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Non-continuous particle-reinforced titanium matrix composites

Preparation Technology and research progress*

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Abstract: particle reinforced chin matrix composites is an important lightweight structure - Functional Integration Material . in aerospace , space technology , Weapon equipment , can source and environmental situation increasingly grim today , This lightweight , High-strength , heat-resistant particulate reinforced Chin matrix composites are aerospace technology , Energy Development and transportation Irreplaceable key materials in several key areas, such as . from composite material preparation technology , Matrix and enhanced body selection , Enhanced body distribution design , configuration Design , hot deformation , superplastic processing , Heat Treatment ,Micro-organization , mechanical properties and engineering applications A review of the development of particle reinforced chin matrix composites , presents problems in research and potential future research directions , For the further promotion and solution of major engineering composite material components processing , Precision to Manufacturing key technologies and equipment guidance , to Promote further development of non-continuous particle reinforced chin matrix composites .

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with our aviation , The launch of the aerospace business show , to air , requirements for aerospace structural materials more prominently focused on lightweight , High strength , Gao Wei and high stiffness , to accommodate this development trend potential , as high-performance Lightweight titanium alloy and its complex materials ,become national major new material research One development direction [1-3]. High intensity , High toughness , high modulus titanium matrix composites first The important research direction of the development of the material into the structure one '[%]. to enter a • step to broaden the strength , High- modulus junction binding Service temperature range , The appears with the "" " add stable enhancer to increase intensity and High modulus report [3-4].

This particle reinforced titanium matrix composites (TMCs) is composed of one or more ceramic particles with the different metal matrix composites , The has Many good features , Its high temperature strength , creep anti- Force , ratio stiffness , impact resistance , Fatigue Performance All improves performance over single material , applicable to navigation space Spaceflight Extremely harsh working conditions , are considered is a way to break through the existing High-temperature titanium alloy hot Strong

New generation of aviation , Aerospace Materials [1-4] .

currently restricts China's advanced particle reinforced titanium Basic Composite application and development bottleneck problem is in the reinforcement control and processing science lack scientific guidance [1,

5-10] :(1) composite Preparation tedious , and inefficient metal complex High material cost ; (2) metal matrix

compositesCompound preparation difficult ; (3) metal matrix composites 's microstructure is associated with macro performance , table Sign difficult ; (4) subsequent processing in superplastic forming means research is weaker ; (5) lacks about multivariate multi-scale titanium Matrix Composites Base Foundation Research , so it is difficult to clarify thecoupling response mechanism for a multiple-field effect , Complex microscopic organization Evolution Law ,, inheritance effect on composites Effect mechanism of the law ;(6) is low in plasticity and Low toughness results in lower composite reliability . so , This paper is mainly from the composite material preparation technology , Matrix and enhancer selection , Enhanced body distribution Design , configuration design , hot deformation machining , super-plastic machining , Heat Treatment , Micro Organization ,mechanical properties to

and engineering applications Brief introduction to particle reinforced Titanium base The development of composite materials , and propose future can Research Focus .

Preparation technology

enhanced for discontinuous particles for many years after research on Titanium Matrix composites , Research scholar keep up to sum up experience , at lower cost of processing can further enhance the composite mechanics of the material can , Its main preparation methods are additive method and in-situ self -code. Traditional Plus-* technology enhancements body about a few microns , Dozens of microns or even no m-level [4], and the preparation technology still needs to resolve enhancements body design , infiltration , and enhanced with matrix metal boundaries face compatibility , process complex and expensive etc key issues , gradually unused . Current use in- situ production of particulate reinforced titanium matrix composites becomes the main direction of research , Main preparation Technology have : smelting method , Powder Metallurgy [11-12] , Mechanical alloying method [+], Self-propagating high-temperature synthesis [/], exothermic diffusion Method [a] , Rapid Solidification [16-17] , excitationLight cladding [18-19] and a variety of other in-place native technology [2 °-]. can be divided into solid - solid reaction , solid - Liquid reaction and gas - solid reaction [7] . where solid - - liquid reaction and solid - solid reaction is mesh The most applied method before . solid - liquid reaction includes rapid solidification technology , Casting and Laser Quick Melt Method, etc. . solid - solid reaction includes Reactive hot-Pressing method , discharge plasma sintering , machine mechanical alloying method , and Self-propagating high-temperature synthesis [7] .

where , using powder metallurgy to prepare in situ self-particles reinforced titanium matrix composites are more Universal Methods , But some disadvantages : such asprocess complex , high cost and more device requirements high . in preparing aviation , Aerospace Large widget or enter Insufficient in the row mass production . but currently Domestic and foreign research units such as City University of Hong Kong , US State University of California South Central College , Harbin Industry University ,Beijing nonferrous Metals Research Institute , CAs Metals have been used in powder metallurgy combined with heat Processing successful preparation of a large number of particles reinforced titanium base complex Combined materials , synthesizing in an enhanced body , Microscopic organization of and performance testing have yielded a large number of Research results the [6-7].

non-continuous increase by smelting casting method strong particle reinforced Titanium matrix composites , with This low , simple easy , the advantages of being able to prepare large complex Structural parts are .. The is mainly in the casting process to cause the appropriate reactants , reactants and substrates The thermodynamic in- Place reaction of the alloys, can generate Required in-situ autogenous particle enhancer , as TiB ,TiC wait . at the same time , because enhancer is original bit synthetic , avoids enhancer and matrix alloy interface wetting problems between , hot-working can Improve enhanced distribution uniformity , so significant increasing particle reinforced titanium matrix composites mechanical Properties . currently Shanghai Jiaotong University [1,5] etc research institutions mainly through this process non- The preparation of continuous titanium matrix composites , for The composite exhibits excellent comprehensive performance .

Particle reinforced composites

can be designed

1. enhanced body and matrix design

particulate reinforced titanium matrix composites (TMCs) is a unit or multivariate , multiphase structure material , main by ceramic intensifier and metal matrix materialcomposition , You can select a different according to your design requirements reinforced materials and metal material , by changing its content , Distribute features , to achieve different In-situ preparation of various composite materials with energy , Preparation of particulate reinforced Titanium matrix composites [] for greater degrees of freedom [1, 5-7] . Recent decades come , Researchers have used different methods to prepare all kinds of particle reinforced titanium matrix composites , includes cell enhancements and multiple hybrid enhancements , and due to ceramic particles TiC and TiB with titanium alloy matrix binding Stable , thermodynamic match high , is widely used as particulate reinforced Titanium matrix composites Enhancements [1, 5-6,18].

(1) Matrix Design selection . based on research reports on , particle reinforced Titanium matrix composites pass always show high strength , Low density , high heat resistance and other good features , The main reason for the matrix titanium combination Gold's good performance is inseparable , sometimes metal base selection of body material directly determines in-situ composite Comprehensive performance of composite materials [1,5-6]. based on group to, Matrix Titanium can be divided into :a type ,near a type , (a + P) type , near P and P Titanium Golden [[]]. type and near a type titanium alloy low , with high ductility , high toughness and good High temperature performance , (a + P) type Titanium alloy has a more High high temperature tensile strength and tensile plasticity at ambient temperature , better room temperature low cycle fatigue strength , Comprehensive performance excellent , P The type titanium alloy has a high room temperature intensity , But poor thermal stability , Brittle Large ,cannot use at high temperatures . also , when in titanium alloy plus a large number of form intermetallic compounds type titanium , as : a_2 Alloy (T ^ Al type), Y Alloy (TiAltype) and O Consistency Gold (Ti_2 alnb type) , This type of alloy has a high ratio Strength , high heat resistance and good creep resistance and anti-oxidation performance ,strength up to 1300MPa, Use temperature up to 700°C above , but its room temperature plastic low , forming difficult [a]. when designing TMCs matrix material , should be based on the TMCs matrix Material The purpose and performance requirements for the use of are considered in combination with .

a Type Pure titanium plastic is good , to get a with high elastic modulus titanium matrix composites , can make it the base system with high content titanium matrix composites [8] . (a + + P) type titanium Gold Comprehensive Mechanics , in particular TC 4 Alloy , is The most widely used titanium alloy , Use it to prepare titanium Base Composite can achieve excellent combination Learning Performance . if pure for higher room temperature , to design P type Titanium alloy for to Matrix , as TB8,TB19, TBetc [24] . P type titanium alloy heat treatment Hardening , Through the powder End Metallurgical method or casting method for preparing titanium base compound Material ,With the appropriate heat treatment to obtain a super high-strength titanium matrix composites . but because of its hot stability difference , uses low temperature . for airmail The motivation for structural materials requires high temperature mechanical properties and usage temperature , Select some near a type Titanium alloy , such as China Ti 60, Ti 600, US Ti 1100, UK IMI 834, Russia BTetc [a] , to prepare the titanium base complex with its base system The composite material is expected to further improve the usage temperature and its High Temperature performance . addition , for intermetallic combination ti-titanium , KAl , Ti_2 ALNB To fit Gold use temperature up to 700~850C , on air The engine has good application foreground [26-27].

(2) Enhancer Design Selection . TMCs products Material Enhancements In addition to high strength , high Hard

outside , The also has a good with the titanium alloy matrix physical and chemical compatibility . The lack of compatibility for causes the to cause a bad combination or an enhanced distribution of inconsistencies, Direct Connect to lower material performance . simultaneous composite material to to improve its heat resistance , the Enhancer and the substrate cause differences cause high residual stress , so , Reducing thermal residual stress caused by physical differences is one of the key considerations ; plus ,also should avoid high temperature prompting interface reaction , Live into intermetallic compounds or other compounds , Damage Material final performance [28-29] .

through long-term research by researchers , is currently the ideal enhancements are TiB, TiB2 , TiC . where TiB,TiC Thermal expansion factor vs Ti , (9.41~10.03)XL 0^{-6}/ K) = bad on 50% The following , can effectively reduce

the compound The thermal residual stress that is generated when the material is prepared . and TiB: will be generated with Tibase in situ reaction TiB , and the elastic modulus of such enhancements is Ti Matrix 4~5 times , Can obviously improve the mechanical properties of titanium '

In recent years , Shanghai Jiaotong University Luvy , etc [30-32] in Titanium matrix composites soil elements , generate rare earth oxides , like La2 0 3 , Nd2 0 3 , Y2o3 , and so on , can not only play a diffuse Hardening Effect , and can be effective with matrix oxygen elements combine to purify the matrix , thereby significantly increase the high temperature of titanium matrix composites Strength and persistent strength [33-35]. through design + strong combination , such as (TiB_w * + TiC_p) blending + strong , (TiB_w+La) 2 0 3), (TiB_W +TiC_p+ La 2 0 3) etc , play an enhanced body synergy , like (TIBW + TiC_p) symbiotic effect [+], Rare earth oxidation objects Diffuse hardening and TIBW ,TiC_p The Synergy enhancement effect [37-40] , adjusts different enhancement volume fractions compared to , get comprehensive performance to meet different needs .

2. The distribution design of the enhanced body

century years ago , of the enhancer Uniform distribution is often used by materials scientists in the preparation of Titanium base complex materials pursued by , But with metal base Composite Development , More research results Table Clear , and The enhanced uniform distribution increases the fit material Strength , But the plastic toughness also drops more than more , Results in poor comprehensive mechanical properties of the material .

Mining Composite properties for deep people potential , Improving composite strength and plasticity in conjunction with , Many scholars at home and abroad through regulatory increase strong ^ Non-uniform distribution of this micro-space preparation of metal bases composite , where due to aluminum (Al) from 20 World last applied extensively , The most studied person , The enhanced rod Enrichment is produced successively [a], net for each other [42-43] , Discrete Enrichment [44-46] of the distributionaluminum matrix composites . plus , on MG base , Titanium base , Copper base , iron-based Composites , In addition to preparing the vs. aluminum matrix composite reinforced body similar to distribution outside [47-50], also successfully prepared enhanced body ring Enrichment reinforced magnesium matrix composites [a] , three -D continuous mesh reinforced Titanium matrix composites [?] , Dual-connect Al 2 0 3- TiAl Composites [%] . vs . Traditional reinforced homogeneous metal matrix compositesmaterial compared to , This control enhances space is not all uniformly distributed metallic matrix composites with better comprehensive mechanical properties .

Enhanced body non-uniform Distribution form main package Around diagram 1[a] show 4 class : Enhanced Body Bureau Department Rich , Rich area evenly distributed in depleted area Department , Enhanced dilution area is interconnected , Increase strong body enrichment mutually isolated (Chart 1 (a)); Add strong body enrichment is banded distribution , in one-dimensional or two-dimensional form connect (| 1 (b)); Enhanced body to three-dimensional mesh distribution , on three-dimensional mutualconnect , (enhanced body dilution isolated from each other) (diagram 1 (C))); enhanced body enrichment and depletion areas in three dimensions are connected (Chart 1 (d))[?].

A variety of non-uniform distributions of the enhancer and their combination for the design of composite materials

for more possibilities , to improve previous non-connected Add strength and toughness of titanium matrix composites severely uncoordinated bugs expands new ideas .

Harbin Institute of Technology Huang Lujun etc [+] with hashin-shtrikma grain boundary theory [56-57] is the base to,, using reactive hot-pressing sintering in situ nativepreparing three-dimensional quasi-continuous mesh distribution tibw/ Ti complex materials , As shown in figure 2 shows [+] . vs. traditional reinforced body evenly distributed titanium matrix composite phase vs ., The composite is relative to the base alloy not only on yield strength and tensile strength increase big , and less plastic reduction ,Proven for excellent mechanical properties . then , on This basis above , Change different enhancer types , such as TiC_p enhanced [%] , (TIBW + TiC_p) blending enhancement [],($Ti2C_p$ +Ti5Si 3_Pmixed) Enhancement [+] etc three-dimensional quasi-continuous mesh distribution reinforced Titanium matrix

composites . Comprehensive analysis , This three-dimensional quasi-continuous mesh distribution enables composite materials to have excellent strength Learn performance .

3. Composite Bionic configuration design

Enhanced Titanium Base complex with in situ autogenous particles Composite material as an example , improving material ratio intensity and ratio stiffness at the same time , inevitably make material plastic and toughness have decreased , severely hindered the material material in major national areas such as aerospace Show with application . so , increase TMCs Strong toughness is a research focus for material researchers .

and in Nature , Multiple organisms passing long Natural filtering of the period to build its own defenses with a material best for its own sake , as Bamboo , wood , Bone I , Shell etc , These natural biomaterials are often has excellent mechanical properties . with respect to biology material Research continues to deep people , the Research scholar begins gradually realizes this excellent performance Materials for the preparation of modern materials and heuristic , so it's the research field of materials science new -- bionic material . where the bay the The pearl layer in the shell is distinguished by the "" mechanical performance concerns , macro to microscopic structure diagram3[?] . Researchers find that the beta shell material has extremely high strength and toughness , main related to its internal microstructure , with layers , Convex up , tile ,Bridge and mesh structures make up . These microscopic groups during its deformation and fracture Fibers

Weaving features synergy to improve material strength The purpose of toughness .

from this , The design idea of bionic configuration is material material scientists have paved a new path. , on Material Preparation science is a craze. , each The species of biomimetic structural materials came into being [%]. at the same time , Developing bionic structure of metal matrix composites The design of the has also emerged in succession . current , about non-connectedContinuous-enhanced bionic configuration design of titanium matrix composites basic imitation shell Pearl layer layer structure . ha Riverside polytechnical University Cui etc [62-63] to pure Ti Foil Film and TiB2/ Al composite foil as raw material , with vacuum hot pressing , hot rolling and multi-step reactions the Annealed method successfully produced a completely dense TiB2-TiAl Layered composites , as shown 4 . final layered structure from TiB2 Layer , «2 «- Ti 3 Al layer and Y - TiAl The layer alternately makes up ,

:)Top view

(f) nanoparticles on the surface of the wafer and

The mineral bridge between the chips

with a few microns thick TiB 2 layer is valid The blocks the grain coarsening of the layered structure . on performance , with multiple twins y-tial same nanometer hardness ,And in yield strength than Y-TiAl alloy above 20% at the same time , with better plasticity , Subsequent studies also found [+],

TiB 2 content is 2.6% for TiB 2- TiAl Composite material with sec- Ti 3 Al compared to , tensile strength and extension has been increased 1 times above . 2015 year ,Cui and , and so on [65-66] the uses the same method , to pure Al foil and TIBW / Ti Composite Material material foil for raw material and a tibjti-tial layered composites , and show more metal matrix composites better plasticity and high temperatures performance .

Liu , and so on [i] use hot-pressing sintering method to prepare out contains three-dimensional mesh structure tibw/ Ti Composite Layer and pure Ti Double-scale layered titanium Base composite , as shown 5[+] :, On the macro scale , Titanium matrix composites as layered structure , on micro-scale enhanced body to three-dimensional quasi-continuous net distribution . mechanical properties Test at ambient temperature , The layered Titanium Matrix composites exhibit A very high plastic deformation behavior ,compared to matrix pure titanium , its yield strength and tensile strength reached 496 MPa and 617MPa , far above pure titanium 431 MPa and 546MPa , this XI bu , its extensibility rate to reach 19.4%, higher than matrix pure titanium elongation value 16.9%.

Because of the difficulty of precise control over the hot-pressing sintering process layer Thick , to precisely design

layered Titanium complex Composite material performance . so ,Liu etc [all] and through Preparation of layered titanium matrix composites by diffusion-bonding method . through precise control layer thickness [on] , layer thickness ratio and Enhancer Volume score [[]], prepared layer - Titanium matrix composites modulus of elasticity , yield Strength and tensile strength are more pure Tisignificantly improved ,, at the same time extend the maximum up to 26.6%. composite , material with high plasticity may be due to extension necking delay effect , multi-tunnel crack toughening

(b) Rich TiB2 layer and complete slice TiAl Layer Interface

caused by the and delamination shielding effect .

The author of the article, etc. [71-72] with a pure Ti Powder and LaB_6 powder , combined with powder metallurgy and hot rolled Make law , in- place self -produce (TiB +La_2O_3) / Ti- Ti layered Composites , As shown in figure 6[71-72] "show." with same enhancer content (TiB) + LaA) /Ti Composite , its tensile strengthdegrees drop Less , But the extension is from 13% Significantly increased to17%, Show excellent Comprehensive mechanical Properties . Preliminary research results show that , The elongation of the layered Titanium matrix composites is enhanced by the main if because of : (1) hot rolling process grain fine effect ; (2) rolling deformations can effectively improve TiB " and La_2O_3 dispersibility ; (3) High-plasticity Pure Tilayer and high-strength (TiB + La_2O_3)/ Ti Complex The combined effect of the material layer . crack initiation First occurred in composite layer , When the crack expands fair to pure Ti layer , pure Ti layer of plenty of plasticity transform to effectively suppress crack extensions , simultaneous composite layer can also slow down the neck of a pure Ti layer

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