K. Metal Matrix Composite

Organizers: Gaohui Wu, Lin Geng, Di Zhang, Chaoli Ma, Xuanhui Qu, Zongyi Ma

K-01 (Invited)
Microstructure and Property Evolution of TiBw/Ti6Al4V Composite Sheet after Gas Tungsten Arc Welding
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TiBw/Ti6Al4V composite with a novel network microstructure achieved a significant improvement in mechanical properties by tailoring the microstructure at a higher level. This particular novel network structure is proved to not only decrease the brittleness, but also favorably improve the strengthening effect and service temperature of Discontinuously reinforced titanium matrix composites (DRTMCs). In order to further extend their potential applications, it is necessary to investigate microstructure and property evolution of the novel the composites. In this study, network structured TiBw/Ti6Al4V composite sheets mentioned above were joined by GTAW. Effects of various welding parameters especially welding current (I) and welding speed (v) on microstructure and mechanical properties were investigated. Microstructure evolution of the FZ and the HAZ were revealed for the welded sample with favorable appearance. Certainly, property evolution including the tensile tests under both room and elevated temperatures, and the microhardness were investigated on the joined TiBw/Ti6Al4V composite sheets.

The material investigated in this study was in situ TiBw/Ti6Al4V composite with a novel network microstructure produced by powder metallurgy process, the volume fraction of the TiB whisker reinforcement was 5 vol. %. Welding procedure was carried out using Cloos 300A AC-TIG welding source with direct current. The welding torch was produced by TBI INDUSTRIES GmbH. TiBw/Ti6Al4V composite sheets were joined in a gas shielding box with the ventilation of argon gas in advance for 2 minutes in case of the titanium alloy oxidation. Two sheets were fixed on the welding platform, with the gap of about 1mm with no single V groove on the joint and welding wire. Welding current (I) was selected ranging from 75 A to 110 A, while welding speed (v) from 120 mm/min to 210 mm/min, with fixed shielding gas flow rate of 8 L/min, 15 L/min respectively, and arc length of 3 mm.

The results showed that the heat affected zone (HAZ) and the fusion zone (FZ) can be clearly distinguished on the base of the network microstructure. The HAZ exhibited unchanged TiBw morphology and network distribution, while transformed β microstructure in matrix. However, the FZ exhibited refined and clustering TiBw with small network distribution by solution, precipitation and pushing effect during the rapid heating and cooling processes. Moreover, the matrix of the composites exhibited refined columnar grains due to the prohibiting effect of TiBw reinforcement. Moreover, increasing the welding currents and decreasing the welding speeds which are equal to increasing heat input can result in the increase of the transformed β microstructure in the HAZ and decrease of small network structure size in the FZ. The tensile testing results showed that all the welded composite sample fractured at the HAZ not the FZ, which certified the weldability and the stability of the GTAW for the composite. The highest ultimate tensile strength of the samples can reach 98 % that of the parent composite (PC); the yield and tensile strength at 500 oC are even higher than those of the PC. These phenomena should be attributed to the above microstructure evolution, which also lead to noticeable enhancement of the micro-hardness.

K-02 (Invited)
Research on key technology of multifunctional SiCp/Al composite and its orbital application in space
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The article focuses on the multifunctional SiCp/Al composite combining structural, thermal control and anti-resonance performances. The key technologies which limit its large-scale engineering application were investigated systematically, including the preparation of large-scale composites processed by pressureless infiltration and the efficient fabrication of large and lightweight components with good dimensional stability. About 100 qualified products were fabricated for 10 satellites and “Tiangong-2” space laboratory. The products are also being used in the space camera system on 6 on-orbit satellites, including 3 "Yaogan" satellites, 1 "Kuaizhou" satellite, 1 "Gaofen" satellite and "Jilin-1" satellite. The application achievements include system lightweight, the increase of system precision and stability which ensures the definition, resolution, stability and reliability of the obtained images, and the improvement of the effect and precision of thermal control in the system.

K-03 (Invited)

**Strengthening and Toughening Metal Matrix Composites by Configuration Design**

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Configuration design is one of feasible strategies to overcome the strength-ductility trade-off of metal matrix composites (MMCs). Understanding the role of configuration design on the mechanical properties is of great significance in guiding the design of next-generation high-performance produces. Here this paper reviews the recent progress on strengthening and toughening MMCs by structural design. Two kinds of microstructural heterogeneity were illustrated: one is Al- and Ti-based composites containing a network distribution of reinforcements, and the mechanical properties are prominently enhanced when compared to the homogenous counterparts; Another example is alternately stacked Ti/Al laminated composites, exhibiting a good strength/ductility combination as well. The fundamental mechanism how microstructural heterogeneity influences the mechanical performance is elucidated by careful examinations of deformed or fractured microstructures, and the strategy of microstructure design is expected to be applied in other MMCs for performance improvement.

K-04 (Invited)

**Near-net shape forming of Near-net shape**

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K-05 (Invited)

**Research on Ultra High Strength Aluminum Matrix Composites**

Chaoli Ma

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K-06 (Invited)

**Application of X-ray micro-computed tomography in metal matrix composites and metallic foams**

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X-ray micro-computed tomography is a non-destructive technique which provides three dimensional visualization and imaging of objects. It is becoming an accepted tool for the characterization of aluminum matrix composites, allowing the imaging of their structure features and the assessment of their modes of deformation and fracture.
In this work, the X-ray micro-computed tomography has been applied to characterize the structure of several aluminum matrix composites or syntactic foams, such as B4C/Al composite, diamond/Al composite and fly ash/Al syntactic foam. Microstructural features, such as size, morphology and distribution of B4C, diamond particles and fly ash microballoons, are visualized and quantified three dimensionally. With the combination X-ray tomographic investigation and interrupted compression, the compressive damage evolution and failure behavior in the fly ash/Al composites are revealed. The compressive plastic deformation is accommodated initially by the dispersed collapse of the fly ash microballoons followed by the formation of densification bands resulting from the localized plasticity. The current work provides useful information to optimise the microstructure of aluminum matrix composites or syntactic foams.

K-07
Effect of in-situ grown carbon nanotubes content on compressive properties and energy absorption capacity of open-cell aluminum composite foams
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Abstract: Owing to the characteristics of non-flammable, recyclable and lightweight, the aluminum foams have been widely used as functional and structural engineering materials. Traditionally, methods for preparing aluminum composite foams include direct melt foaming, powder metallurgy and electron-deposition, through which composite foams reinforced by ex-situ imported Al2O3, SiC particles and their corresponding whiskers. Although these reinforcements can improve the compressive performance and energy absorption capacity of the composite foams to a certain degree, some disadvantages still exist such as the agglomeration of the reinforcements in the cell walls, non-uniform pore distribution, the excessive interfacial reactions, as well as the poor interfacial bonding between the reinforcements and metal matrix. To overcome these bottlenecks in fabricating composite foams, we employ a method to fabricate aluminum composite foams reinforced by in-situ grown carbon nanotubes (CNTs).
Open-cell aluminum composite foams reinforced by CNTs fabricated via a process which combines in-situ chemical vapor deposition and powder metallurgy, using the carbamide particles as the space holders. The in-situ synthesis of CNTs with diameters ranging from 15 nm to 25 nm were homogeneously dispersed on the surface of Al powders, which not only formed a well-bonded interface with the Al matrix but also kepted its structural integrity after a short-time ball milling. Pores of the prepared CNTs/Al composite foams were uniformly distributed and the average pore sizes were 1.5mm, which can be tailored by the carbamide particles. Meanwhile, the relative density of the composite foam was about 0.3.
Compressive tests combined with Digital Image Correlation (DIC) technology were investigated in this work and the results verified that the CNTs can significantly enhance the compressive properties of the composite foams. Especially, when the CNTs content was 3.0 wt%, the yield stress of the composite foams increased to 23.1 MPa, which was about 2.6 times than that of the pure aluminum foam. Moreover, with the addition of CNTs, the fracture of the CNTs/Al composite foams changed from plastic mode to brittle mode.

K-08
Preparation and Properties of Vacuum-melted NiCr-based dense Cermet Coatings
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The densification property of coatings is the necessary prerequisite to the other excellent performances. In this paper, NiCr-based dense cermet coatings were fabricated by vacuum melting on the surface of nickel-base alloy GH4586 after adding a small quantity of metal borides. The thermal shock resistance, hardness and erosion–wear properties were investigated by using resistance wire furnace, thermogravimetric equipment, Vickers hardness tester and solid particle impact test (slurry jet). Surface and cross-sectional morphologies of NiCr-based (NiCr/WC; NiCr/WC-Al2O3) cermet coatings were observed by SEM, indicating that there are almost no holes and pores of the new coating in the microstructure and displaying that good cohesion between cermet particles and good adhesion to the substrate after quenching the specimens from 0 °C to 1000 °C up to 50 cycles, which are attributed to the formation of Ni-Cr alloy liquid phase during the process of vacuum melting. The Vickers hardness and erosion–wear resistance properties of NiCr/WC-Al2O3 cermet coatings are better than NiCr/WC, which are resulted from the synergistic effect of Al2O3 and WC ceramics. Overall, the present study provides a new method of NiCr-based dense cermet coatings, with outstanding mechanical properties.

K-09

In situ synthesis of 3D Ni anchored with graphene reinforced aluminum matrix composites

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In this study, in situ synthesis of 3D Ni anchored with graphene reinforced aluminum matrix composites via chemical vapor deposition (CVD) method cooperated with powder metallurgy techniques and mechanical grinding process was studied. The investigation of the microstructure by the field emission scanning electron microscope (SEM) and high resolution transmission electron microscope (HRTEM) shows the homogeneous distribution and network-shaped structure of Ni catalyst and Al matrix particles anchored with GNS. The tensile strength and Young' modulus increases by 113 % and 143 %, respectively, compared to pure Al. Fractographic observations have revealed the transgranular fracture mode activated due to micro-void coalescence fracture mechanism in composites reinforced with GNS associated with prolonged ductility. A devised dual-link ball structure analytical strengthening model has also demonstrated the profound efficacy of thermal and deformed activated dislocation mechanism in fortifying the matrix, which emphasis the structural control of GNS in the stiffening, strengthening, and toughening of the composites, and enlightens light on the development of 3D CNPs reinforced MMCs with the potential for scale-up applications.

K-10

Microstructure and Scratch Resistance of an In Situ Niobium Carbide Ceramic gradient Composite

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A niobium carbide (NbC) ceramic gradient composite was produced on the surface of an iron matrix by an in situ technique comprising a casting process and a subsequent heat treatment. The grey cast iron and niobium plate (with thicknesses of approximately 1 mm and purities of 99.9 %) were employed as the carbon and niobium sources, respectively. The phase constituents and microstructure the gradient composite were analysed by X-ray
diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) respectively. The results showed that the gradient composite can be divided into three zones according to the variation in the volume fraction of NbC ceramic particulates, which can be labelled as follows: NbC particulates high-density zone[A], NbC particulates partly gathering zone[B] and NbC particulates dispersing zone[C]. From the surface to the matrix, the volume fraction of NbC particulates continuously decreases from 98 % to 0 % while the average particulate diameter gradually increases from 200 nm to 0.8 μm. Along the depth towards matrix, the nano-hardness and elastic modulus of the graded coating decrease from 23.5 GPa to 3 GPa and 435 GPa to 150 GPa respectively, which were analysed using a nano-indentation apparatus. Then, the scratch resistance of the zone [A] and [B] was measured by scratch tests under a progressively increasing load of 0-100N. From the scratch tests, a critical load of 92 N was obtained from the dense ceramic zone [A], and it was only characterised by micro-cracks developed along grain boundaries. Moreover, a higher critical load >100N was obtained from zone[B], it showed good capability of plastic deformation due to the presentation of the matrix in NbC particulates partly gathering zone. The good scratch resistance were ascribed to the metallurgical combination between different layers, and between the NbC ceramic particulates and matrix. Namely, the ceramic gradient composite layer can protect the iron matrix from serious abrasion effectively.

K-11
Research progress on plastic processing techniques of particulate reinforced aluminium matrix composites
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Particulate Reinforced Aluminium Matrix Composites (PRAMCs) have been widely applied in military and civilian areas such as aviation, aerospace, advanced weapon applications and electrical industries due to their good mechanical properties at elevated temperature, low thermal expansion coefficient, excellent wear resistance and low production cost. The main preparation techniques of the PRAMCs are stir casting, powder metallurgy, pressureless infiltration and spray deposition. However, the problems such as low densification and particulate cluster in these techniques often reduce the properties of the materials. The studies were reported that the homogeneity of the distribution of particulate reinforcements in metal matrix can be improved by plastic processing, thus enhancing the material densification. This paper summarizes recent studies on the plastic processing methods of the PRAMCs, with an emphasis on the spinning technique. The effects of various process parameters on the material properties are discussed in detail. A summary of research progress on the numerical simulation of plastic processing of the PRAMCs is presented. In the end, an outlook is given on the prospect of the PRAMCs’ development.

K-12
High temperature oxidation behavior of Ti2AlC coating for C7-zirconium alloy
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1. Purpose
In order to increase the ability to resist the high temperature steam oxidation behavior for the zirconium alloy.
2. Process
The powders of Ti2AlC were used to deposit in the C7-zirconium alloy (Zr-1Nb-0.1Cu wt.%) sheets through
cold-pressing and diffusing under high-temperature to make the composite sheets. With good interface bonding property of these composite sheets dealt under different heat treatment temperatures were tested in high temperature (1200°C) steam atmosphere to detected the corrosion resistance of the coating for the C7-zirconium alloy. This kind of test was designed to detect the resistance of the composite sheets to the loss of coolant accident (LOCA).

3. Results

The deposited and then heat treated Ti2AlC coating can increase the high temperature oxidation resistance for C7-zirconium alloy evidently, as the oxidation weight gain of these composite sheets were all lower than that of C7-zirconium sheets that were not deposited by the Ti2AlC. The distribution of oxygen element at the interface of Ti2AlC/ C7-zirconium alloy was detected by EPMA. The evolution behavior of the microstructure at the Ti2AlC/ C7-zirconium alloy interface was studied.

4. Conclusion

By compared the experiment, the Ti2AlC/ C7-zirconium alloy composite sheets, which heat treated at the 900°C for 3 hours will be better for increasing the resistance to the LOCA.

K-13

Effect of volume fraction of cenospheres/PP composite materials on microstructure and properties

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Cenospheres/ pp composite microstructure and properties affected by different volume fraction. In this paper, different volume fraction of cenospheres /PP composite sample were produced. By the mechanical properties (tensile performance testing and impact performance testing) test and Scanning Electronic Microscopy on the material structure, The results show that volume fraction of cenospheres/PP composites increase from 5% to 50%. Maximum tensile strength of the material decrease from 24 Mpa to 14 Mpa. This shows that with the increase of the volume fraction of the cenospheres, the tensile strength and impact strength of the material decreased, and the mechanical properties of the materials decreased obviously.

K-14

Microstructure and mechanical properties of AZ31 magnesium alloy reinforced with graphene nanoplatelets (GNPs) using powder metallurgy method

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In recent years, graphene has become one of the most attractive reinforcements of metal matrix composites due to its excellent mechanical properties. In this work, graphene nanoplatelets (GNPs) reinforced AZ31 magnesium alloy composites with different weight fractions (0.5 wt.% and 1.0 wt.%) of GNPs were fabricated via a powder metallurgy method followed hot extrusion, and the microstructure and mechanical properties of the composites were investigated. The results revealed that compared to monolithic matrix, the AZ31-0.5 wt.%GNPs composite showed higher tensile yield strength (+13.2 %), compression yield strength (+17.7 %) and lower failure strain (TFS:-38.0 % and CFS:-23.7 % ). No significant change was observed in ultimate tensile strength. Surprisingly, the ultimate compression strength of the composites was lower than monolithic matrix (-8.8 %). The AZ31-0.5 wt.%GNPs composite exhibited higher Vickers hardness compared to monolithic AZ31 alloy (+11.4 %). However,
with the increase of the weight fraction of the reinforcement, no further significant improvement of the mechanical properties of the composites was observed due to the agglomeration of GNPs.

K-15

Effect of Mechanical Stirring and Air Pressure on The Fluidity of SiCp/A357 composites
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Characterized by high strength, good wear resistance and low thermal expansion coefficient, particle reinforced Al-matrix-composites are increasingly applied in the aerospace and transportation industries and so on. SiCp/A357 composites are difficult to machine and form due to its high hardness and wear resistance. Stir casting is a near net shape process which can cast the composites in melt. A357 alloy was used as the matrix alloy with a large semi-solid interval, SiCp/A357 composites with 20wt.% SiC particles were manufactured by vacuum mechanical stir casting, and the type of SiC particles is α-SiC with an average diameter of 12 μm. The fluidity is an important factor for mold filling of casting. In this paper, the effect of mechanical stirring and air pressure on the fluidity of SiCp/A357 composites was investigated with eight thin flow channels. The fluidity compared under different impeller speed and air pressure for 20 wt% SiCp/A357 composites. The flow length varied linearly with the impeller speed. Fluidity increased by increasing impeller speed, this was particularly evident in the semi-solid interval. It was noticed that the amount of oxides increased with air pressure rising, the gas involving and cooling speed were aggravated following an increase in air pressure, all of these reduced fluidity.

K-16

Room temperature tensile strength and crack initiation of continuous SiC(f)/Ti-6Al-4V composites
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The tensile behavior and the associated fracture mechanisms were determined in a Ti-6Al-4V alloy uniaxially reinforced with 37% SiC monofilaments. The measured value of the composite strength was lower than the predicted one. The fractographic analysis and microstructural observations of the tested samples are also presented. The crack take place firstly in the weaker fiber, then blunt by the C coating. Debonding occurs mainly at C coating near the matrix.

K-17

Severe Plastic Deformation on the Microstructure and Mechanical Properties of (TiB+TiC) reinforced Titanium Matrix Composites
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In this study, Forged 5 vol.% (TiB+TiC) in situ synthesized Ti6Al4V titanium matrix composite with a heterogeneous reinforced structure was successfully subjected to equal channel pressing (ECAP). The evolution of the microstructure and mechanical properties (yield strength, ultimate tensile strength and elongation) of (TiB+TiC)/Ti6Al4V during this thermo-mechanical processing is studied. Special attention is also
paid to the thermostability of the material after annealing at the temperature of 700°C–850°C. The number of ECAP-Bc varies in the range of 1-4. The microstructure is much refined with the increasing ECAP pass numbers. Formation of homogenous TiB short fibers and TiC particles with some ultrafine grains and sub-grains are observed after 4 ECAP passes. Strength increases with the increasing ECAP numbers and saturates after 4 ECAP passes to yield strength of 1150MPa. The ductility after 4 ECAP passes is much higher compare with the first ECAP pass. The strengthening effect of small size reinforcements was also significant since its distribution was more homogeneous in the matrix. Moreover, a number of recrystallized grains and more homogeneous equiaxed α phase have been obtained when annealed in high temperature. The grains have no variations when the material is annealed at the low temperature. In addition, the hardness tests demonstrate that it decreases in the high annealing temperature due to the generation of recrystallization.

K-18
A novel route to synthesize micro-laminated TiAl matrix composite sheets with high performance
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TiAl-based alloys are regarded as one of the most promising lightweight high-temperature structural materials due to their attractive properties. However, TiAl-based alloys sheets are quite difficult to be produced by traditional rolling technique because of the limited room temperature ductility and poor formability. This remains primary impediments to their eventual application. Thus, it is rather imperative to explore a feasible forming technique for the production of the TiAl-based alloy sheets. In the present work, fully dense Ti5Si3/TiAl matrix composite sheets with novel micro-laminated architecture were successfully synthesized by employing hot pressing and reactive annealing of pure Ti and Al-Si alloy foils. This near-net-shape processing method avoided direct deformation of brittle TiAl-based alloy billets. TiAl matrix composites showed a refined microstructure due to the presence of in-situ synthesized Ti5Si3 particles and the TiAl matrix alloys displayed unique layered structure composing of alternating fully lamellar TiAl layers and equiaxed TiAl layers. It is noteworthy that the micro-laminated Ti5Si3/TiAl composites exhibited superior mechanical properties compared with conventional TiAl-based alloys, especially for ultimate tensile strength at 800°C, up to 783MPa, with the a total elongation (δ) to failure of 11.3%, far higher than that of the 3rd generation TiAl-based alloys. This was attributed to the strengthening effect of Ti5Si3 reinforcements and formation of unique micro-laminated architecture. Therefore, the micro-laminated Ti5Si3/TiAl composite sheets have relatively potential for light-weight high-temperature structural application.

K-19
The effect of carbon on the tribological behavior of self-lubricating Cu/Si3N4w/carbon composites
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The tribological behavior of self-lubricating Cu/10%Si3N4w/carbon composites (C-10%SN-CMMCs) with various amounts of carbon additions was studied. The results indicated that friction coefficient (COF) of C-10 %SN-CMMCs gradually decreased with the carbon content increasing, but the change of wear rate was not uniform. At 10 N, 0.33 m/s, the wear rate decreased from $3.8 \times 10^{-5}$ mm3m-1 to $1.6 \times 10^{-5}$ mm3m-1 with the help of 1% carbon. However, at 10 N, 0.33 m/s, the wear rate showed a constant increase from $3.3 \times 10^{-4}$

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mm3m-1 to 9.4×10^-4 mm3m-1 with the carbon content increasing from 0 to 4%. The carbon was useless to enhance the wear resistance at high sliding velocity and high load, but was significant to reduce the COF. At 30 N, 0.33 m/s, the COF decreased rapidly from 0.73 to 0.40 as the carbon content increased from 0 to 4%. The carbon released on the surfaces during the sliding wear process formed a lubricant film, thus the COF was decreased. But the carbon addition also resulted in the decreased fracture energy, and it brought about more fractured materials. The change of wear rate was the result of the two competing factors: the lubricant carbon film and the fracture energy.

K-20
Fabrication and Properties of in Situ B13P2 Reinforced Cu-Based Composites
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In this work, a new type of B13P2 reinforced Cu matrix composite (B13P2/Cu) with excellent wear resistance properties has been fabricated. The experimental results reveal that when the total content of P and B is 3 wt. % and the mass ratio of P to B is 2:3, the brittle reticular divorced eutectic Cu3P disappears and B13P2 phase uniformly distributes in Cu matrix. The microstructure can be controlled and designed according to the ratio of P and B. The properties of hardness, wear resistance and CTE of the B13P2 reinforced Cu composite have been measured. Results show that the micro hardness of B13P2 reaches up to 1837 HV as high as SiC, and the micro hardness of Cu matrix is about 5 times more than pure Cu. Then the wear resistance data indicate that the largest weight loss of pure Cu is approximately four times more than that of the B13P2 reinforced composites at the 40 min. The CTE of the new composites is also decreased as compared with pure Cu.

K-21
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.

K22
3D strain mapping applied to hydrogen embrittlement in Al-Zn-Mg-Cu aluminum alloys
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It has been well documented that solute hydrogen atoms increase the mobility of dislocations in metals and alloys, thus promoting highly localized deformation which eventually leads to the rupture of a material. However, little is known about the mechanism of hydrogen-enhanced dislocation mobility that influences the macroscopic fracture process. In this paper, the high resolution X-ray tomography is used to clarify the influence of hydrogen on the initiation and propagation of quasi cleavage fracture in Al-Zn-Mg-Cu alloys. The initiation and propagation of quasi cleavage crack are discussed by measuring 3D strain distribution ahead of a crack tip in terms of hydrogen embrittlement models.

K-23
Effects of pre-extrusion on hot rolling behavior of magnesium matrix nanocomposite
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AZ31-1 vol.% SiC nanocomposites were fabricated by semi-solid stir casting method assisted by high intensity ultrasonic waves. After homogenization at 400°C for 12 h, the nanocomposites were subjected to hot rolling directly or to pre-extrusion followed by hot rolling. For both cases, the rolling was conducted at 350°C with per pass reduction of 15%. For the former deformation process, the coarse original microstructure caused the formation of massive twins at initial stage of rolling process. With progressive rolling, the microstructure was refined and homogenized continuously by dynamic recrystallization, accompanied by the formation and propagation of shear bands. Considerable strength enhancement was attained when the accumulated reduction reached to 84%, while the ductility was relatively low. For the latter one, pre-extrusion with extrusion ratio of 12:1 at 400°C significantly refined the microstructure of the nanocomposite, which largely reduced the occurrence of twining during initial rolling. Similarly, the microstructure was also refined and uniformed by dynamic recrystallization during successive rolling. However, it is surprising to find a combination of comparable strength and excellent ductility was realized with total reduction of only 48%, which is much smaller than that of the direct hot rolling. The comparison between these two deformation ways indicates that pre-extrusion can obviously promote the rolling efficiency of magnesium matrix nanocomposite.

K-24
Microstructure evolution mechanism and hardness of TiBw reinforced composite coating on TC4 by TIG process
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The 20 vol% TiBw reinforced TMCs was designed to produce a hard coating on TC4. First, the spherical TC4 powders and TiB2 powders were mixed homogeneously by ball milling. Then the milled mixtures were hot pressed in vacuum, and the subsequent as-sintered TMCs were cut into a small piece with the thickness of 1mm, which was preplaced on the TC4 alloy surface. Finally TIG cladding process was adopted to prepare this composite coat.
There were no obvious defects in the coating such as cracks or holes, and the metallurgical bonding between coat
and substrate was achieved. XRD results show the coating was mainly consisted of TiBw and Ti matrix, SEM microstructure analysis revealed the TMCs coating with two different TiBw morphologies, hexagonal cylinder with a hollow core and needle-like respectively. During the hot pressed process, some rod-like and bulk primary TiB whiskers were formed due to the first in-situ reaction of partial TiB₂ powders with TC₄ matrix. These TiBw would prevent the contact between TC₄ matrix and those residual TiB₂ particles. When it came to the TIG cladding procedure, the temperature would soon increase to Ti melt point (1668°C) but below that of TiB (2200°C) with appropriate heat input, and the melt pool was consisted of liquid Ti, solid primary TiBw and TiB₂. TC₄ matrix melted quickly then led to a redistribution of those reinforcements, primary TiBw would grow as a result of heating. The second in-situ reaction between them would take place for TiB₂ was surrounded by liquid Ti and the ΔG of this reaction is negative, thus secondary TiB whisker was formed. Owing to the impeding effect of bulk primary TiBw and β-Ti during solidification, directional growth at some local areas was observed, leading to the formation of needle-like secondary TiBw. Meanwhile, TC₄ substrate surface also melted a little and fully mixed with liquid coating. Therefore, the strongly metallurgical bonding was obtained. Heat affected zone was full of needle-like martensite as a result of rapid cooling. Consequently, the hard coating was consisted of primary TiBw with hexagonal cylinder with a hollow core morphology, needle-like secondary TiBw, β-Ti and α-Ti. Micro-hardness of the surface coating in different depth have been tested, the results show that with increasing distance the hardness first decreased slowly till to the interface and then declined to the TC₄ substrate rapidly. Maximum hardness value reached 663HV0.2 especially near the bulk primary TiBw, and average hardness of this sample was 572HV0.2 which is about 63% increase compared to the TC₄ substrate with 350HV0.2. The high hardness of the TIG coating was due to the fine-grained structure and the dispersed hard TiB reinforcements which obstruct the movement of dislocations. In order to evaluate overall performance of coating hardness, Rockwell hardness had been measured, HRC48 of the cladding TMCs was also obviously superior than HRC33 of TC₄. Thus, surface hardness and wear resistance of TC₄ had been greatly improved by this technology.

K-25

**High volume fraction heterogeneous Mg/SiC nanocomposite with extreme malleability**

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A heterogeneous Mg-based nanocomposite reinforced with SiC nanoparticles was synthesized by planetary ball milling and subsequently spark plasma sintering. The material has two distinguished phases, which was characterized by scanning electron microscope (SEM) and atomic force microscope (AFM). Such a heterogeneous structure includes following features: (i) the samples contain two phases, one is Mg with a high volume fraction of nanoparticles (hard phase), and the other is pure Mg without nanoparticle (soft phase); (ii) the soft phase is isolated by the hard phase; and (iii) both phases take flake-like morphology. The result of quasi-static compression test demonstrates that the heterogeneous composite obtains a huge malleability than that of counterpart with homogeneous microstructure, partially result from the unique flake like soft phase. The results also highlight a new strategy for designing Mg-based composites for high performances.

K-26

**Effect of Boron on Microstructure and Property of Sn-Ag-Cu Low-silver Lead-free Solder**

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With the rapid development of microelectronic technology and continuous concern of environmental issues, the adoption of high reliability and green production are required in modern electronics industry. A key role of meeting such requirements is the use of a viable lead-free solder. So far, the lead-free solder Sn-3.0Ag-0.5Cu (SAC305) has been used widely in the industry because of its low eutectic temperature, good wettability and high reliability, even though the cost is relatively higher because of the Ag of up to 3.0%. In addition, the coarse pieces of intermetallic compound (IMC) in the solder can also lead to the failure of solder joints. As a result, it’s significant to develop low-silver lead-free solder. In practice, low-silver solders also have problems such as the rise of melting point, the deterioration of wettability, the decrease of mechanical property and the fast growth of brittle IMC. These problems can lead to poor welding performance, interface crack in stress concentration spot and expander tearing. It was considered that new additives could be added into solder alloys in order to refine their alloy microstructure, restrain the rapid growth of IMC during wetting reaction and aging process, improve the physical and mechanical properties of solder alloys, and thus improve the reliability of solder joints.

**K-27**

**Study on the Process and Properties of Ultrafine Silver-Coated Electrolytic Copper Powders**

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In this paper the ultrafine electrolytic copper powders were coated by silver by displacement reaction and reduction method, and copper particles of 10wt.% of silver loading were obtained. The effects of concentration of complexing-dispersing agent, concentration of reducing agent on the silver coated copper powders were studied. And the morphology, composition and core-shell structure of coated powders were characterized by scanning electron microscopy, X-ray diffraction and energy dispersive spectroscopy. The oxidation resistance and electric conductivity of the coating powders were studied. The experimental results show that the powders have better oxidation resistance and high conductivity using EDTA-2Na (10g/L) as complexing-dispersing agent and formaldehyde at the concentration of 30 g/L as a reducing agent.

**K-28**

**Numerical Simulation on Filling Process of SiCp/A357 Composites**

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SiCp/Al composite characterized by high module, high strength, good isotropy, has been widely applied in the fields such as airspace, transportation and electronic packaging. Stir casting process with low cost, high efficiency and near-net shape has become a main production method, but the two-phase flow behavior of the SiCp/Al composite during casting process has greatly effect on particle distribution and ultimate properties of casting. So it is important to understand the filling flow field of the SiCp/Al composite in the casting process.

In this study, a two-phase flow computational model was developed, and the filling flow process of SiCp/A357 composite based on a benchmark test die was numerically simulated by using commercial software Fluent. The effects of SiCp volume fraction and SiCp size on the flow field of SiCp/A357 composite were studied. The results
show that difference of flow fields between A357 alloy and SiC/A357 composite is presented, and the simulation results would be helpful to optimize the casting process.

K-29
Phase Transition and Mechanical Properties of TiAl/Ti2AlC Composites Synthesized With Different Carbon Sources
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Ti2AlC as the most light-weight layered ternary carbide belonging to MAX phases has drawn great attention to be used as structural materials. Here we report a series of TiAl/Ti2AlC composites synthesized by vacuum arc melting with TiC, graphite powder and CNTs as carbon sources. Phase transition plays an important role in the microstructures and properties of products. With the increase of Ti2AlC ceramic, the microhardness and compressive strength of the TiAl/Ti2AlC composites improved linearly. What's is important is that the TiAl/Ti2AlC prepared with TiC as the carbon source possesses higher microhardness and compressive strength than that one prepared with carbon of graphite powder and CNTs. During the process of vacuum arc melting, there are three reactions taking place successively: Ti+Al→TiAl, Ti+C→TiC, TiAl+TiC→Ti2AlC. Ti2AlC was formed by peritectic reaction between TiAl melt and TiC particles. And also, there are a large amount of TiC left in the TiAl matrix, which makes contributions to improve the hardness and strength of the composites. The fracture behavior of the composite mainly comprised of transgranular fracture. The pinning, pulling out and effect of crack deflecting of TiC particles, together with the interlayer tearing, plastic shearing, folding and crimping of Ti2AlC played a key role in the improvement of strength and plasticity of the composites.

K-30
Microstructure and properties of TiC steel-bonded carbide used Fe/Mo pre-alloyed powder as binder
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Fe/Mo pre-alloyed powder was manufactured by water atomization method with different molybdenum content of 1.25%, 2.25%, 2.88%, 3.75%, respectively, and this kind of powder was used as binder to fabricate TiC steel-bonded carbide. The ball milled powder was made into experimental samples after mixing glue, granulation, forming, sintering and heat treatment, and so on. The mean grain size of the mixed powder was smaller because of the increase of hardness and brittleness due to the existence of molybdenum in Fe/Mo pre-alloyed powder, and it is expected to obtain finer structure of the alloy. Additional, hard phase particles grew slowly and uniformly owning to the uniform distribution and low activity of molybdenum element as a result of the adding method (compared with the adding method of pure molybdenum powder), and the abnormal grain growth was suppressed. Results showed that the density, hardness, strength and impact toughness of the alloy all increased to some extent, then the microstructure of the alloy was finer obviously.

K-31
Investigation on wear and corrosion of Fe-based Alloy coatings by laser cladding
Yulong Qi, Haiyan Chen, Lihua Dong, Yansheng Yin, Chenyang Shu, Xuan Zhao
In order to make the material can be used in various environments, surface modification is the most convenient method. The essence of the laser cladding with powder is producing coatings by one-step process using a laser beam and additive material in the form of powder. Nowadays, the laser cladding method is widely used in the development and application. By this method can to improve surface of steel products, in particular those for which is required good resistance for corrosion and wear, often at high temperature.

Iron-based alloy is used as the most common alloys in many areas have been fully developed and applied. However, due to the iron-based alloy corrosion resistance is poor, so often joined other alloying elements in the iron-based alloy to improve its corrosion resistance. For example, FeCrNiSi coatings are widely employed to improve the quality of components such as bolt, pipe, plunger, piston rod whose surface is subjected to severe tribological and corrosion conditions. Usually, FeCrNiSi coatings can be deposited by using thermal spraying methods such as high velocity oxy fuel (HVOF) spraying, plasma spraying (PS) and flame spraying (FS). However, thermally sprayed FeCrNiSi coatings usually possess low to moderate adhesion to the substrate and have porosity. These disadvantages, fortunately, can be overcome by using laser cladding to replace thermal spraying, providing an alternative solution in particular for components or products with high added value. A lot of experiments have proved that the laser cladding FeCrNiSi coating has good density and strong metallurgical bonding to substrates.

In this paper, we use an alloy powder containing Cr, Ni, Si and Mo to form a laser cladding coating. The same friction test, electrochemical test and salt spray corrosion test were carried out on different components of the film, so as to get the best proportion of the components.

Our experiments are divided into three parts: friction and wear test, electrochemical test and salt spray corrosion test. In the process of the experiment, the 2kg force was used to carry out the reciprocating friction test on the sample surface for 2 hours. The obtained friction coefficient will be used to describe the wear resistance of the coatings. The hardness and elastic modulus were analyzed by the means of Brinell hardness test and nanoindentation. In the electrochemical test, the test sample is cut into the size of 10mm*10mm. The polarization curves were tested with the aid of the electrochemical work station, and the corrosion current density was obtained. The corrosion current density is directly related to the corrosion resistance of the film, the greater the corrosion current density, the more serious the corrosion resistance.

Salt spray corrosion experiment, the use of salt spray corrosion experiment box to make the material in the 35 % NaCl environment and maintain a constant temperature of 10 degrees Celsius, in order to simulate the marine environment. It is helpful to analyze the resistance ability of different components to corrosion. Moreover, microstructure and composition were studied by Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD).

In this investigation, laser cladding process aims at developing anti-corrosion claddings onto substrates for protection. The physical-mechanical and electrochemical corrosion behaviors of the additively manufactured Nickel-Chromium-based alloy are evaluated in this research. The significance of this work can be summarized in several folds. Firstly, this study explores the capabilities of laser cladding technique to fabricate the anti-corrosion claddings. Secondly, this study was carried out for different laser cladding component composition of comparative experiments to explore the differences in the proportion of different composition of the material properties. Finally, simulating the adaptability of the package layer components in various environments.

In this experiment, because it involves many factors, so the result is more complex, only to the simple prediction. Prediction results are as follows: the surface hardness and wear resistance of the film with Cr content increase and enhance; in Cl- containing materials resistant to corrosion resistance with the increase of Mo content increased; because powder containing Si element, so the melting point is obtained control remained at a low level, and
overall size of powder low, density should be higher.

K-32
Plastic Deformation and Bonding Ability of TiCx Reinforced Fe(Al) Composites
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The properties of metal matrix composites were extremely determined by the size of dispersion dimension and the interfacial action among the components. The investigation of plastic deformation behavior and bonding ability are significant for understanding the deformation mechanism of TiCx reinforced Fe(Al) Composites. Novel TiCx/Fe(Al) composites have been produced from reduced iron and Ti3AlC2 powders using in-situ reaction technique. The effects of different particle sizes and contents of Ti3AlC2 precursor on the flexural behavior of TiCx/Fe(Al) composites were studied by SEM, HRTEM and three-point bending test, and the bonding ability of different bonds in the TiCx/Fe(Al) composites was calculated by the Cheng's improved Thomas-Fermi-Dirac theory (TFDC). The bending test results show that the synthesized composites exhibit high toughness, and this high toughness allows TiCx/Fe(Al) composites to be bent in a V-shaped curve with 76.4 degrees. The high plastic deformation of TiCx/Fe(Al) composites can be attributed to the high bonding ability between the TiCx and Fe(Al) matrix matrix. The HRTEM image of the grain boundary shows that the bonding in the interface is a chemical bonding which is a high performance bonding than just physical adsorption in the interface, and the orientation relationship between Fe and TiCx is (110)Fe-Al/(100)TiCx. This relationship also can be confirmed by the calculation results.

K-33
Effect of Y2O3 nanoparticles on the microstructure and mechanical properties of 2 vol % TiB/Ti composites
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In this paper, 2 vol. % TiB/Ti composites with different weight percent (0.2~2wt. %) of Y2O3 nanoparticles were in situ synthesized by casting route. The microstructure and mechanical properties of the composites were presented and discussed. The results revealed that the TiB whiskers are tend to segregate at prior β boundaries. The prior IFN-b grain size as well as IFN-a lath width was significantly refined with increasing of weight percent of Y2O3 nanoparticles. Vicker hardness and compression tests performed at room temperature revealed the strengthening effect of Y2O3 nanoparticles. However, as the content of Y2O3 nanoparticles reaches 2 wt. %, the vicker hardness, compression strength and compression ratio are significantly decreased due to large amounts precipitation of Y2O3 particles.

K-34
Ni-CNTs Microtubes via Electrodeposition Process
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Objective
To find out the mechanism of Ni-CNTs microtubes electrodeposition.

Methods
Three-dimensional (3D) carbon nanotubes (CNTs) reinforced nickel composite was found in a common Watts bath with dispersed CNTs. Stereo-microscope, field emission scanning electron microscopy (FESEM) and electrochemical test were conducted to study the deposits in different baths.

Results
These composite microtubes have similar diameter and wall thickness. It was found that there were no microtubes formed in bath without CNTs, or with surfactant for hydrogen evolution.

Conclusion
Hydrogen adsorption on sample surface and CNTs adsorption on hydrogen bubbles played important role in this tubular electrodeposition phenomenon.

K-35
Microstructural and dry sliding wear behavior of TiB2 reinforced copper matrix composite fabricated by in situ casting process
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Particulate reinforced copper matrix composites TiB2 particles reinforced copper matrix composites were fabricated by traditional casting from in-situ synthesized between Cu-B and Cu-Ti master alloy. The microstructure and mechanical properties of the composites with different content of TiB2 and loading wear condition on the tribological behavior of Cu/TiB2 composites were investigated. The results show that TiB2 particles are in situ formed in the copper matrix and the TEM images show the well bonding between copper and TiB2. With the increasing amount of in-situ TiB2 particles in copper matrix, the tensile strength and hardness are significantly improved, but the elongation and electrical conductivity slightly decrease. The friction and wear characteristics of the composites have been determined by carrying out dry sliding tests on pin-on-disk machine under different loads, speed and time. The volume loss rate of the composites under different condition shows the significant improvement of wear property with the addition of TiB2 particles in copper matrix.

K-36
Effect of Fe addition on the microstructure and properties of Cu–24 wt.%Ag alloy
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Fe up to 0.1 wt.% was added into Cu-24 wt.%Ag alloy. Microstructures of both containing-Fe alloy and the reference Cu-24 wt.%Ag alloy were investigated by using field emission scanning electron microscopy(FESEM) and transmission electron microscopy (TEM). The kinetics of precipitation of Ag and Fe from Cu-matrix in both alloys were studied by differential scanning calorimetric (DSC) measurement and X-ray diffraction (XRD) analysis, and properties of hardness and electrical conductivity were measured. Both alloys were subjected to a series of heat treatments. The effect of the Fe addition on the electrical conductivity and micro-hardness under
various temperatures was investigated. The addition of Fe increased the micro-hardness, and decreased the electrical conductivity. Because of the precipitation of Fe out of Cu-matrix at 450°C, the electrical conductivity of Cu-24 wt.%Ag-0.1 wt.%Fe alloy was achieved 80 %IACS (decreasing by 16 % compared with the reference alloy), and micro-hardness was 145HV (increasing by 12 % compared with the reference alloy). Precipitation behaviors were detected by DSC to indicate two distinct exothermic reactions in this containing-Fe alloy. Activation energy was 102±1 kJ/mol for precipitation of Ag, and 86±1 kJ/mol for precipitation of Fe. X-ray diffraction analysis indicated that both the dissolved Ag and Fe in Cu were dependent on the ageing temperature. The microstructures indicated that both the size and volume fraction of Ag and Fe precipitated from Cu matrix played important roles in the electrical conductivity and micro-hardness. Quantitative relationship among the microstructural characterization, concentration contributions, and relevant properties at peaked temperature was modeled and the prediction values were in good agreements with experimental values.

K-37
Fabrication of high-performance Al-4Mg alloy reinforced by CNTs via mechanical alloying
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CNTs is considered as an excellent reinforcement due to its excellent physical and mechanical properties. In this work, carbon nanotubes (CNTs) reinforced Al-4Mg alloy matrix composites were successfully fabricated by high-energy ball milling, cold-pressing sintering and hot extrusion. The microstructures of the ball-milled powders and CNTs/Al-4Mg composites were characterized by X-ray diffraction, Raman spectroscopy, scanning electron microscopy and transmission electron microscopy. The results showed that the CNTs could dispersed homogeneously in the Al-4Mg alloy substrate after high energy milled for 1.5 h. Through TEM micro-area analysis, the Al4C3 phase was found in bulk CNTs/Al-4Mg composites, suggesting that some of the CNTs reacted with Al matrix and formed Al4C3 during the consolidation process and the interfacial bond strength was improved. Tensile tests revealed that both the yield strength and ultimate tensile strength of the 1.5 wt.% CNTs/Al-4Mg composite were increased by 32% compared with pure Al-4Mg alloy fabricated under the same procedure. The relevant strengthening mechanisms of the composites were discussed.

K-38
Preparation of precursor fiber for SiC fiber reinforced Ni-Cr-Al alloy composites
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In preparation of SiCf/Ni-Cr-Al precursor wire, (Al+Al2O3) diffusion barrier layers and Ni-Cr-Al alloy coating have been deposited on the surface of SiC fiber via magnetron sputtering. The microscopic morphology, composition and phase composition of (Al+Al2O3) coating and Ni-Cr-Al alloy coating were researched, and the influence of the coatings on the mechanical property of SiC fiber was measured. The precursor wires were treated in vacuum at 850°C and 900°C for 150 hours. The results show that (Al+Al2O3) coating is uniform and dense, and the Al2O3 coating is in the form of amorphous. The composition of Ni-Cr-Al alloy coating is uniform and close to that of Ni alloy target. The (Al+Al2O3) layer and Ni-Cr-Al layer combine well with SiC fiber and have extremely slight negative effect on the tensile strength. After heat treatment in vacuum, the Ni-Cr-Al alloy coating remains intact, and Al2O3 coating effectively blocks the element diffusion and restricts the reaction between SiC fiber and Ni-Cr-Al alloy, which can ensure the preparation of high performance of SiCf/Ni-Cr-Al composites.
Study of Joining TiBw/TC4 to Inconel 718 by Tungsten Argon Arc Welding
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A good joint of TiBw/TC4 to Inconel 718 was obtained by using lap joint as the substitution of butt joint and focusing the heat input on the TiBw/TC4 composites side. Due to the location of heat input a reaction layer that was not fused during welding was obtained. The reaction layer was similar to the diffusion layer in diffusion welding and its thickness was controlled by the value of heat input. Formation of reaction layer was attributed to the diffusion of elements in matrix. Therefore, reaction layer can be divided into Ti-rich zone and Ni-rich zone, and brittle intermetallic phase Ti2Ni was found in both two regions. In the Ni-rich zone, the relatively coarse dendrites are the predominant microstructure, however the network microstructure of TiBw/TC4 has been broken in the Ti-rich zone. As the results of intermetallic phase in the reaction layer, microhardness was much higher than the matrix. Few cracks were found in the whole joint, while more cracks in the Ti-rich zone.

Finite Element Simulation on the Dynamic deformance of Aluminum Matrix Syntactic Foam
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The mechanical behavior of aluminum matrix syntactic foam under dynamic loading was investigated by Hopkinson pressure bar system and finite element simulation. The aluminum matrix syntactic foam was fabricated by pressure infiltration technique, which had different matrix of 1060 aluminum and 6061 aluminum alloy. During the deformation process, the damage method of cenospheres was different between them. The crack under dynamic loading was along the direction of force in the syntactic foam of 1060 matrix. However, The crack under dynamic loading was present nearby the “equatorial band” of cenospheres in the syntactic foam of 6061 matrix. The microstructure by SEM affirmed this results. Therfore, plastic deformation was present in matrix during the dynamic deformation, and influence on the damage of cenospheres.

Preparation and thermo-physical properties of unidirectional oriented SiC/Al-Si-Mg composites by pressureless infiltration
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SiC/Al-Si-Mg composites were fabricated by pressureless infiltration of Al-12wt%Si-8wt%Mg into an unidirectional oriented porous SiC preform obtained by squeeze casting process. The microstructure and thermo-physical properties of the composites were investigated. The initial continuous microstructures of the porous ceramic after pressureless infiltration could be maintained and the resultant SiC/Al-Si-Mg composites exhibited significant thermo-physical anisotropy with relatively higher thermal conductivity (TC) and lower coefficient of thermal expansion (CTE) in the longitudinal direction. According to the results obtained by SEM and TEM analyses, we found that the longitudinal thermo-physical properties of the composites was mainly dependent on the TC and CTE of the Al-Si-Mg matrix itself, and the transverse thermo-physical properties was
attributed to the combined action of the interfacial reaction and the cooperation of the Al alloy and SiC preform.

K-42
Preperatation and Magnetic Properties of Iron Based Powder Cores
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The main work of this paper is based on powder metallurgy production process, drawing on traditional magnetic core industrial production processes, systems research powder morphology, insulating coating, pressing process, to stress annealing process for the preparation of the magnetic properties of the magnetic core law, prepared by a high performance magnetic core. The use of improved process for preparing a high performance magnetic core. On this basis, the effects of magnetic field annealing the metal soft magnetic powder cores performance. The main conclusions obtained are as follows:
(1) In this study, obtained by two-step thermosetting polyimide film (PI), namely first by PAA coating solution, and then dehydrated to form after subsequent heat treatment PAA PI film, film layer uniform and dense. PI film can withstand 500 ℃ high temperature, the working temperature can reach 260 ℃, can significantly improve the stress relief annealing temperature after forming, reduce the iron loss.
(2) In the present experiment, the traditional molded 800MPa pressure compared to high-speed pressing process can significantly improve green density up to 7.47g/cm³, can be better to reduce the gap between the particles, the magnetic material to improve conductivity, lower coercivity. The resulting sample was pressed at high velocity 8.7m/s, the coating amount of 3 wt% of an atomized iron powder optimum magnetic properties.
(3) It can be obtained by this experiment, high temperature heat treatment, can effectively remove the molding stress, bridging coating layer due to friction between the particles during the pressing process due to breakage, increased insulation, electrical resistivity increase, reducing the coercivity, iron loss reduce.

Poster

K-P01
Study on Preparation and Electrical conductivity of Polyaniline coated nickel fiber
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In order to improve the conductivity of the nickel fiber, polyaniline (PANI) of synthesis by chemical oxidative polymerization coated and modified nickel fibers. Experiment with aniline, a nickel fiber as base material, the influences of dopant type, dopant content, reaction time, reaction temperature and stirring rate of PANI coating nickel fiber were studied. SEM, NMR and elemental analysis were used in the experiments to characterize and morphology analysis of products. The conductivity of PANI coated nickel fiber was tested by four-point probe conductivity tester. The results showed that the PANI coating layer was uniform and stabilize when the p-toluene sulfonic acid (PTS) as dopant, the C(PTS) = 0.1mol/L; the reaction time was 5 hours, the reaction temperature was 5 ℃, and stirring rate was 60 r/min, the conductivity of nickel fiber coated with PANI was the highest and its maximum was 5×10-5S/cm.
K-P02

Analyzing hysteresis and coefficient of thermal expansion of M40/AZ91D during thermal cycling
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2. School of Materials Science and Engineering of Harbin Institute of Technology

In this work, AZ91D composite reinforced with M40 fiber was prepared by pressure infiltration method. Expansion behaviors of M40 / AZ91D composite were studied with thermal expansion instrument in 25-150 °C and 25-150 °C temperature range of internal heat circulation, and then analyzed the influence law of hysteresis, residual strain and coefficient of thermal expansion by different temperature change rate. The results revealed that residual stress and strain in process of pressure impregnation would lead to strain hysteresis and residual strain of composite material in thermal cycling. At the same time, coefficient of thermal expansion of the composites decreased with the increase of cycle times. Residual strain of the composite went up with the increase of temperature change rate of the thermal cycling and coefficient of thermal expansion decreased with temperature change rate ascending in the 25-150°C temperature range. The coefficient of thermal expansion of the composites decreased with the increase of temperature during the heating process, which cut down with the increase of temperature in process of cooling in the 25-495°C temperature range.

K-P03

Reciprocating Wear Resistance of PTAW Deposited Ni60/WC Composite Coatings
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Stainless steel has been wildly used in manufacturing of mining machine, power steering system devices and pressure containers etc. due to their fine properties such as suitable hardness and toughness, allowable design stresses and lower prices. Nevertheless, the stainless steel shows poor resistance to abrasion in adverse working conditions, which restrict the further application in many industries. Surface treatment technique can change the microstructure, component and phase composition that plays a role in improving the material’s resistance to abrasion. Plasma transferred arc welding, known as a surface treatment technique, has been extensively applied in the hardfacing industry since it has several properties such as lower dilution rate ratio, 3 to 10% in PTA against 10 to 15% in TIG, high volume of production and excellent metallurgical bond. Focus on reducing the impact of wear, causing the failure of materials, has grown as great deal in recent years in mining, petrochemical and chemical industry. Nickel-based alloys possess plenty of properties that ensure them to be reliable under conditions of abrasion, impact, erosion or corrosion. Normally, nickel-based alloys coatings, with high bonding strength, a better corrosion resistance characteristic and excellent resistance to adhesive and abrasive wear, have bought good prospects in engineering application. For example, Ni60 coatings are widely applied to strengthen the property of components such as roller, piston rods, stabilizer, wearing plates, turbines, tools, extruders, plungers, rolls for rolling mills whose surface is subjected to severe tribological conditions. To increase the life of metallic materials requiring extremely high wear resistance, metal matrix composite (MMC) coatings composed of Ni60 and tungsten carbides (Ni60-WC) are frequently used to solve problems of reduced life under severe abrasive conditions.

K-P04

Comparison of residual stress measured by diffraction method and matrix etching method in SiC fiber

20
Measurement and modeling of residual stresses in SiC fiber reinforced titanium matrix composites (SiCf/Ti) is still a challenge. Diffraction method and matrix etching method can characterize the strains of matrix and fiber, respectively, and different models based on test methods would be used to calculate the residual stress. Comparison of residual stress measured by different method is helpful to achieve reliable approach. In this work, SiCf/Ti samples with perpendicular and parallel cross-sections to the fibers have been fabricated, and the residual stress is measured by X-ray diffraction, neutron diffraction and matrix etching. X-ray diffractions based on triaxial stress model have been applied to analyze the stress in samples with perpendicular and parallel cross-sections to the fibers, respectively, in which the longitudinal matrix stress in sample with perpendicular cross-sections to the fibers is larger than that in sample with parallel cross-sections to the fibers. For comparison, both neutron diffraction and matrix etching also measure the residual stress of composite, and the longitudinal matrix stress calculated from neutron diffraction and matrix etching is consistent with that from X-ray diffractions based on triaxial stress model, confirming the reliability of triaxial stress model.

K-P05
Substrate Bias Dependent Microstructure and Properties of TC17 Titanium Alloy Coatings Deposited by Magnetron Sputtering
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While matrix coated fiber method is used to fabricate SiC continuous fiber reinforced TC17 (Ti-5Al-2Sn-2Zr-4Mo-4Cr) matrix composites (SiCf/TC17), the properties of SiCf/TC17 composite are strongly affected by the microstructure and properties of TC17 alloy coatings in precursor wires. In this work, substrate bias (Vb) was adopted to tailor the microstructure and properties of TC17 coatings, and Vb dependent microstructure, morphology, composition, stress, hardness and adhesion for TC17 coatings have been investigated by X-ray diffraction, scanning electron microscope, atomic force microscope, auger electron spectrometer, surface profiler and nanoindenter. The experimental results show that all coatings crystallize with hexagonal structure ($\alpha$-Ti). The migratory ability of incoming ions rises with increasing Vb from floating to -120V, smoothing growth surface, and re-sputtering come into prominence with further increasing Vb, roughening the surface and accompanying by transition of growth mode from column grains to compact-grain structures. As Vb is increased, Al content increases and Ti content decreases, in addition, compressive stress and hardness show a rising trend caused by ions implantation. Interface ions implantation and stress state act together on the adhesive force between TC17 alloy coatings and SiC fiber.

K-P06
Residual stress measurements in continuous SiC fiber reinforced titanium matrix composites with different fiber volume fraction
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Residual stress inevitably occur in continuous SiC fiber reinforced titanium matrix composites (SiCf/Ti), which is caused by the mismatch in the coefficient of thermal expansion between the Ti alloy matrix and the SiC fiber during cooling from the consolidation temperature, having considerable effect on the mechanical response and failure of SiCf/Ti. In this work, SiCf/Ti with different fiber volume fraction has been fabricated to study the effect of fiber volume fraction on residual stress. A matrix etching technology was used to measure the relaxation of fibers upon dissolving the matrix in a part of the composite and obtain the longitudinal fiber strains. The stresses in the fiber and the matrix were then calculated using a concentric cylinder model. The measured fiber residual strain was found to depend on fiber volume fraction and was reduced significantly with increasing fiber volume fraction, which can be ascribed to that stress relief occurs at higher fiber volume fraction while the stress maximum value is in excess of the matrix yield stress.

K-P07
Effect of spark plasma sintering temperature on the Microstructure of SiC fiber reinforced titanium alloy matrix composites
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Continuously SiC fiber reinforced titanium alloy matrix composite (SiCf/Ti) is a potential material in aeronautical field for its excellent mechanical properties, and Spark plasma sintering (SPS) technology has been extensively used for materials consolidation due to its low temperature and short time. In this paper, continuously SiC fiber reinforced titanium alloy matrix composites (SiCf/Ti) have been fabricated by SPS under different sintering temperature from 750 °C to 950 °C at the interval of 50 °C. Consolidated samples have been investigated with the help of Scan Electron Microscopy (SEM), Energy Diffraction Spectrum (EDS) and Push-Out test. The results show that the densification degree as well as the thickness of interfacial reaction layer increases with the rise of sintering temperature. In addition, the interface reaction layer performances typical tooth shape microstructure, which is quite similar with the situation of HIP. Due to the aggravation of interfacial reaction, the interface shear strength grows. In a conclusion, SPS is an effective method for SiCf/Ti composites manufacturing, and the composites can be consolidated at a lower temperature compared to HIP processing, which is beneficial to control the interface reaction together with the cost.

K-P08
Effect of deposition pressure and substrate bias on microstructure and properties of nickel alloy coatings deposited by magnetron sputtering
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In the course of preparation of SiC continuous fiber reinforced nickel matrix composites (SiCf/Ni) by fiber-coating method, it is one of important procedure to deposit nickel alloy coatings onto SiC fibers by
magnetron sputtering. Sputtering pressure and substrate bias can control the energy of incoming atoms and ions, respectively. Thus the influences of sputtering pressure and substrate bias (Vb) on microstructure, morphology, stress and hardness for Nickel 738 alloy coatings are explored by X-ray diffraction, atomic force microscope, surface profiler and nanoindenter. The experimental results show that all coatings exhibit a strong cubic (200) preferred orientation, in which the gain size drops with increasing deposition pressure, while gain size first increases and then decreases with increasing Vb. Both low deposition pressure and high Vb are beneficial to smooth the surface by overcoming the shadow effect. Compressive stress is helpful to maintain the integrity of precursor wires. When only -30 V bias is applied to substrate, compressive stress cannot be obtained by varying deposition pressure, but by increasing Vb compressive stress is achieved above -160V, meanwhile, realize good adhesion between Nickel 738 coating and SiC fiber. Hardness is strongly dependent on the energy of incoming atoms or ions, and increases with decreasing deposition pressure or increasing Vb.

K-P09

The microstructure and mechanical properties of NiAl-Cr (Mo)-(Hf,Dy,Fe) eutectic composite at different withdrawal rates and heat treatment processes
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The microstructures, room temperature fracture toughness and elevated temperature strength of directionally solidified NiAl–Cr (Mo)–0.05Hf–4.0Fe (at. %)–0.1Dy (wt %) eutectic composite at different withdrawal rates and heat treatment processes were investigated using SEM, TEM, STEM, EPMA, three-point bending tests and elevated temperature tensile tests. With increasing the withdrawal rate from 6 μm/s to 240 μm/s, the solid-liquid interface undergoes the transition of planar→cellular→dendritic morphology, and the interlamellar spacing decreases gradually. The lamellar structures at the center of eutectic dendrite are well-aligned and parallel to the growth direction, thus resulting in the improvement of fracture toughness (13.7 ± 0.2 MPa·m1/2) and elevated temperature tensile strength (308 MPa) at a moderate withdrawal rate (60 μm/s). This is higher than that of high-strength NiAl-Cr (Mo)-0.5 Hf(at.%) eutectic composite (6.24 ± 0.3 MPa·m1/2, 297 MPa). The heat treatment results in the lamellar coarsening and local dissolution, correspondingly improves the fracture toughness (18.4 ± 0.9 MPa·m1/2). Unfortunately, the heat treatment lowers the elevated temperature tensile strength (270 MPa). To better understand the corresponding fracture behavior, the crack propagation and fracture surface are also observed.

K-P10

The study on the morphology of intermetallic compound and interface bonding state in pure Al/St clad plates after 645 °C/1h diffusion annealing
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The correlation between intermetallic compound (IMC) and interface bonding state of the pure Al/08Al steel clad plate after 645°C/1h diffusion annealing was studied using the SEM. In order to eliminate the defects possibly caused by mechanical polishing process, the focused ion beam (FIB) technique was employed to obtain the intrinsic interface bonding states. Firstly, the SEM observation of mechanical polished samples showed that, after annealing at 645°C for 1h, the IMC grows completely continuously along the interface with the thickness of 2-6
µm, while, at some region grows abnormally with the thickness up to 10-30 µm. The relatively thin and continuous IMC part showed the dentition interface to the Al side at micro level and fine wavy interface toward the steel side. And the locally expanded IMC part showed the similar interface to the Al side, but larger dendritic interface toward the steel side. In order to further eliminate the effect of mechanical polishing, some craters cross the interface with different IMC thickness were dug for more than 10µm in depth with the FIB. After the fine cleaning of the cross section, the morphology of IMC and both Al and Steel sides was observed with SEM. It indicated that, at the position where the thickness of IMC was of 2.0±0.5µm, a crack longer than 5µm along Al/IMC interface appeared. On other hand, at the position where the thickness of IMC was 15±5µm, it was observed that, a long crack also appeared along Al/IMC interface, moreover, some voids with different sizes hid inside the IMC at the part near the Al side. Finally, the mechanism of the formation of the cracks at Al/IMC interface was discussed from the point view of thermal expansion coefficient difference among Al, steel and the grown interface IMC. It indicated that the cracks formed at Al/IMC interface could be attributed to the thermal stress during the cooling process because of larger difference of thermal expansion coefficient between Al and Al-Fe IMC. The observation of intrinsic cracks and defects in IMC at the interface of Al/Steel could supply a novel way to correlate the morphology of IMC and interface bonding strength.

K-P11

**Microstructure evolution of Cu-Cr-Zr alloy joint welded by continuous drive friction welding**

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Continuous drive friction welding has many advantages, includes low cost, high efficiency, high degree of automation, and also can be obtained without defects forging joint. In this paper, the Cu-Cr-Zr alloy which has high strength and conductivity was jointed by continuous drive friction welding, and the microstructure of welded joint, mechanical properties and physical properties were evaluated by optical microscopy, micro hardness tester and eddy current conductivity meter respectively. The results show that: from the weld to the base metal, in turn, forming the weld zone, heat mechanical affected zone and the transition zone. The weld zone is equiaxed grains. The heat mechanical affected zone appears equiaxed grains with few elongated grains. And the grains in transition zone only occurs some deformation and recrystallization. But it still has a handful of equiaxed grains in the transition zone. After solid solution and aging, the original fibrous tissue completely turns into bulky equiaxed grains with a small amount of annealing twins in the area of welded joint. At the same time, the welded joint has a certain level of improvement on its hardness and electrical conductivity while the hardness of the base metal declines.

K-P12

**Effect of in-situ grown carbon nanotubes content on compressive properties and energy absorption capacity of open-cell aluminum composite foams**

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Owing to the characteristics of non-flammable, recyclable and lightweight, the aluminum foams have been widely
used as functional and structural engineering materials. Traditionally, methods for preparing aluminum composite foams include direct melt foaming, powder metallurgy and electron-deposition, through which composite foams reinforced by ex-situ imported Al2O3, SiC particles and their corresponding whiskers. Although these reinforcements can improve the compressive performance and energy absorption capacity of the composite foams to a certain degree, some disadvantages still exist such as the agglomeration of the reinforcements in the cell walls, non-uniform pore distribution, the excessive interfacial reactions, as well as the poor interfacial bonding between the reinforcements and metal matrix. To overcome these bottlenecks in fabricating composite foams, we employ a method to fabricate aluminum composite foams reinforced by in-situ grown carbon nanotubes (CNTs).

Open-cell aluminum composite foams reinforced by CNTs fabricated via a process which combines in-situ chemical vapor deposition and powder metallurgy, using the carbamide particles as the space holders. The in-situ synthesis of CNTs with diameters ranging from 15 nm to 25 nm were homogeneously dispersed on the surface of Al powders, which not only formed a well-bonded interface with the Al matrix but also kept its structural integrity after a short-time ball milling. Pores of the prepared CNTs/Al composite foams were uniformly distributed and the average pore sizes were 1.5mm, which can be tailored by the carbamide particles. Meanwhile, the relative density of the composite foam was about 0.3.

Compressive tests combined with Digital Image Correlation (DIC) technology were investigated in this work and the results verified that the CNTs can significantly enhance the compressive properties of the composite foams. Especially, when the CNTs content was 3.0 wt%, the yield stress of the composite foams increased to 23.1 MPa, which was about 2.6 times than that of the pure aluminum foam. Moreover, with the addition of CNTs, the fracture of the CNTs/Al composite foams changed from plastic mode to brittle mode.

K-P13
Preparation and Properties of Vacuum-melted NiCr-based dense Cermet Coatings
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The densification property of coatings is the necessary prerequisite to the other excellent performances. In this paper, NiCr-based dense cermet coatings were fabricated by vacuum melting on the surface of nickel-base alloy GH41586 after adding a small quantity of metal borides. The thermal shock resistance, hardness and erosion-wear properties were investigated by using resistance wire furnace, thermogravimetric equipment, Vickers hardness tester and solid particle impact test (slurry jet). Surface and cross-sectional morphologies of NiCr-based(NiCr/WC; NiCr/WC-Al2O3) cermet coatings were observed by SEM, indicating that there are almost no holes and pores of the new coating in the microstructure and displaying that good cohesion between cermet particles and good adhesion to the substrate after quenching the specimens from 0℃ to 1000℃ up to 50 cycles, which are attributed to the formation of Ni-Cr alloy liquid phase during the process of vacuum melting. The Vickers hardness and erosion–wear resistance properties of NiCr/WC-Al2O3 cermet coatings are better than NiCr/WC, which are resulted from the synergistic effect of Al2O3 and WC ceramics. Overall, the present study provides a new method of NiCr-based dense cermet coatings, with outstanding mechanical properties.

K-P14
In situ synthesis of 3D Ni anchored with graphene reinforced aluminum matrix composites
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In this study, in situ synthesis of 3D Ni anchored with graphene reinforced aluminum matrix composites via chemical vapor deposition (CVD) method cooperated with powder metallurgy techniques and mechanical grinding process was studied. The investigation of the microstructure by the field emission scanning electron microscope (SEM) and high resolution transmission electron microscope (HRTEM) shows the homogeneous distribution and network-shaped structure of Ni catalyst and Al matrix particles anchored with GNS. The tensile strength and Young’ modulus increases by 113% and 143% , respectively, compared to pure Al. Fractographic observations have revealed the transgranular fracture mode activated due to micro-void coalescence fracture mechanism in composites reinforced with GNS associated with prolonged ductility. A devised dual-link ball structure analytical strengthening model has also demonstrated the profound efficacy of thermal and deformed activated dislocation mechanism in fortifying the matrix, which emphasis the structural control of GNS in the stiffening, strengthening, and toughening of the composites, and enlightens light on the development of 3D CNPs reinforced MMCs with the potential for scale-up applications.

K-P15
Microstructure and Scratch Resistance of an In Situ Niobium Carbide Ceramic gradient Composite
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A niobium carbide (NbC) ceramic gradient composite was produced on the surface of an iron matrix by an in situ technique comprising a casting process and a subsequent heat treatment. The grey cast iron and niobium plate (with thicknesses of approximately 1 mm and purities of 99.9 %) were employed as the carbon and niobium sources, respectively. The phase constituents and microstructure the gradient composite were analysed by X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) respectively. The results showed that the gradient composite can be divided into three zones according to the variation in the volume fraction of NbC ceramic particulates, which can be labelled as follows: NbC particulates high-density zone[A], NbC particulates partly gathering zone[B] and NbC particulates dispersing zone[C]. From the surface to the matrix, the volume fraction of NbC particulates continuously decreases from 98 % to 0 % while the average particulate diameter gradually increases from 200nm to 0.8μm. Along the depth towards matrix, the nano-hardness and elastic modulus of the graded coating decrease from 23.5 GPa to 3 GPa and 435 GPa to 150 GPa respectively, which were analysed using a nano-indentation apparatus. Then, the scratch resistance of the zone[A] and [B] was measured by scratch tests under a progressively increasing load of 0-100N. From the scratch tests, a critical load of 92N was obtained from the dense ceramic zone[A], and it was only characerised by micro-cracks developed along grain boundaries. Moreover, a higher critical load >100N was obtained from zone[B], it showed good capability of plastic deformation due to the presentation of the matrix in NbC particulates partly gathering zone. The good scratch resistance were ascribed to the metallurgical combination between different layers, and between the NbC ceramic particulates and matrix. Namely, the ceramic gradient composite layer can protect the iron matrix from serious abrasion effectively.

K-P16
Research progress on plastic processing techniques of particulate reinforced aluminium matrix composites
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Particulate Reinforced Aluminium Matrix Composites (PRAMCs) have been widely applied in military and civilian areas such as aviation, aerospace, advanced weapon applications and electrical industries due to their good mechanical properties at elevated temperature, low thermal expansion coefficient, excellent wear resistance and low production cost. The main preparation techniques of the PRAMCs are stir casting, powder metallurgy, pressureless infiltration and spray deposition. However, the problems such as low densification and particulate cluster in these techniques often reduce the properties of the materials. The studies were reported that the homogeneity of the distribution of particulate reinforcements in metal matrix can be improved by plastic processing, thus enhancing the material densification. This paper summarizes recent studies on the plastic processing methods of the PRAMCs, with an emphasis on the spinning technique. The effects of various process parameters on the material properties are discussed in detail. A summary of research progress on the numerical simulation of plastic processing of the PRAMCs is presented. In the end, an outlook is given on the prospect of the PRAMCs’ development.

K-P17
Fabrication of high-performance Al-4Mg alloy reinforced by CNTs via mechanical alloying
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CNTs is considered as an excellent reinforcement due to its excellent physical and mechanical properties. In this work, carbon nanotubes (CNTs) reinforced Al-4Mg alloy matrix composites were successfully fabricated by high-energy ball milling, cold-pressing sintering and hot extrusion. The microstructures of the ball-milled powders and CNTs/Al-4Mg composites were characterized by X-ray diffraction, Raman spectroscopy, scanning electron microscopy and transmission electron microscopy. The results showed that the CNTs could disperse homogeneously in the Al-4Mg alloy substrate after high energy milled for 1.5 h. Through TEM micro-area analysis, the Al4C3 phase was found in bulk CNTs/Al-4Mg composites, suggesting that some of the CNTs reacted with Al matrix and formed Al4C3 during the consolidation process and the interfacial bond strength was improved. Tensile tests revealed that both the yield strength and ultimate tensile strength of the 1.5 wt.% CNTs/Al-4Mg composite were increased by 32% compared with pure Al-4Mg alloy fabricated under the same procedure. The relevant strengthening mechanisms of the composites were discussed.

K-P18
Microstructures and Mechanical Properties of β-Si3N4 whiskers Reinforced Aluminum matrix composites
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In the present investigation, Aluminum matrix composites reinforced with different volume fraction (0%, 5%, 10%, 15%, 20%) of β-Si3N4 whiskers were prepared by the powder metallurgy method. The composites were prepared via mechanical milling followed by hot pressing processes. The phases composition of the samples were investigated by X-ray diffraction (XRD), and microstructures were investigated by scanning electron microscope (SEM) and transmission electron microscope (TEM). Mechanical property tests revealed the remarkable enhancement effects of β-Si3N4 whiskers. Even though the densification was weakened, the highest Vickers hardness, bending strength and tensile strength were improved by 108.1%, 138.6% and 129.9% respectively, compared with the pure Al. Moreover, appearances and fracture surface micrographs of failed composite samples
indicated that the composites became more and more brittle with the increase of the β-Si3N4 whiskers content.

K-P19
Processing and Electrical Properties of Nano-Al2O3/Cu Composites
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Objective: Find the best adding amount of Al2O3 powders by investigating the effect of the adding amount of Al2O3 powders on copper matrix composites.

Method: Al2O3/Cu composites were fabricated by vacuum arc melting technology and the effects of Al2O3 powders on mechanical and electrical properties were investigated. Optical microscopy (OM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD) were used to analyze the phase composition of the composites. Metal conductivity meter and optical brinell hardness tester were used to measured the conductivity and hardness of composites.

Result: With the addition of Al2O3 from 0.2 to 1.0 wt.%, the densities of materials decreased from 98.5 to 97.0%, The hardness of the composites increases with Al2O3 powders content increasing, 1.0 wt.% Al2O3/Cu composites were up to 60.6 HB and increased by 18.6 % compared to Cu alloy in this paper. With the addition of Al2O3 reinforcement, the IACS % of Al2O3/Cu composites decreased from 88.97 to 86.16.

Conclusion: With the addition of Al2O3 from 0.2 to 1.0 wt.%, the mechanical properties of the Al2O3/Cu composites were enhanced, the conductivities of the composites decreased but the range of decline is small and the value of decline range is only 3.5 %.

K-P20
High-temperature Oxidation Mechanisms of (TiCp+TiBw)/Ti-6Al-4V Composites with Tailored Three-dimensional Network Microstructures
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It has been highly desirable to improve the high-temperature mechanical and physicochemical properties of titanium based materials especially for aerospace applications, but their strong oxidation tendency brings in a great challenge against this objective. Previous investigations revealed that Ti-6Al-4V alloy reinforced with TiC particles showed strong oxidation resistance in the temperature range of 873-1073 K, but the mechanical properties were deteriorated due to the formation of hives-like TiC walls. When reinforced with TiB whiskers, it displayed desirable high-temperature mechanical properties, but the oxidation resistance decayed owing to the evaporation of B2O3. According to the recently investigated ‘hybrid effects’ in titanium matrix composites, in this work these two kinds of ceramic reinforcements were combined for Ti-6Al-4V alloys so as to achieve both ideal mechanical properties and satisfactory oxidation resistance.

(TiCp+TiBw)/Ti-6Al-4V composites were successfully fabricated with low-energy milling and high-vacuum hot pressing techniques. The TiB whiskers and TiC particles were inhomogenously distributed at the edge of the large Ti-6Al-4V powders and thus formed a three-dimensional network microstructure. High-temperature isothermal oxidation experiments were carried out at 873 K, 973 K and 1073 K respectively. Thermodynamic calculations and XRD analysis confirmed that TiO2, Al2O3 and B2O3 were the main probable oxidation products at such temperatures. However, the experimentally measured weight-gain/time curves demonstrated conspicuous discrepancies in the kinetic oxidation mechanisms at various temperatures. This could be explained through the
macro scale morphologies of the oxidized specimens. The SEM analysis of oxidized specimen surface revealed that the network microstructure could sustain at 873-973 K but was totally destroyed when temperature raised up to 1073 K. The average oxygen concentration in TiC particles was much higher than that of Ti-6Al-4V matrix at the initial state, and such a phenomenon may have resulted from the selective oxidation effects. The block-slot model was also applied to theoretically predict the controlling factors of oxidation processes. Accordingly, it is inferred that at 873 K the pure diffusion of oxygen atoms is the intrinsic reason of oxidation, whereas at 1073 K it is the chemical reactions between the composites and oxygen that play the dominant role, and at 973 K both two factors control the oxidation process. The outward diffusion of aluminum atoms and multi-layered oxide scale were also observed by SEM analyses, but the detailed mechanisms are still to be further explored.

K-P21
Hot deformation behavior and processing map of Pb-Mg-10Al-0.5B alloy
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The hot deformation behavior of the nuclear radiation shielding materials Pb-Mg-10Al-0.5B was studied in the range of 493-653 K and strain rate range of 0.01-10 s\(^{-1}\) employing hot compression tests on the Gleeble-3500 thermal simulator. The results show that peak stress increases with decreasing of temperature and increasing of strain rate. The hot deformation behavior can be described by a constitutive equation with hyperbolic sine function or Zener-Hollomon parameter. The hot deformation activation energy of this alloy is 129.266 kJ/mol. Processing maps were developed for all of the hot compression tests at strains of 0.1, 0.3, 0.5, and 0.7. According to the developed processing maps and the microstructures of the hot-compressed specimens, the domains of 620-653 K and 0.01-0.1 s\(^{-1}\) are corresponded to optimum conditions for hot working of the Pb-Mg-10Al-0.5B alloy.

K-P22
Application of graphene in the aluminum alloy conductor
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Steel core aluminum stranded wire (ACSR) is one of the most widely used wires currently. However, the goal to reduce heat resistance of Al-Zr-Y meet its bottleneck. Graphene has drawn much attention because of its excellent mechanical properties and conductivity in recent years. For ACSR, whether resistance reduction or enhanced strength with the addition of graphene both make sense. It will make a big significance if we can introduce graphene into molten aluminum alloy by solidification. The main challenge is to get uniformly dispersed graphene without chemical reactions at the interfaces. In our study, we want to explore a novel method combined with ultrasonic dispersion and pouring at suitable temperature. The graphene-aluminum composite shows increased strength and hardness but decreased conductivity. This method shows the potential to bring about low-cost and large-scale production of graphene/aluminum composite material.

K-P23
Research on laminate structure graphite film/Al composites by pressure infiltration method and thermal physical properties
Laminate structure consisting of graphite films reinforced aluminum has been fabricated to improve the interfacial properties between the carbon materials and aluminum matrix materials by pressure infiltration method. The characterization, thermal conductivity (TC) and thermal expansion coefficient (TEC) of graphite films/Al composites were investigated. The graphite films/Al composites prepared from 50 vol. % graphite films has a high TC as high as 743 W/(m·K) in the plane to the graphite films, and with a low TEC (22.4×10^{-6} K^{-1} to 24.3 ×10^{-6} K^{-1}). Microstructural analysis demonstrates that the graphite films and aluminum matrix distribute uniformly, no visible pores. Meanwhile X-ray photoelectron spectroscopy was used to monitor the composition of the composites. Scanning electron microscopy images revealed that graphite film/aluminum hierarchical composite was achieved and no interface products (Al_4C_3, etc) were generated, which is contributed to the excellent TC and TEC of graphite films/Al composites.

K-P24
Calculation of volume fractions of TiB and residual stress distributions in Ti-TiB-TiB2 composites by spark plasma sintering
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The six-layered functionally gradient material (FGM) of Ti-TiB-TiB2 was rapidly fabricated in a vacuum under 40 MPa for 5min using the temperature gradient field (TGF) sintering method. A gradient temperature field was formed during the spark plasma sintering (SPS) process. The volume fractions of TiB were determined from the integrated intensities of peaks in the X-ray diffraction spectra using the direct comparison method. Based on elastic axial symmetry model, the residual stress distributions in FGM were calculated using the finite element method (FEM) which indicating a relative low thermal residual stress can be achieved by the TGF sintering method.

K-P25
The research of the new-type high strength heat and wear resistant Al matrix composites system reinforced with in-situ particles
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In this paper, based on the liquid-solid reaction principle, in-situ SiCp, AlNp and Al_3BCp were synthesized from Al melts, and then the new-type particle reinforced Al matrix composites with the high strength, heat resistant and wear resistant were fabricated. In in-situ AlNp reinforced Al matrix composites, the size of the AlNp was less than 500 nm, the morphology of AlNp was irregular, and the three-dimensional network structure between AlNp and the matrix was formed, which is helpful for the mechanical properties of the composites. The tensile strength at room temperature of 16.4 wt.% AlNp /Al composites was about 518 MPa, and the tensile strength at 350 °C of it was about 190 MPa. It indicated that the heat resistance of AlNp /Al composites is excellent. In the Al_3BCp/6061 composites, Al_3BCp with the 147nm average size uniform distributed in the Al matrix and the morphology of it was flake shape. The tensile strength at room temperature of 25Al_3BCp/6061 composites was 622 MPa, and the tensile strength at 300 °C was about 258 MPa, which indicate that Al_3BCp can improve the mechanical...
properties of the 6061 aluminum alloy. The multi-scale SiCp reinforced Al matrix composites hold the excellent wear resistance and heat resistance. The morphology of the in-situ SiCp was nearly spherical shape and the size was range from 50 nm to 4 μm. Comparing with the Al-16Si alloy, the wear volume loss of 16SiCp/Al-16Si composites is less than 50 % and the CET of composite decreases about 35% due to the synergistic strengthening effect of multi-scale SiCp. The tensile strength at 350 °C of 2SiCp/Al-18Si-4.5Cu-2Ni composite was about 130 MPa.

K-P26
Deformation mechanisms in compositional gradient lamellar-structured Ti-Ta alloy
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Most lamellar-structured materials possess the interfaces with discontinuous component leading to the relatively independent deformation mechanisms within the adjacent layers. Here, we obtain a compositional gradient lamellar-structured Ti-Ta alloy which deformation mechanisms are based on the component. According to the content of Ta, the lamellar-structured alloy is divided into Ti-enriched lamellas, Ta-enriched lamellas and transitional zones. Suffering the hot-swaging and annealing, the Ta-enriched lamellas exhibit matrix twins \{110\}<111>\text{bcc} and martensitic twins \{111\}<110>\text{M} while the precipitated \(\alpha\) phase with orientation relationship of [11-20]_\text{hcp} // [111]_\text{bcc} can be detected in the Ti-enriched lamellas. The martensite with [111]_\text{bcc} // [110]_\text{M} and (110)_\text{bcc} // (111)_\text{M} appears in the transitional areas. In further tensile deformation, secondary twins and dislocations inside the martensitic twins appear in Ta-enriched areas and abundant dislocations accumulate at the interfaces of \(\alpha\) phase in Ti-enriched areas. The transitional zones remain the martensitic microstructure but with more and finer phase inside.

K-P27
Research on preparation and properties of Cu-Sn/C composites
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The Cu-Sn/C composites were successful prepared though high energy ball milling and heating-press sintering, the influences of the mixing process and graphite content on the mechanical properties and friction and wear behavior were investigated. The composites were subjected to density, hardness, high temperature tensile strength, and friction and wear tests. The composite density is 6.59~7.01g/cm3 and high temperature tensile strength is 120~152MPa at 300°C, the friction coefficient is 0.08~0.10. The results reveal that the density of composites decreases with the increase of graphite content. The high temperature strength of the composite decreases with the increase of temperature.

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The dynamic properties of B4C/6061Al neutron absorber composites fabricated by power metallurgy
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The dynamic compression properties of B₄C/6061Al neutron absorber composites (NACs) with three B₄C volume fractions (20%, 30% and 40%), fabricated by power metallurgy (ball-milling and vacuum hot-pressing sintering), were studied in this paper. The compression tests of these composites at strain rate ranging from 760/s to 1150/s were conducted by using split Hopkinson pressure bar (SHPB). The damage mechanism of the B₄C/6061Al neutron absorber composites was studied through the microstructural analysis. Results show that the B₄C particles exhibited uniform distribution in the 6061Al matrix. The B₄C/6061Al NACs dynamic strength was found to improved with increasing amount of B₄C particles and strain rate. The damage mechanisms include particle fracture, particle/matrix interface debonding. Dislocation pile-up was observed in the grain boundary and the interface between B₄C and 6061Al. A constitutive model under dynamic compression was developed based on Johnson-Cook model, and the model prediction agrees well with experimental results.

Investigation on microstructure and properties of Nb/Nb₅Si₃ composites strengthened with CNTs by Spark Plasma Sintering
Wenyuan Long
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High-Temperature Sliding Wear Behavior of Micron-sized and Nano-sized TiC Particles Reinforced Al-Cu Matrix Composites
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Jilin University

Objectives: Dry sliding wear behavior of micron-sized and nano-sized TiC particles reinforced Al-Cu matrix composites were investigated. The effects of different sized TiC particles on the wear behavior were compared.
Methods: In this study, the nano-sized and micron-sized TiCp/Al-Cu composites were fabricated by adding Al-TiC master alloys into the molten Al-Cu matrix alloy. The Al-TiC master alloys consisted of micro-sized and nano-sized TiC particles were prepared by combustion synthesis reaction and hot pressing. Dry sliding wear tests were performed using a pin-on-disc wear apparatus at 180°C.
Results: With the addition of 1 wt.%, 3 wt.% and 5 wt.% micron-sized TiC particles, the wear rates of the composites were decreased by 25.4%, 29.6% and 36.5% compared with the unreinforced Al-Cu alloy, respectively. The distribution of the micron-sized TiC particles was examined by scanning electron microscopy. The results indicate that the addition of TiC particles could improve the wear resistance of the composites significantly. The strengthening effect of the nano-sized TiC particles for the Al-Cu matrix alloy was more significant than that of the micron-sized TiC particles. With the addition of 0.5 wt.% nano-sized TiC particles, the wear rate was decreased by 45.5 % compared with the Al-Cu matrix alloy.
Conclusion: Dry sliding wear tests at 180C, with the load of 20 N and speed of 200 r/min, show that the wear rate of 0.5 wt% nano-sized TiCp/Al-Cu composite was lower than that of 1–5 wt% micron-sized TiCp/Al-Cu composites. Nano-sized particles are more effective to increase the wear resistance than micro-sized particles.

Effect of the process parameters on the interfacial binding force and microstructure of Al/Cf
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In order to achieve a good interface bonding between copper cladding aluminum and carbon fiber, the main
The purpose of this paper is to study the effect of different temperatures (700 °C, 750 °C, 800 °C, 850 °C, and 900 °C) and shape of carbon fiber (bunch shape, rope shape) on the interfacial binding force and microstructure of Al/Cf (Aluminum/Carbon fiber). The results show that with the increase of temperature, Al/Cf binding force shows a trend of first increased and then decreased. When adopting the bunch of carbon fiber, the binding force of Al/Cf is rather low under the different temperature. The maximum binding force of Al/Cf is 29.63 N at 800 °C. Additionally, the interfacial microstructure of Al/Cf is nonporous, but without liquid Al inside the carbon fiber. When using the rope-like carbon fiber, the binding force of Al/Cf is significantly improved. The maximum binding force of Al/Cf is up to 134.25 N at 800 °C. A large number of liquid Al seep into carbon fiber, resulting in the high binding force of Al/Cf.

**Effect of Mg content of matrix alloy on the microstructure and properties of Sip/Al-Mg-Si composites prepared by pressure infiltration method**
Jiaoyan Liang  
Beijing Institute of Control Engineering

Si particles reinforced Al matrix composites (Sip/Al) have been widely used in the electronic packaging filed, and higher mechanical and thermo-physical properties are required for their application. In the present work, the effect of Mg content (from 0.21 to 16.65 wt.%) in the matrix alloy on the microstructure, mechanical and thermo-physical properties of Sip/Al-Mg-Si composites. Sip/Al-Mg-Si composites with 55 vol.% Si particles were prepared by pressure infiltration method. Sip/Al-Mg-Si composites reached the maximum bending strength (223.2MPa) with 1.68wt. % Mg, and further addition of mg element led to the decrease of the mechanical properties. Moreover, the thermal conductivity and the coefficient of thermal expansion of Sip/Al-Si-Mg composites were decreased with the increase of Mg content. The mechanism of Si content on the microstructure of performance of Sip/Al-Mg-Si composites has been discussed.

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**Effect of Si content of matrix alloy on the microstructure and properties of Sip/Al-Si-Mg composites prepared by pressure infiltration method**
Jing Sun¹, Xuwei Hou¹  
¹. Beijing Institute of Control Engineering  
². Beijing Oriental Institute of Measurement and Testing

Si particles reinforced Al matrix composites (Sip/Al) have been widely used in the electronic packaging filed, and higher mechanical and thermo-physical properties are required for their application. In the present work, the effect of Si content (from 0.28 to 6.95 wt.%) in the matrix alloy on the microstructure, mechanical and thermo-physical properties of Sip/Al-Si-Mg composites. Sip/Al-Si-Mg composites with 55 vol.% Si particles were prepared by pressure infiltration method. It has been found that the increment of Si content led to the improvement of relative density of composites. Moreover, the bending strength and thermal conductivity of Sip/Al-Si-Mg composites reached its maximum at Si content of 1.98 wt.%, which were 238.8 MPa and 159.5 W/(mK), respectively. Furthermore, the coefficient of thermal expansion of Sip/Al-Si-Mg composites was decreased with the increase of Si content. The mechanism of Si content on the microstructure of performance of Sip/Al-Si-Mg composites has been discussed.
**Enhanced Tensile Performances of Mg-6Zn-0.5Zr Alloy Reinforced by Graphene Nanoplatelets**

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Beijing University of Technology

Graphene nanoplatelets (GNPs) were thoroughly dispersed in solvent, uniformly mixed with magnesium particles, and hot-extruded as precursor to synthesis Mg-Zn-Zr (ZK60) alloy composites by a melt casting method in this study. Graphene, a two-dimensional material with one-carbon-atom thickness, has excellent elasticity values with advantage of dispersion than one-dimensional materials, which is good candidate as reinforcement for metal matrix. Here, GNPs/ZK60 composites exhibited enhanced tensile performances ascribed to the well dispersion and undamaged structure of GNPs in the magnesium alloy matrix. The microstructure characterization and mechanical behaviors of GNPs/ZK60 composites were examined by Optical Microscope (OM), X-ray Diffraction (XRD), Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM) and tensile tests at room temperature. The addition of 0.05 wt.% GNPs to ZK60 alloy resulted in ultimate tensile strength of 336 MPa and tensile yield strength of 293 MPa, with respectively 20% and 85% enhancements than those of extruded materials with no GNPs. The good dispersion and compatibility of GNPs in the matrix realized the effective mechanical enhancement of ZK60.

**Electromagnetic shielding effect of aluminum foam in 10~500KV electrical substations**

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With the ongoing attention drawn to the electrical substation electromagnetic environmental problem, the application of material with electromagnetic shielding effect gains more and more popularity. This work evaluated the electromagnetic shielding effect of 304L stainless steel, aluminum foam and their composite material in four electrical substations, a 10 KV Xifaxian single transformer, a 66 KV Niluo substation, a 220 KV Hexi substation and a 500 KV Keerqin substation. The results were compared with the environmental data. It shows that the power frequency electric field intensity near the transformer of 500 KV Keerqin substation is sightly higher than the national standard, whereas the power frequency electric field intensities and power frequency magnetic field intensities near the transformer and outside wall of other substations are lower than the national standard. The power frequency electric and magnetic field intensities were reduced with increasing measuring distance from enclosing wall for all substations. 304L stainless steel, aluminum foam and their composite material all have certain electromagnetic shielding effect, and aluminum foam’s shielding effect is significantly superior to that of the 304L stainless steels while their composite material has the best electromagnetic shielding effect.

**Fabrication and microstructure properties of SiC fiber reinforced Ti/Ti2AlNb laminated composites**

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SiC fiber reinforced Ti/Ti2AlNb laminated composites were fabricated through vacuum hot pressing technology based on foil-fibre-foil method using SiC fiber, Ti foil and Ti2AlNb foil. Microstructure of the composites were
observed by SEM and energy spectrum, and the process of preparation was optimized. Performance of the laminated composites were evaluated by high temperature tensile test combined with Archimedes drainage method. The results indicated that when the vacuum hot pressing parameters were 920°C/40MPa/30min, the composite material showed ideal interface state, SiC fibers distributed uniformly in the Ti matrix, and the interface reaction layer thickness was 0.8μm. The interface between Ti layer and Ti2AlNb layer was smooth and straight, which presented ideal laminated structure. The interfacial reaction product of SiC fiber and Ti matrix was TiC, which indicated the strengthening effect of SiC fiber was guaranteed by consuming carbon coating, and damage to SiC fiber was avoided. Elements around interface between Ti layer and Ti2AlNb distributed in gradient, which explained Ti and Ti2AlNb had great diffusion welding under the optimum hot pressing conditions. In addition, high temperature strength of SiC fiber reinforced Ti/Ti2AlNb laminated composites was 800MPa when the temperature was 600°C, and its density was4.0g/cm3. Compared with the laminated composites, high temperature specific strength was increased by 20% after added SiC fibers. Therefore, using SiC fiber reinforced Ti/Ti2AlNb laminated composites could meet the requirements of high temperature and light weight, which laid a theoretical and technological foundation for its application on the components such like high thrust-weight ratio aeroengine compressor and hypersonic vehicle high temperature skin.

The interfacial peel strength and microstructure of titanium/aluminium foil manufactured by ultrasonic consolidation process
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An experimental investigation was performed on the ultrasonic consolidation of bi-metallic foil materials, 1100 aluminium and TA1 titanium. The layer-metal composite laminate specimens were prepared using the ultrasonic consolidated Ti/Al foil, which were used to investigate effects of amplitude and static force on the interface bonding strength of Ti/Al foil by peel test. In addition, the microstructure morphology observation and energy spectrum analysis of the peeled interfaces were performed using SEM and EDS respectively. The results have shown that a good bonding interface of Ti/Al foil can be obtained using the ultrasonic consolidation technique. The interface bonding strength increased first then decreased with increasing the static force, while increasing monotonically with increasing the amplitude. The optimum ultrasonic consolidated interface with a peeling strength 11.325 N/mm can be obtained using an amplitude 35 um and static force 2.0 kN. A uniform distribution of Al element can be found in the peeled interface of Ti foil accompanying with the obvious nest microstructure, which further certificated the good interface quality using ultrasonic consolidation process.

Effect of WC and Co on the microstructure and properties of TiC steel-bonded carbide
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TiC base high manganese steel-bonded carbide was manufactured by conventional powder metallurgy method to service in wear and impact resistant condition. WC phase was added in the alloy in the form of (Ti, W) C
compound carbides to strengthen the impact toughness and expand its application, meanwhile cobalt powder was used to enhance the wettability of the binder on hard phase. Results showed that the impact toughness of the alloy was increased remarkably with the increase of WC content. The impact toughness could reach 9.6 J/cm² when the WC content was 12.5%, while the hardness of the alloy decreased slightly. It indicates that appropriate content of WC and cobalt can improve impact toughness of the alloy greatly with little increase of the production cost.

Residual stress measurement and its effect on the interface shear strength in SiCf/Ti-17 composites
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After fabrication under high temperature, the residual stress will exit in the SiCf/Ti composites (TMCs) due to the mismatch of CTEs (coefficients of thermal expansion) between reinforcement SiC fiber and matrix titanium alloy. The residual stress will affect the mechanical properties of the composites through changing the stress state of reinforcement and matrix as well as the interface shear strength. Therefore, the research on the residual stress and its effect on the interface shear stress will conduct the design, fabrication and application of TMCs. In this paper, the composites with fiber volume fraction of 50% was fabricated by Hot Isostatic Pressing (HIP) and then was heat treated respectively at 550 °C for 3 hours and 100 hours under vacuum. Residual stress in the samples under three states was tested by X-ray diffraction (XRD) method and then the interface shear strength of the three samples was tested through push-out experiment at room temperature. The results showed that residual stress in TMCs under HIP was about 1000 MPa. Heat treatment 550 °C/3h did not affect the residual stress while 550 °C/100h could reduce residual stress, and the interface shear strength decreased as the residual stress reduced.

Research on fabrication and interfacial behavior of SiCf/Ti2AlNb hybrid matrix composites
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SiC fiber reinforced Ti-Ti2AlNb matrix composites were fabricated through the method of magnetron sputtering physical vapor deposition (MS-PVD) during which the target materials were Ti and Ti2AlNb, followed by hot isostatic pressing (HIP) technology. Microstructure of the composites were observed by SEM and energy spectrum, residual stress distribution was analyzed through Abaqus finite element method, and interface reaction mechanism between fiber and matrix was explored using the Boltzmann method. The results indicated that when the parameters of HIP were 920°C/150MPa/2h, SiC fibers uniformly distributed in the composites and its volume percentage reached 50% which made sure the SiC fibers had strengthening effects. Ti matrix consisted of alpha-Ti and beta-Ti, and the Ti2AlNb matrix was mainly composed of B2 phase and O phase. Compared with single Ti2AlNb matrix, the hybrid Ti-Ti2AlNb matrix showed great performance, the reason was that residual stress in matrix and fiber was significantly reduced in the hybrid matrix composites owing to the coordinating role of Ti. Kinetic analysis of interface reaction between fiber and matrix showed that the interfacial reaction activation energy was 198.243 kJ/mol. It was closed to the titanium element diffusion activation energy, 193.61 kJ/mol, obtained through the Boltzmann method. This showed that interface reaction of SiC matrix was controlled by the diffusion of titanium element. Based on these experiments, the preparing conditions and interfacial behavior of SiC fiber reinforced Ti-Ti2AlNb matrix composites were studied, which could provide data support for its
application on high thrust-weight ratio aeroengine vane-integrated ring component.

**Effect of sintering time on the microstructure of SiC fiber reinforced titanium alloy composites prepared using spark plasma sintering (SPS) technology**

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Ti Matrix composites are regarded as a kind of candidate materials for aero-engine due to their high specific strength, specific stiffness, and high temperature tolerance. Spark plasma sintering (SPS) technology, known as its low sintering temperature and short sintering time, has drawn much attention in materials consolidation field. The processing of four SiC fiber reinforced titanium alloy composites (SiCf/Ti) with varying sintering time of 5-20 min at 800 °C was prepared using the SPS technology. The microstructure, morphology, chemical composition distribution, residual stress, hardness and the interfacial bonding strength of each sample were characterized with the help of Scan Electron Microscopy (SEM), Energy Diffraction Spectrum (EDS), X-ray diffraction, atomic force microscope, surface profiler, nanoindenter, and Push-Out test. The results show that an interface reaction layer with typical tooth shape formed in the samples. Moreover, the increasing sintering time led to an increase in the densification degree and the thickness of interfacial reaction layer, and then improve the interfacial bonding strength; however, the residual stress increased slightly. In conclusion, the SiCf/Ti composites can be fabricated at 800 °C with the sintering time of 5~10 min by SPS technology, which is beneficial to control the interface reaction to obtain excellent performance.

The Production of Ni-W-P/grapheme Composite Coating and Research on its Structure and Performance

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It produced Ni-W-P/grapheme composite coating in the mixed plating solution of Ni-W-P and graphene oxide by adopting the ultrasonic agitation– composite electrodeposition technology. The article discussed the influences of ways of agitating on the surface quality of composite coating and figured out the optimal technical parameters to produce Ni-W-P/grapheme composite coating on the basis of orthogonal experiment. It also made a study on the representation of the graphene in the coating and analyzed the morphology, structure, and composition of the coating with the help of various technologies including scanning electron microscope (SEM), energy dispersive spectrometer (EDS), X ray diffractometer (XRD), raman spectrometer (Raman) and differential thermal analyzer (DTA). Based on various experiments such as microhardness, frictional wear, AC impedance spectroscopy and potentiodynamic polarization curve, the author made a analysis on the performance of the coating.

The experiments show that the coating has compact amorphous structures with curly grapheme inside; the content for Ni, W, P and grapheme is 80.03 %, 3.72 %, 11.7 % and 4.55 % respectively; The hardness of Ni-W-P/grapheme composite coating is a little higher than Ni-W-P composite coating. After heating treatment with temperature of 600 °C, compared with Ni-W-P composite coating, the hardness of Ni-W-P/grapheme composite coating is increased by 27 %, the friction coefficient is reduced slightly with wear rate dropped by 78 % while the corrosion resistance performance is basically maintained.

The experiments produced anticorrosive and abrasion resistant Ni-W-P/grapheme composite coating.
Preparation of AlB12-type Al-B alloys
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AlB12 has wide application prospects in the grinding industry and weapon equipment composite armor field due to the advantages of high melting point, low density, high hardness and good wear resistance. In addition, the mass fraction of boron in AlB12 is about 82.8%, the highest in all borides, making it a good neutron material. In industry, AlB12 powder is generally produced by pickling of the AlB12-type Al-B alloys. The acid pickling has an effect of removing the aluminum matrix in the alloys, and thus AlB12 powder can be obtained after drying. The produced AlB12 powders are from the AlB12 particles distributed in the AlB12-type Al-B alloys used. Thus, during the preparation of the AlB12-type Al-B alloys, it is of great significance to control the size and morphology of the AlB12 particles in the alloys.

For the sake of economy and practicality, commercial Al-B alloys are produced via chemical reactions of KBF4 with molten aluminum. The formed aluminum borides are mainly AlB2 in the reaction temperature range of 700~850°C, so the produced Al-B alloy melts are AlB2-type. According to the Al-B phase diagram, a peritectic reaction, L+AlB12 → AlB2, takes place at 975°C. AlB12 is a high temperature phase. At a temperature higher than 975°C, AlB2 will transform into AlB12. This means that AlB12-type Al-B alloys can be prepared by high temperature treatment of the produced AlB2-type Al-B alloy melts.

In this work, AlB12-type Al-B alloys have been prepared by high temperature treatment of different AlB2-type Al-B alloy melts. The AlB2-type Al-B alloy melts were produced by mixing KBF4 into molten aluminum. Two mixing techniques, named the “immersion” method and the “vortex” method, were adopted in the production. For the “immersion” method, KBF4 was immersed into molten aluminum in packets, after each immersion manual stirring or mechanical stirring was conducted. For the “vortex” method, KBF4 was sucked into molten aluminum through a vortex created by mechanical stirring using a graphite impeller with inclined grooves. After taking samples using a graphite ladle the produced AlB2-type Al-B alloy melts were heated to 1100°C for high temperature treatment. During the high temperature treatment, the alloy melts were manually stirred at a slow speed (~50 r/min) or a rapid speed (~200 r/min). The raw materials used include commercial purity aluminum (99.7 wt.%) ingots and high purity KBF4 (>99.0 wt.%) powders of 200~400 μm in diameter. Experiments were conducted using a medium-frequency induction furnace (2000 HZ). Microstructure analysis was carried out by optical microscopy (OM) and scanning electron microscopy (SEM). Phase identification was done with energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD). Quantitative analysis of the boride particles was performed using the Micro-image Analysis & Process image analysis software.

The results show that, when using the “immersion” method, the produced AlB2-type Al-B alloy melts contain a small amount of AlB12 phase and many boride agglomerations. Some sizable boride agglomerations can be observed when slow manual stirring was carried out after each immersion, while no large agglomerations can be found when vigorous mechanical stirring was exerted, which means that the vigorous stirring can effectively break up the large boride agglomerations. The AlB2-type Al-B alloy melt produced by using the “vortex” method contains no AlB12 phase and exhibits a well dispersion of AlB2 particles. BF3 gas emission can be effectively prohibited by mixing KBF4 salt into molten aluminum during the production of AlB2-type Al-B alloy melts, and thus relative high boron recoveries can be obtained. For the AlB2-type Al-B alloy melt in which the boride
particles are severely segregated and some sizable boride agglomerations exist, when slow stirring is adopted during the high temperature treatment, the produced AlB12-type Al-B alloy has a microstructure characterized by severely segregated AlB12 particles. For the AlB2-type Al-B alloy melts in which the boride particles are mainly in the form of small agglomerations or dispersed particles, the AlB12 phase in the produced AlB12-type Al-B alloys is in the form of dispersed near-spherical particles, no matter what kind of stirring is used during the high temperature treatment. The large AlB12 particles form due to the coalescence of the AlB2 particles in close contact with each other in boride agglomerations. The high-speed stirring adopted during the high temperature treatment has an effect of prohibiting the coalescence of AlB2 particles in boride agglomerations, and thus the size and size distribution range of AlB12 particles in the produced AlB12-type Al-B alloys can be effectively reduced. The high-speed stirring adopted during the high temperature treatment could also effectively prohibit the formation of AlB12 agglomerations, thereby improving the dispersion of AlB12 particles in the produced AlB12-type Al-B alloys.

Preparation of laminate structure graphite films/Al composites and thermal physical properties by pressure infiltration method
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Laminate structure consisting of graphite films reinforced aluminum has been fabricated to improve the interfacial properties between the carbon materials and aluminum matrix materials by pressure infiltration method. The characterization, thermal conductivity (TC) and thermal expansion coefficient (TEC) of graphite films/Al composites were investigated. The graphite films/Al composites prepared from 50 vol. % graphite films has a high TC as high as 743 W/(m·k) in the plane to the graphite films, and with a low TEC (22.4×10-6 K-1~24.3 ×10-6 K-1). Microstructural analysis demonstrates that the graphite films and aluminum matrix distribute uniformly, no visible pores. Meanwhile X-ray photoelectron spectroscopy was used to monitor the composition of the composites. Scanning electron microscopy images revealed that graphite film/aluminum hierarchical composite was achieved and no interface products (Al4C3, etc) were generated, which is contributed to the excellent TC and TEC of graphite films/Al composites.

Grain size and adhesion strength of the V8C7 coatings produced in situ
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The vanadium carbide coating was fabricated by in situ reaction which used gray cast iron and vanadium plate as raw materials providing carbon and vanadium sources. The microstructure, phases, and adhesion strength of V8C7 coating / substrate were studied by scanning electron microscope (SEM), X-ray diffraction (XRD) and a single scratch test under 0 ~ 100 N. The XRD results show that the coating consists of α-Fe phases and V8C7 phase which the peaks of (222), (400), (440), (622) and (444) are confirmed. Moreover, the average diameter (D) of the V8C7 grain crystals with the range of 432~582 nm is calculated on the basis of Scherrer and Halder-Wagner equations. The acoustic emission signals are observed at 98.3 N where the V8C7 coating occur the large area of spalling, which indicates the critical load of interface between V8C7 and substrate is 98.3 N. High critical load implies that the interface of V8C7 coating / substrate has excellent adhesion strength.
Research Progress on Preparation, Microstructure and Mechanical Property of Graphene Reinforced Aluminum Matrix Composite
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Graphene materials with unique two-dimensional structure and excellent mechanical properties has been an ideal reinforcement. With the increasingly mature of aluminum matrix composites preparation, being structural materials, graphene reinforced aluminum matrix composites have attracted many interests. This paper mainly reviews the latest research progress on preparation of graphene reinforced aluminum matrix composites, and especially discusses the effective dispersion technique of graphene, meanwhile, the microstructure and interfacial structure of graphene reinforced aluminum matrix composites were also emphasized and discussed. Studies show that graphene can significantly improve the mechanical properties of composites and refine matrix grain. By controlling preparation parameters, the problem of graphene agglomeration can be effectively solved, and adverse reaction between graphene and substrate interface can be avoided. Finally, the current challenges and solutions of graphene reinforced aluminum matrix composites were presented.

Effect of TaC content on microstructure and properties of Ti (C, N)-based cermets
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Effects of TaC on the microstructure and mechanical properties of Ti(C, N)-based cermets were studied. The microstructure was investigated by means of optical microscopy and scanning electron microscopy in combination with energy dispersive spectrometry. Mechanical properties, such as transverse rupture strength, hardness and fracture toughness, were measured. The microstructures of TiCN-based cermets are composed of black core-grey ring and black core-white ring–grey ring surrounding structures with Ti(C, N) black phase, (Ti, Mo, Ta, W) (C, N) grey phase and (Ti, Mo, Ta, W)C-Co-Ni white phase. With increasing TaC contents, the black core becomes finer and the amount of solid solution phase (Ti, Ta, W) (C, N) and black core-white ring–grey ring structures increase, and the bending strength of TiCN-based cermets increases and hardness decreases slightly. The optimum addition of TaC is 10 %, with the bending strength and Vickers hardness of the cermets being 1900 MPa and 1450, respectively.

Study on Mechanical Properties and Damping Capacity of AlN Particle Reinforced Magnesium-Aluminium Matrix Composites
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The AlN particle reinforced magnesium-aluminum matrix composites were prepared by powder metallurgy. The mechanical properties and damping capacity of the matrix alloy and composites were investigated through electronic universal testing machine and dynamic mechanical thermal analysis. The results show that the best mechanical properties of composite are reached with the addition of 6wt% AlN reinforcement. The compressive strength and bending strength of composites are 217.06 and 207.4MPa, respectively, which increased by 79.2 % and 91.12 % compared with matrix alloy. The damping capacity of the AlN particle reinforced magnesium matrix composites is better than that of the alloy at room temperature. Meanwhile, the damping capacity of composites decreases with the increasing content of reinforcement. The internal friction peaks related to dislocation appear at 100°C-150°C. There is also an internal friction peak of magnesium matrix composite reinforced by AlN particles at the temperature of 200°C-250°C, which is related to interface sliding.

Fracture toughness of tungsten carbide reinforced Fe-matrix surface composites by indentation
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In this article, WC-reinforced Fe-matrix surface composites were prepared by in situ synthesis between tungsten plate and graphite phases in grey cast iron. The microstructure, fracture toughness, and fracture characteristics of the WC layer were investigated by scanning electron microscope (SEM), X-ray diffraction (XRD) and the Vickers indentation technique. The results revealed that, the specimen was subjected to heat treatment at 1125°C for 135min in argon atmosphere and the main phases were WC and a bit of α-Fe. The fracture toughness(KIC) of the WC layer was 5.21MPa·m1/2, which was calculated by Niihara equation. A close examination of the indentation fracture characteristics of the WC layer showed that cracks propagated along the grain boundary under 2 kg load. Moreover, both WC particles and the interface of the WC layer and the matrix had a strong bonding strength.

Evolution of Bonding Interface in Solid-liquid Cast-rolling Bonding(SLCRB) of Ti/Al Composite Strip
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Ti/Al composite strip has good stability, heat insulation, sound insulation and excellent heat-resistant performance, which is mainly used as coating material for special parts of the aircraft. However, the productivity of explosive welding process is low and the cost is high, which limits the application of Ti/Al composite strip in the automotive, cookware and special solder field. In this study, Ti/Al composite strips with a total thickness of 2 mm, and 0.3mm cladding titanium, were fabricated in a solid-liquid cast-rolling bonding (SLCRB) process on a 160×150mm twin-roll experimental caster. The microstructures, composition of the interface reaction products and their evolution of bonding interface in the SLCRB process were investigated by scanning electron microscope (SEM), energy dispersive spectrometer (EDS) and X-ray diffraction (XRD). It indicates that, at the beginning of the roll casting process, diffusion reaction occurs at the interface of the liquid aluminum and the titanium strip, whose composition is mainly brittle TiAl3 phase. Below the Al kiss point, the brittle diffusion layer is torn due to severe elongation of the substrate, which leads to virgin aluminum crushed into the cracks and forming a mechanical combination mechanism. The result of peeling test shows that the fracture happens in the aluminum substrate and a number of dimple patterns form. Neither crack nor separation was found in the bonding interface after 90°-180° bending. Therefore, the SLCRB process meets the requirement of further composite plate processing.
Fabrication and formation process of diffusion bonding joint of aluminium foam sandwiches enhanced by TA2 sheets
Yukun An, Siyi Yang, Ertuan Zhao, Xu Huang
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Aluminum foam sandwiches (AFSs) served as sheet materials have enormous marketing potential for their interesting combinations of excellent properties, such as low density, high specific strength, energy absorption and thermal insulation. In this paper, transient liquid phase (TLP) bonding method is introduced to prepare AFSs by assembling TA2 sheets to the semi-liquid foams. AFSs enhanced by TA2 sheets with the dimension of 80×80×18 mm have been prepared, which present uniform foam core and good metallurgical bonding joint. Results show continuous cotton-shaped composite oxide layer adhering on TA2 sheet transforms into discontinuous layer and disappears in bonding joint view with the holding time increasing. The thickness of bonding interface increased also with the increasing holding time. Metallic compounds such as Ti3Al, Ti2Al and Al20CaTi2 constitute the bonding joint.

Synthetic, microstructure and mechanical properties investigation of boride layer by molten-salt boronizing on titanium surfaces
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In order to modify the properties of pure titanium surfaces, boride layers had been fabricated by molten-salt diffusion of boron on pure titanium surfaces in the 900-1100℃ temperature range. The phase and analysis shows that the boride layers are mainly composed of whiskers TiB and thin and continuous TiB2 phase. The growth kinetics of boride layer had been studied, and the results revealed that the thickness of boride layer and the time can be fitted in the equation: \( X^2 = Kt \). Microhardness and wear resistance test indicated that the microhardness and wear resistance had been improved significantly compare to the pure titanium. The friction and wear mechanism of boride layer were micro-cuts wear and adhesive wear.

The process research of carbon fiber coated silica
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Carbon fiber is a kind of material with high strength and high modulus, but the infiltration property of carbon fiber is poor, and the strength of the two phase interface is weak. On the carbon fiber surface coated silica can combine well with matrix metal, and can occur chemical reaction to produce a chemically stable conjugates of medium substance, with the metal aluminum react and at the interface to generate strong conjugates, also can be firmly attached to the surface of carbon fiber, silica good assume the role of "media". In this paper, the sol-gel technique is used to cover the silica on the surface of carbon fiber. First of all, the carbonfiber pretreatment, which involves three steps, respectively: 1) high temperature oxidation (in addition to plastic); 2) surface coarsening (with nitric acid corrosion) ; 3) activation. (4) the pretreated carbon fibers are put into the sol, and the ultrasonic wave is used to vibrate and stir, and then the silica is coated onto the carbon fiber surface. In this paper, we discussed on the surface of the carbon fiber coated silica technology, and analyzed the various process parameters about the cladding process. Using scanning electron microscope to the sample surface with observed compared, then the optimum process parameters is obtained.
Effects of internal oxidation methods on microstructures and properties of Al2O3 dispersion strengthened copper alloys
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With CuAl alloy powder as raw material and Cu2O powder as oxidant, two internal oxidation methods, namely step-by-step internal oxidation-reduction method (referred to as the step-by-step method) and integrated internal oxidation-reduction method (referred to as the integrated method), were respectively adopted to achieve the oxidation of Al. Then hot extrusion without canning was respectively applied to prepare Al2O3 dispersion strengthened copper alloys. The effects of internal oxidation methods on microstructures and properties of the alloys were compared. The results show that both the step-by-step method and the integrated method can achieve the complete oxidation of Al. However, the excessive oxidant can not be reduced thoroughly in the integrated method. The residual oxidant increases oxidation degree of the sintered body during hot extrusion and the formed oxides of copper distribute in the grain boundaries as well as in the grains. While in the integrated alloy, the oxides of copper mainly distribute in the grain boundaries. The step-by-step method improves the alloy electrical conductivity and ductility, but lowers the hardness and strength. The ductility of the alloy prepared through the integrated method is worse, but the hardness and strength are higher. The alloy with 0.34wt% Al2O3 content prepared through the step-by-step method has the best comprehensive properties, and its electrical conductivity, hardness, tensile strength, yield strength and elongation is 87.0%IACS, HRB70, 425MPa, 394MPa and 27.2%, respectively, which are comparable to those of C15725.

Microstructures and properties of Al2O3 dispersion strengthened copper alloys prepared through different methods
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Al2O3 dispersion copper alloy powder was prepared by internal oxidation, and three consolidation methods, i.e. high-velocity compaction (HVC), hot pressing (HP) and hot extrusion (HE), were adopted to prepare Al2O3 dispersion strengthened copper (Cu-Al2O3) alloys. The microstructures and properties of these alloys were investigated and compared. The results show that the alloys prepared by HP and HE method have the coarsest and finest grain size, respectively; the alloy prepared by HVC method has the lowest relative density (98.3% vs 99.5% for HP and 100% for HE), which causes the lowest electrical conductivity (81 vs 86 for HP and 87 %IACS for HE). However, this alloy has the highest hardness (77 vs 69 for HP and 70 HRB for HE), the highest compressive strength (443 vs 386 for HP and 378 MPa for HE) and the best hardness retention. The results illustrate that the alloy prepared by HVC method has a high softening temperature and a good mechanical property at high temperature, which implies a long service life when used as spot-welding electrodes.

Effects of aging temperatures on the microstructure and high temperature tensile properties of TiBw reinforced Ti60 composites
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The TiBw reinforced Ti60 composites were successfully synthesized by powder metallurgy and hot extrusion route. The effects of aging temperatures on the microstructure and high temperature tensile properties of the composites have been investigated. The results of microstructure evolution reveal that, after one step aging treatment, mounts of the S2 silicide are precipitated from the residual β phase at the interface between α phase and β phase. While after solution followed by aging treatment, S2 silicide is precipitated in the inside of both αp and transformed β phase. The α2 phase mainly precipitated from α phase in the composites after solution and aging treatment. With increasing the aging temperature from 600 °C to 750 °C, the size of α2 phase increased from 5nm to 20nm. The TiBw are stable without any interfacial reaction during the heat treatments. The results of 600 °C tensile properties show that the composites performed by solution and aging treatment exhibit well strengthen effects. With increasing the aging temperature from 600 °C to 750 °C, the strength of the composite increased and the elongation of that deceased due to the increment of α2 phase. The strength of 600 °C of the composites can be increased to 980 MPa after 1000°C/2hrs/WQ and 700 °C/5hrs/AC heat treatment.

Microstructures, solid solution formation and high-temperature mechanical properties of ZrB2 ceramics doped with 5 vol.% WC
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ZrB2 (ZB) and ZrB2-5 vol.% WC (ZW) were prepared by hot-pressing at 2100C. Combining experimental and theoretical methods, the tungsten (W) element in solid solution with ZrB2 and ZrC was investigated. Experimentally, solid solution formation in ZW samples was supported by XRD and EDS. Theoretically, atomic scale computer simulations based on density functional calculations were used to interpret the different amount of solid solution and the changes in lattice parameters. The flexural strength of the samples was measured from room temperature to 1600C. This attributed to the clean boundary, interface morphology and grain boundary atoms arrangement.