, steering arm, etc, because that it possesses low density, good formability, excellent corrosion resistance and high fatigue strength. The flow stress of material is a very important element which is needed to be studied during its hot deformation process. The relationship between stress and strain, working rate and temperature is commonly expressed by a constitutive equation. There are many studies on constitutive equation but the accuracy of the calculated data varies widely. This paper introduce a method to derive the constitutive equation of 6061 aluminum alloy and the equation’s reliability is evaluated by the mean error of flow stress.

The 6061 aluminum alloy specimen is in the as-cast condition and cut to the diameter of 10 mm and length of 15 mm. Before the test, the specimens were heated to 773K and keep the temperature for 3 min, then cooled to the test temperature. Isothermal compression tests were conducted on 6061 aluminum alloy using a Gleeble-3500 thermal simulator under constant strain rates of 0.001, 0.01, 0.1 and 1 s\(^{-1}\) and at deformation temperatures of 623K, 673K, 733K and 773K up to a 60% height reduction of the sample. The specimens were water-quenched to keep the microstructure after compression. The data obtained from the tests were used to calculate the true stress-strain data.

The true stress-strain data obtained from the compression tests at different temperatures and strain rates can be used to calculate the material constants of the 6061 aluminum alloy’s constitutive equations. This paper introduce the constitutive equation derived by Sellars and McTegart which can describe the plastic deformation behavior of 6061 aluminum alloy at strain rates ranging from 0.001 to 1 s\(^{-1}\) and at temperatures ranging from 623K to 773K.
The three material constants of the constitutive equation, lnA, n, Q, evaluated at strains ranging between 0.05 and 0.9 with an interval of 0.05, are plotted and fitted using fifth-order polynomial equations. The R-squares between fitted and experimental data are above 0.96. By applying the determined material constants above to the deformation constitutive equations, the flow-stress values are calculated for true strain from 0.1 to 0.9 with an interval of 0.1, at strain rate of 0.001, 0.01, 0.1 and 1 s\(^{-1}\) and at deformation temperatures of 623 K, 673 K, 733 K and 773 K. It shows the distinction between the calculated data and experimental data from the different tests at different temperatures and strain rates. In order to evaluate the accuracy of the deformation constitutive equations, the mean error is calculated. The values of the mean error present a better agreement at middle temperatures than that at high and low temperatures except at the strain rate of 1 s\(^{-1}\). The biggest mean error is 13.4% which appears at the temperature of 623 K and strain rate of 1 s\(^{-1}\). The smallest mean error is 1.6% which appears at the temperature of 673 K and strain rate of 0.01 s\(^{-1}\). The average value of all the mean error is 6.68%.

Conclusions:

(1) This paper presents a serial of stress-strain curve at different temperatures and strain rates then proposes a constitutive equation which the material constants A, n and Q are presented by functions of strain.

(2) The accuracy of the constitutive equations is evaluated by the mean error of the stress-strain curves at different conditions. The biggest mean error is 13.4% and the average value is 6.68%. The results indicate that the proposed constitutive equations present a good estimate of the flow stress for 6061 aluminum alloy.

Microstructure and magnetic properties of (Nd\(_{1-x-y}\)Pr\(_x\)Y\(_y\))\(_{2.28}\)Fe\(_{13.58}\)B\(_{1.14}\) melt-spun alloys

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Rapid solidification refers to the process of transition from a liquid to a solid state at the high cooling rate, compared the conventional solidification process. The alloys prepared by rapid solidification technology not only have the characteristics of fine grain size, non or less segregation of micro crystalline structure, but also form different stable/metastable phase constitution \[^{[1,2]}\]. Melt-spun quenching as rapid solidification technologies is one of importance in the production of Nd\(_2\)Fe\(_{14}\)B-based rare-earth permanent magnets. Generally, expensive heavy rare earth elements (e.g. Dy, Tb) are used in Nd-Fe-B permanent magnets to obtain excellent magnetic properties. In order to reduce the costs and the effective utilization of rare earth elements, it is feasible to use cheap light rare earth elements (e.g. La, Ce, Pr, Y) to substitute partially heavy rare earth elements in the development of high-abundant rare earth permanent magnets \[^{[3-9]}\]. In this work, (Nd\(_{1-x-y}\)Pr\(_x\)Y\(_y\))\(_{2.28}\)Fe\(_{13.58}\)B\(_{1.14}\) melt-spun ribbons were prepared firstly from the ingots with high cooling rate. The microstructure, crystal structure and magnetic properties of the melt-spun ribbons were investigated by means of X-ray diffraction (XRD), scanning electronic microscope (SEM) ,different thermal analysis (DTA) and physical properties measurement system (PPMS). The influence of substitution of Y and Pr for Nd on the microstructure and magnetic properties was discussed.

References

Deformation mechanism of Fe-6.5\textit{wt}\%Si alloy

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Fe-6.5\textit{wt}\%Si alloy is an excellent soft magnetic material. Fe-6.5\textit{wt}\%Si alloy shows high magnetic permeability, low iron loss, low coercive force and much low noise when being used as iron core in transformer or electrical engine.

However, due to the higher Si content in the alloy, the appearance of ordered phases, like B2 and D03 structures, makes it hard and brittle. The room-temperature plasticity of the Fe-6.5\textit{wt}\%Si alloy is almost zero. It is generally believed that the emergence of the ordered phases, like B2 and D03 structures, play a leading role in the embrittlement of the alloy. The variation of the deformation mechanism with temperature need to be exactly determined in the Fe-6.5\textit{wt}\%Si alloy. This could be helpful for decreasing the processing temperature.

The tensile deformation at high temperature indicated that the effect of the ordering structure becomes small with the increase of deformation temperature. It was found that the dislocation configuration varies with the temperature. The dislocation configuration below 500 °C mainly exists in the form of superlattice dislocations. APBs followed movement of superlattice dislocations. Dislocation motion resistance is bigger; Above 500 °C, with the increase of thermal activation energy and the expansion of disordered region of superlattice dislocations, dislocation motion resistance begins to decrease.

Effect of high density electropulsing current on microstructure and mechanical properties of Fe-6.5\textit{wt}\%Si alloy sheet

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Fe-6.5\textit{wt}\%Si alloy is an excellent soft magnetic material. However, due to the appearance of ordering structures, the alloy shows poor ambient temperature ductility, and could only be cold rolled by specific rolling process. During the process, the heat treatment is complex and time consuming. Meanwhile, high-density electropulsing energies is promising for the energy and time saving effect. In this paper, heat treatment effect of high-density electropulsing on microstructure and mechanical properties were investigated. The hot rolled sheet with 1 mm in thickness can be uniformly recrystallized in 33 s at 690 °C by appropriate high density pulses and the ductility is better in comparison to the conventional heat treatment in furnace. After appropriate high density pulses treatment, the hot rolled sheet could be warm rolled by 50% reduction of the thickness after one pass without edge crack.

The formation mechanism and strengthening effect of Ti\textsubscript{3}Alp/Ti-6Al-4V composite surface layer
produced via Additive Friction Stir Processing and in-situ reaction
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For the particle-reinforced titanium matrix composites (PRTMCs), reinforcements play a key role in some enhancement of their mechanical properties. The in-situ process route is regarded as the priority to produce PRTMCs. For many applications it is sufficient or even desirable to reinforce only a surface layer while the other part of component retain its original composition and structure with high toughness. Various in-situ preparation means, e.g. laser surface melting, are applied to fabricate PRTMCs as a composite surface layer structure. However, their extra high processing temperatures easily generate melting-solidification induced the metallurgical defects, such as cold cracks, pores, dendritic grain coarsening, reinforcement dissolution and some harmful interfacial reactions. Thus, solid-state processing methods to fabricate PRTMCs surface layer, in the absence of Ti-matrix melting, are strongly motivated to develop.

A Ti₃Alp/Ti-6Al-4V composite surface layer was produced via a processing method of Additive Friction Stir Processing (AFSP) according to its coupled thermal-mechanical effect and Ti/Al in-situ reaction mechanism. The AFSP is performed on the principle of Friction Stir Welding and Processing (FSW/P), which is well-known as an attractive solid-state processing technique. FSW for Ti-alloys was well researched. Nevertheless, the reported AFSP studies pertaining to the high melting-point alloys are extremely limited. In this work, it is the aim to utilize the AFSP and Ti/Al in-situ reaction mechanisms to prepare Ti₃Alp/Ti surface composites. The formation mechanisms and surface-strengthening effects were elucidated. Meanwhile, the surface hardness and anti-wear performance of Ti-6Al-4V alloy were improved by the prepared surface layer. A relatively uniform dispersion of Ti₃Al particles was obtainable in the near surface layer, contributed by the coupled thermal-mechanical effect of AFSP and the Ti/Al in-situ reaction. The annealing treatment after AFSP improved the composition homogenization. The complex effect of in-situ Ti₃Al particles as reinforcements and Ti-matrix grain refinements benefited the surface-hardening effect and the improvement of surface layer anti-wear performance.

The formation mechanisms of the AFSP produced Ti₃Alp/Ti surface composites were detailed as follows:
(i) The thermal effect during AFSP
Some references had reported that the maximum processing temperature of FSW on Ti-6Al-4V alloy was significantly higher than beta-transus point. Its produced microstructure was transformed as a new alpha+beta duplex-phase morphology of beta-regions with acicular-alpha and GB-alpha. The duration time upon the Ti-6Al-4V beta-transus during AFSP using the optimized parameters was more than 15 s. And that upon 500 °C was more than 35 s. The Binary Ti-Al Phase-Diagram shows that with increasing Al content the Ti₃Al (alpha₂) phase will be formed and that the two phase region (alpha-Ti + Ti₃Al) starts at ~5wt.% Al for about 500 °C temperature. It was found that the Al content in the Ti₃Al particle forming position was generally higher than 10 wt.% after AFSP. The duration time upon 500 °C was sufficient to make the diffusion-controlled in-situ reaction occur between Al powders and their adjoining Ti-matrix. The main heating resources of AFSP or FSP for the metals were tool/substrate friction heats and metallic latent-heats released by its severely plasticized deformation. Particularly, during the Ti/Al AFSP procedure, the plastic deformation heating of Ti-grains and Al powders accelerated the Ti/Al inter-diffusion rate. Further, when the processing temperature was higher than the melting point of Al, the liquid-Al could be reacted with solid-Ti very fast, following the phase transformation sequence: TiAl₃ → TiAl → Ti₃Al.
The rapid in-situ Ti/Al reaction-diffusion, at the positions of Al-rich point, finally generated Ti₃Al particles. And
the Ti$_3$Al had a more stable phase structure than TiAl$_3$ and TiAl in the state of high temperature. Thus, a larger number of Ti$_3$Al particles were then remained in the produced surface composite after cooling. In addition, as the alpha-Ti phase-stabilizing element, some Al was dissolved in the alpha-Ti lattice to finally form the alpha-Ti (Al) solid-solutions. 

(ii) The mechanical effect during AFSP

The tool stirring action and its regular ration-travel behavior promoted the Ti/Al mixing and the dispersion of Al powder and/or liquid-Al in stir nugget zone. The tool-shoulder dawn-pressure ensured the densification of produced layer. More important is the plastic state of Ti-matrix grains during AFSP. The severely plasticized deformation induced by friction-stir behaviors could significantly increase the density of Ti-crystal defect as the atom diffusion channels, and thus shorten the diffusion distance between Al atom and its adjacent Ti-grains. The squeezing actions of deforming Ti-grains on their contiguous Al powder and/or liquid-Al also promoted the inter-diffusion and diffusion-controlled rapid reactions.

**Effects of La and Ce mischmetal on microstructure and properties of Al-Mg-Si alloy**

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The effects of La and Ce mischmetal on microstructure and properties of Al-0.75Mg-0.6Si alloy were studied by optical microscopy, eddy current conductive instrument and tensile testing machine. Results show that the addition of mischmetal has an effect on the grain refinement and purification of Al-0.75Mg-0.6Si alloy, which is beneficial to improve the electrical conductivity and strength. With increasing the additive amount of mischmetal, the electrical conductivity, tensile strength and elongation of Al-0.75Mg-0.6Si alloy are improved. When the additive amount of mischmetal is increased to 0.5%, the electrical conductivity of Al-0.75Mg-0.6Si alloy is 55.7% IACS, the tensile strength and elongation of Al-0.75Mg-0.6Si alloy are 236 MPa and 16.7%, respectively. The electrical conductivity is increased by 5.69%, tensile strength and elongation are increased by 11.32% and 15.17% compared with that of Al-0.75Mg-0.6Si alloy without adding the mischmetal.

**Grain refinement mechanism and effective nucleation phase of Al-5Ti-1B master alloy**

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The Al-5Ti-1B, Al-10Ti, Al-4B master alloy and TiB$_2$ powder were applied to refine the pure aluminum, respectively. The effects of the TiAl$_3$ phase, TiB$_2$ particle, and AlB$_2$ phase on the grain size of pure aluminum was compared. The grain refinement mechanism of the Al-5Ti-1B grain refiner was studied. Results show that the TiAl$_3$ phase is an effective heterogeneous nucleus of the $\alpha$-Al grain. But the TiAl$_3$ phase in the Al-5Ti-1B grain refiner is not the heterogeneous nucleus of the $\alpha$-Al grain due to its remelting in the Al melt. The alone TiB$_2$ particle or AlB$_2$ phase is not the heterogeneous nucleus of the $\alpha$-Al grain. However, the TiB$_2$ coated by the TiAl$_3$ phase can be the effective heterogeneous nucleus of the $\alpha$-Al grain. The grain refinement mechanism of the Al-5Ti-1B grain refiner can be summarized as follows: when the Al-5Ti-1B grain refiner is added into the Al melt, the TiAl$_3$ phases are remelt to release the Ti atoms and the TiB$_2$ particles are remaining in the Al melt. During the solidification of the Al melt, the Ti atoms are segregating on the surface of TiB$_2$ particles to form the TiAl$_3$ phases. The TiB$_2$ particles coated by the TiAl$_3$ phases then reacts with the Al melt to generate $\alpha$-Al crystal nucleus.

**Research on different cast process for microstructure and mechanical property of ZTC4 Titanium alloy**
Due to the effects of casting structure and process, the difference of microstructure and mechanical property are obviously in ZTC4 casting. To investigate the casting microstructure and mechanical property, choose three different centrifugal rotational speeds of ZTC4 casting. Analysis and research on the titanium alloy casting itself specimens for microstructure and mechanical property. The results show that with the centrifugal rotational speed increasing, the microstructure of grain size of the thick area is increasing linearly, the thin area isn’t increasing. With the centrifugal rotational speed increasing, the tensile strength and yield strength of the thick area aren’t increasing, the elongation of the thick area is obviously increasing.

Manufactured process of high strength and high electrical conductivity Cu-Cr-Zr-Mg alloy bars
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In the present work, a hot extrusion–quenching process is developed to manufacture Cu-Cr-Zr-Mg alloy bars with high strength and high electrical conductivity. The microstructure and properties of the alloys were investigated by observations of optical microscopy and scanning electron microscopy, and measurements of microhardness, tensile strength and electrical conductivity. The results show that the process and thermomechanical treatments are successfully developed to manufacture Cu-Cr-Zr-Mg alloy bars with good combinations of tensile strength (602.5 MPa) and conductivity (85.4% IACS). The achievement of high strength and high electrical conductivity in the alloys can be ascribed to the interactions of strain hardening and precipitation hardening.

Nano-crystallization of ductile iron induced by introducing nanoscale ceria particles coupled with austempering treatment
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Carbide austempered ductile iron (CADI) is a new generation of Ductile Iron and is attractive as a promising wear resistant material. However, the presence of coarse carbide phase endows the CADI with poor ductility and less resistance to cleavage fracture, which limits its applicability and reliability. This study aims to explore the microstructure changes induced by synergistic effect of ceria nanoparticle and ausferrite transformation and to elucidate the mechanism for improved hardness and toughness.
In this study, carbide austempered ductile iron with improved hardness and toughness was prepared by introducing ceria nanoparticles combined with austempering treatment. A field emission transmission electron microscopy was used to characterize the microstructure. Thermodynamic calculation was used to evaluate the potential reaction between ceria and alloying elements in the ductile iron melt. Thermodynamic calculation together with high resolution TEM observation indicated the introduced ceria reacted with Si, inducing the formation of Ce₂O₃ and SiO₂ which acted as nucleates for ausferrite and graphite, respectively, leading to refined microstructure. Ce₂O₃ absorbed oxygen in the melt and formed nonstoichiometric ceria, which retarded the ausferrite transformation and promoted the precipitation of...
The evolution of precipitates in Cu-2.8Ni-0.8Si-0.8Cr alloy during aging

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In this work, the aging precipitation and its products in a Cu–Ni–Si–Cr alloy were investigated to clarify the ambiguities about the structures of the precipitates in age-hardened Cu–Ni–Si alloys.

An ingot with nominal composition Cu–2.8Ni–0.8Si–0.8Cr (wt.%) alloy was prepared in a vacuum medium-frequency induction furnace. The ingot was hot rolled to a plate with a thickness of 3 mm at 850 °C and then solid-solutionised at 900 °C for 2 h before water quenching. Then the plate was cold rolled with the thickness reduction of about 50%. The specimens were cut and then isothermal aged at 500 °C for various time.

Samples for TEM were thinned to a thickness of 0.1 mm by paper grinding (2500 grit). And disks of 3 mm in diameter were punch out from these samples. These disks were further thinned for electron transparency using a twin jet electropolisher with a solution of 25% HNO3+75% CH3OH at -30 °C. The microstructural investigations were performed on JEOL 2100 high-resolution transmission electron microscopy (HRTEM) operating at 200 kV. High angle annular detector dark-eld-emission transmission electron microscope (JEOL JEM-2100F) equipped with a scanning unit. Energy Dispersive X-ray Spectroscopy (EDS) was performed with a X-Max SDD detector and a probe size of 0.2 nm.

The hardness and conductivity of the alloy increase rapidly at the early stage of aging until 2 h. The hardness reaches a maximum of 253 HV and the electrical conductivity is 43.6 IACS% after aging for 2 h. Subsequently, the hardness decreases continuously with aging time, while the electrical conductivity keeps increasing slightly. After aging for 5 h, the hardness of this alloy decreases to 212 HV and the conductivity increases to 48% IACS. The hardness and electrical conductivity of the present alloy at peak aging is slightly higher than those of Cu–3.3Ni–1Si–0.8Cr–Mg alloy (about 245 HV and 40 IACS%, respectively) and Cu –3.2Ni–0.7Si–0.3Zn without Cr addition at peak aging (240 HV and 38 IACS% for 0.5 h) reported previously.

The morphology, orientation and crystallographic structure of the precipitates were examined for the samples aged at 500 °C for various times. Aging for 0.5 h at 500 °C, there were no evidence to reveal the occurrence of any precipitate. Aging for 2 h at 500 °C, a high number density of spherical and fully coherent with the Cu matrix ordered fcc beta-Ni3Si (about 5 nm in diameter) distributes uniformly in the Cu matrix. In addition to this, two disc-like delta-Ni2Si variants precipitated among the Cu matrix. Between the Cu matrix and precipitates, there are two crystallographic orientation relationships (ORs). One is (001)_{Cu} // (001)_{beta} // (001)_{delta}, [110]_{Cu} // [110]_{beta} // [010]_{delta} and other is (110)_{Cu} // (110)_{beta} // (100)_{delta}, [112]_{Cu} // [112]_{beta} // [012]_{delta}.

For the specimen aged for 5 h at 500 °C, in addition to the former precipitates, there exist a third kind of fine precipitate(~5 nm in diameter) coherent with the Cu matrix. The delta-Ni2Si exhibit six variants precipitates. The average size of delta-Ni2Si particles increases to 8–15 nm in diameter and 3–4 nm in thickness. Beta-Ni3Si particle grows up to 20 nm ellipsoid in length direction. The third kind of precipitate is an ordered fcc (Ni, Cr, Si)-rich phase with cube-on-cube OR corresponding to Cu matrix Its lattice parameter is a = 0.4284 ± 0.01 nm.

In summary, the three kinds of precipitates are found in the studied alloy, namely: ordered fcc beta-Ni3Si, orthorhombic delta-Ni2Si and ordered fcc (Ni, Cr, Si)-rich phase, respectively. These precipitates play an essential role in enhancing the hardness and mechanical properties. The morphology of beta-Ni3Si changes from spheroid to ellipsoid, while delta-Ni2Si maintains disc-like and has six variants lying on the {011}Cu habit planes during the whole aging process. The ORs are (001)_{Cu} // (001)_{delta}, [110]_{Cu} // [010]_{delta} for delta-Ni2Si, and cube-on-cube ones for beta-Ni3Si and (Ni, Cr, Si)-rich phase.
Investigation on filling of microarray fabricated by micro powder injection molding
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Flow analysis during injection molding is crucial for dimensional control in micro powder injection molding. In the paper, numerical simulation of injection molding of ZrO2 microarray based on in-house feedstock was conducted. A powder-binder two fluid model was developed to analyze temperature, viscosity and powder volume fraction of the feedstock for micro pillars of different dimensions, diameters of 0.2, 0.5 and 1 mm, respectively. It is found that in general the binder temperature decreases with size reduction of the micro cavity caved on the silicon wafer and increases with mold temperature. The micro pillars of φ0.2 mm exhibit the highest viscosity, which indicates difficulty for filling during injection molding. An increase in mold temperature facilitates the decrease of the feedstock viscosity, which improves the filling of the micro cavities. Powder-binder segregation becomes evident as the size of the micro cavities reduces to 0.2 mm.

Effect of heat treatment on microstructure evolution and mechanical behavior of SKLB3 alloy
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In this paper, the effect of heat treatment on the microstructure and mechanical properties of hot forging SKLB3 alloy was studied. Specimens of hot forged SKLB3 alloy were subjected to first solution treating at 900 °C for 2 hrs and then aging at different temperatures for 2 hrs. The mechanical properties including tensile performance and impact energy, and the microstructure were measured for specimens before and after heat treatment. The results show that both solution and aging treatment have an influence on the grain growth. After heat treatment, the tensile strength decreases very slightly and yield strength decreases seriously from 235.96 MPa to 136.12 MPa, while the elongation increases sharply from 36% to 48%. It was also observed that hardness of the heat-treated alloys are all lower than that of hot forging alloy. The measurement of Charpy impact energy with V-type notch were performed at 25 °C and -196 °C for different specimens. At both temperatures, the impact energies of the specimens are higher than 200 J. The microstructure results show that and the alloys are fractured in a ductile mode.

A predictive model of hot rolling flow stress by multivariate adaptive regression spline
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A new modeling method called multivariate adaptive regression spline (MARS) was firstly employed to predict the hot rolling flow stress and explain the relationship among flow stress and various parameters such as major chemical compositions, rolling temperature, rolling speed, compression ratio, thickness, roll radius, furthermore, analyze the importance of the predictor variables. It were showed that the error of training and testing was less than 2%, and rolling temperature, rolling speed, and strip thickness had much contribution to flow stress. Moreover, the impact of various factors on the flow stress can be validated by real production data, which proved the reliability of MARS model to predict the flow stress and guide the practical production.

The optimal selection of extrusion parameters of as-cast TC27 titanium alloy based on processing-map
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The hot deformation behavior of TC27 titanium alloy at the temperatures of 900-1150 °C and the strain rate of 0.01-10 s⁻¹, the height reduction of 70%, was investigated in the isothermal compression test to identify the optimal extrusion parameters.

According to the experimental data of isothermal compression test, the stress-strain curves at different temperatures and the constitutive equation of TC27 titanium alloy were built. The deformation activation energy was calculated to be about 300KJ/mol. The processing-map of TC27 titanium alloy was constructed based on dynamic materials model (DMM) and principle of Prasad’s instability.

The conclusion shows that temperature and strain rate of deformation have a great influence on flow stress. At the beginning of deformation, the flow stress increases quickly with the augment of true strain and decreases slowly after flow stress reaching to the maximum value. Finally, flow stress tends to relatively stable condition. The flow stress decreases with the increase of temperature and increases with the increase of strain rate. The TC27 titanium alloy is sensitive to temperature and strain rate. Processing-map exhibits two peak efficiencies of power dissipation; one is 49% at 900 °C/0.01s⁻¹, which dynamic recovery occurs, the other one is also 49% at 1050 °C/0.01s⁻¹, dynamic recrystallization occurs in the domain. Besides, there are two instability areas in the processing-map which should be avoided during the extrusion. The deformation mechanism and microstructure change are linked to the temperature and strain rate. Therefore, in order to obtain the satisfactory properties, the parameters that 1050 °C and 0.01 s⁻¹ are selected in the extrusion.

Microstructure and mechanical properties of TC4 titanium alloy subjected to high static magnetic field
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The TC4 titanium alloy is subjected to high static magnetic field (HSMF) treatment with different magnetic induced intensity (B=0T, 1T, 2T, 3T, 4T, 5T, 6T and 7T). The effects of B on the texture, dislocation density, grain size, tensile properties and micro-hardness of TC4 titanium alloy have been investigated, and the influence mechanism of magneto-plastic effect on the plastic deformation ability of titanium alloy have been studied. The results show that the dislocation density has been increased after the HSME treatment. It reaches a maximum when B=2T, which is enhanced by 1.6 times compared to that of the untreated samples. In the view of quantum scale, the magnetic field promotes the transition from singlet to triplet state, which causes the movement of dislocation, leads to the dislocation depinning from the depinning center, and increases the flexibility of dislocation. Subsequently, the inevitability of optimized 2T parameter is further discussed in the dislocation pile-up. Furthermore, the magnetic field not only promotes the orientation preference of crystal plane along the slipping direction, also have the effect on the grain refinement. Meanwhile the elongation has been increased due to HSMF treatment. The average elongation of TC4 alloy is 13.12% which is enhanced by 31.07% compared to that of the untreated sample which is 10.01%. And, the elongation increases with the increase of magnetic induction intensity B. The HSME treatment can also play a role in hardening alloys. When B=2T the micro-hardness is 344.88 HV, which is increased by 8.09% compared to that without treatment. The micro-hardness is consistent with the change of the "point" of the dislocation density, which is characterized by dislocation strengthening.

The investigation on the dissimilar material overlapping region via friction stir lap welding of copper and
The technological innovation for dissimilar joining titanium (Ti) and copper (Cu) still stays in demand. The promising joining method of friction stir lap welding (FSLW) was successfully introduced to produce the defect-free and high-performance joints of dissimilar Cu and Ti sheets. The dissimilar Cu/Ti joints were successfully produced via FSLW method using a designed tool with the Cutting Pin, under an introduced argon atmosphere. The special Cutting Pin was utilized for promoting Cu/Ti mixing and transferring, and limiting the evident formation of Cu-Ti inter-metallic compound (IMC) phases in overlapping region. The good formability of dissimilar Cu/Ti lap joints was produced. The macro- and micro-structures, and mechanical tensile properties of the lap joints were carefully analyzed. It was indicated that the adequate material plasticized deformations, with higher friction heat quantity generated between tool-pin and its adjacent metals, benefited the dissimilar material mixing and transferring at the Cu/Ti lap weld interface. The composite-like structure played a so-called mechanical locking effect on the Cu/Ti lap joints. The strengthening effect was also provided by the metallurgical bonding at the Cu/Ti band interfaces without cracking in micro scale. The fracture resistant strength of the joint reached 95% of that of the used parent copper. The results of tensile properties indicated that when the joint retreating side (RS) of the upper Cu sheet was placed closer to the loading fixture position, the joint anti-fracture strength was significantly higher than that when the advancing side (AS) was placed as the same position. The fracture cracking path was propagated not at or along the lap-welded interface. But when the AS was closer to the loading fixture position, the cracking path would appear at the lapping interface. Thus, it claimed that the RS at the lapping interface location had a stronger resistance against the applied shear force than the AS. It was strongly related to the micro-structure characteristics of RS and AS at the Cu/Ti lap-welded interface. Due to there was no evident or bulky and continuous IMC phases formed in the overlapping region, then the strengthening effect of the composite-like micro-structure at the lap-welded interface was so-called as the mechanical locking effect. The alternate, mixed and soundly-bonded Cu/Ti bands formed by Ti embedding, Cu/Ti dual-phase compositing and Cu/Ti inter-diffusion could be deemed to be locked with each other for composite strengthening. Moreover, a higher FSW traveling speed and a higher plunged depth of pin into the lower Ti sheet are both adverse to the enhancement of the joint anti-failure force.

The formation mechanisms of the Cu/Ti alternate band structure were discussed in detail. It was strongly related to the tool-pin mechanical behaviors and the heating effect provided by FSLW procedure. The heat generation during Cu/Ti FSLW was provide by both tool/material friction heating and material plastic-deformation heating. Due to that the Cu in upper sheet occupied a large part of the weld, the heat-input from the upper sheet was more than that of the lower Ti sheet. And the more outstanding thermal conductivity of Cu benefited the heat transport towards the lapping interface location and the lower Ti sheet. On the other hand, the sustaining rotation behavior of tool pin under the relatively lower travel speed promoted the dissimilar metal flow and mixing in their plasticized state. The Cutting Pin, which had milling cutters on surface, could make the harder Ti in the lower lapping sheet to be fractions, stripes or particles. Thus, they were migrated and mixed with the softer, plastic-deformed Cu in the upper sheet. The fine harder Ti particles or bands then embedded within the softer Cu-matrix in SNZ behind the traveling tool, after the cooling procedure. Meanwhile, during the heating procedure during and after FSLW, the Cu/Ti inter-diffusion could exist at the interfaces between the adjacent Cu/Ti bands in overlapping region, to form soundly-bonded interfaces in micro scale. The micro metallurgical bonding effect also benefited the mechanical locking effect on joint strength by the Cu/Ti alternate band.
structure. The alternate band structure at the lapping interface location plays an strengthening role on joints, contributed by the mechanical locking effect. In macro scale, the embedding harder Ti bands in Cu-matrix could be deemed to be locked with the adjacent materials for composite strengthening of the Cu/Ti dual-phase. In micro scale, soundly-bonded interfaces between the adjacent Cu/Ti bands reaches the metallurgical bonding due to the Cu/Ti inter-diffusion, without micro interfacial cracking.

**New equipment for production of super hard spherical tungsten carbide and other high-melting compounds using the method of plasma atomization of rotating billet**

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In order to ensure high wear resistance of parts and tools, operating at significant dynamic loads in the extreme conditions, the layers different in their function purpose obtained using surfacing methods are widely used. In such surfacing compositions, the powders of high-melting compounds characterized by high hardness and strength, are used as a wear resistant component, for example, alloys of tungsten carbide WC + W₂C (cast tungsten carbide), and as binder matrix the plastic and metal alloys are used. The great interest is the development of methods allowing producing powders of cast tungsten carbide and other high-melting-point materials of uniform composition, characterized by a high sphericity of the particles and having higher physical-mechanical properties. In this paper, The spherical tungsten carbide was produced by plasma atomization of rotating billet. The universal installation for production of super-hard spherical tungsten carbide and other high-melting-point compounds by plasma atomization of rotating billets was designed for industrial application. The results show that the application of the technology of plasma rotary atomization of rotation billet to obtain granules of powders of high-melting-point materials is promising, in particular tungsten carbide with sphericity over 90%, microhardness HV0.1 more than 3000 kg/mm² characterized by high flow ability more than 7.5 s / 50 g. Due to the use of new materials and innovative design and technological solutions the high reliability, maximum interval of technical service, high resource of operating units and executing mechanism of the equipment are ensured. Due to the use of new high-power plasma system with power supply source with high efficiency coefficient and improved dynamic characteristics, the system of preliminary heating of billets, innovative gas systems, high performance vacuum system, the developed universal system for the production of granules of powders of high-melting-point material is also applicable for the manufacture of spherical powders of metals and alloys, including highly active, and provides lower costs of products (powder) with an increased productivity, economic efficiency of the atomization process and reduce the impact of atomization process on the environment.

**A promising method to fabricate 5083 aluminum alloy with excellent corrosion resistance**

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The 5083 aluminum alloy was prepared and rolled at cryogenic or temperature after heat treatment. The samples are rolled from 15mm to 1.5 mm at cryogenic temperature and the amount of deformation is 90%. Other
samples rolled at room temperature in same condition were for comparison. The corrosion behavior and microstructure before and after corrosion have been studied through SEM, metallographic and electrochemical test. The influence of cryogenic rolling on the corrosion behavior of 5083 aluminum alloys was explored. Experiment results suggest that anti-corrosion ability of 5083 aluminum alloys can be enhanced through cryogenic rolling. The corrosion potential elevates and the corrosion current density reduces according to the electrochemical test. The primary reasons and the mechanism of are discussed.

Deformation-induced texture and strain rate sensitivity of an ultrafine structured Cu matrix nanocomposite
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Ultrafine structured face-centered cubic (FCC) metals exhibit enhanced strain rate sensitivity in comparison with their coarse-grained counterparts. This increased strain rate sensitivity tends to be linked with their uniform elongation during room temperature tensile test. Such unique plastic flow behavior of ultrafine structured FCC metals may be affected by the presence of ceramic nanoparticles at their grain boundaries. To answer this question, we tested different specimens cut from an ultrafine structured Cu-5vol.%Al₂O₃ nanocomposite in tension at various strain rates and measured its strain rate sensitivity. The tensile results demonstrated that the tested specimens showed a near-perfect plastic flow and an increased ductility with decreasing strain rate. Moreover, the measured strain rate sensitivity was found to be comparable to those reported in literature for ultrafine structured pure Cu. However, deformation texture was surprisingly observed in a tensile tested and fractured specimen just below its fracture surface. The formation of such texture may be partially responsible for the near-perfect plasticity observed during tensile plastic deformation of ultrafine grained metal matrix nanocomposites.