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固溶处理对CoCrW合金组织及耐磨性能的影响*

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摘 要 以铸造CoCrW合金为研究对象, 通过XRD, SEM和EDS分析以及硬度测试和室温耐磨实验, 研究了不同温度的固溶处理对该合金的组织及耐磨性能的影响. 结果表明, 铸态和固溶态CoCrW合金组织均由$M_{23}C_6$, M_6C和γ-Co基体3种相组成, 但固溶后合金中碳化物的大小、形貌及分布发生明显变化. 固溶后合金中起强化作用的碳化物大量溶解, 使合金硬度和耐磨性能降低; 随着固溶温度的升高, 部分碳化物中的Cr, W等合金元素大量固溶到基体中, 提高了基体的强度, 使合金的硬度和耐磨性能有所提高; 铸态和固溶态CoCrW合金的磨损机制均为磨粒磨损、黏着磨损和氧化磨损的共同作用.

关键词 CoCrW合金, 固溶处理, 硬度, 耐磨性能
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EFFECTS OF SOLUTION TREATMENT ON MICRO-STRUCTURE AND WEAR-RESISTANT PROPERTIES OF CoCrW ALLOYS

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ABSTRACT CoCrW alloy is a kind of stellite alloy, which has high strength, good wear resistance, and is widely used in aviation industry, nuclear industry and other fields. For a long time, the CoCrW alloy is mainly used as coating to have an effect on wear and the corrosion resistance. With the development of the industry, the conventional cast CoCrW alloy has been widely studied. The mechanical properties of the cast CoCrW alloy can be changed by heat treatment, which is of high hardness and great brittleness. In this work, hardness and wear-resistant properties of the CoCrW alloys as-cast and after solution treatment were studied by combining XRD, SEM, EDS, hardness test and wear resistance test, and effects of the solution temperature on the microstructure and wear-resistant properties were also investigated. The results showed that the microstructures of the CoCrW alloys as-cast and after solution treatment were both composed of $M_{23}C_6$, M_6C and γ-Co matrix, but the size, morphology and distribution of carbides occurred in the alloy changed obviously by solution treatment. The dissolution of a large amount of carbides in the alloy after solution treatment was mainly responsible for the decrease in hardness and wear resistance of the alloy compared with that of the as-cast one. With the increase of the solution temperature, the Cr, W and other alloying elements in the carbides were dissolved into the γ-Co matrix so as to strengthen the matrix resulting in the improvement of the hardness and the associated wear resistance of the alloy. The mecha-

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镍基高温合金叶轮熔模铸造过程的数值模拟

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摘要：采用有限元分析软件 ProCAST 模拟了 IN792 合金在叶轮熔模铸造工艺中的充型凝固过程，分析了在充型凝固过程中缺陷形成的原因，分别探究了不同的浇铸速度、浇铸温度和型壳温度对凝固过程所产生缺陷的影响，通过正交试验的方法得到了最佳的工艺并对其充型凝固过程进行了分析。模拟结果表明：叶轮中存在缺陷，且缺陷主要集中在叶片薄壁处；叶片薄壁处缩松的数量随着浇铸速度的增加而增加，即减小浇铸速度可以得到质量较好的铸件；随着浇铸温度的提高，缩松逐渐减少，但是叶片上的缩松减少到一定程度后趋于平稳，说明浇铸温度对于缩松来说在一定范围内所产生的影响较小；型壳温度对铸件的缩松有很大的影响，随着型壳温度的增大，叶片上的缩松随之增加；最终得到了一套最佳的工艺方案：浇铸温度 1420 ℃，浇铸速度 0.8 $m \cdot s^{-1}$，型壳预热温度 350 ℃；采用该工艺后，铸件中疏松数量明显减少，单个疏松尺寸明显缩小。

关键词：叶轮；熔模铸造；数值模拟；缩松

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Numerical Simulation of Investment Casting Process of Nickel-based Superalloy Impeller

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Abstract: Solidification process of investment casting of Nickel-based superalloy impeller was simulated using the ProCAST software, the reason leading to formation of defects of the impeller during the solidification process was analyzed, and the influence of pouring speed, pouring temperature and mold shell temperature on formation of defects was investigated. According to the results of the orthogonal experiment design, an optimized casting process parameter combination was obtained and the filling and solidification process of the scheme was analyzed. Simulation results show that the defects of impeller mainly present in the thin-walled positions of the blades, that with the increase of pouring speed the degree of shrinkage in impeller increases and low pouring speed can get a better impeller, that with the increase of pouring temperature the degree of shrinkage in the impeller decreases gradually and pouring temperature affects the degree of shrinkage slightly, that with the increase of mold shell temperature the degree of shrinkage increases and mold shell temperature

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Phase transformation of ZrO_2 doped with CeO_2

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Abstract Thermal barrier coatings (TBCs) protection is widely used to prolong the lifetime of turbine components. The outermost layer of TBCs is ceramic layer, whose function is heat insulation, and the main composition of the ceramic layer is ZrO_2. In this study, the micro-ZrO_2 and the nano-ZrO_2 doped with 10 wt% CeO_2 as well as micro-ZrO_2 and nano-ZrO_2 were prepared by air plasma spraying (APS) to study the advantages of the addition of rare earth element. The effect of CeO_2 on the phase transformation of ZrO_2 was studied. The results show that there are few cracks in micro- and nano-ZrO_2 doped with 10 wt% CeO_2, and rare earth oxides can affect the phase transformation significantly. The morphologies, hardness and elastic modulus of the four ceramic layers were also discussed.

Keywords Ceramic layer; Rare earth oxides; Phase transformation; CeO_2

1 Introduction

Thermal barrier coating (TBC) is a multilayer material applied to the surface of the high-temperature alloy, playing a key role in protecting the metallic materials [1]. TBCs have a wide application on aviation turbine engine blades, whose major functions are heat insulation, oxidation resistance and corrosion resistance [2, 3]. It is composed of three layers, i.e., a ceramic layer, an oxide layer and a metal bonding layer, one following another. The bonding layer is directly contacted with the substrate, and the commonly used material is MCrAlY, whose purpose is to provide better integration of the ceramic layer and the substrate. As ceramic layer is an oxygen ion conductor under high temperature, it also takes the role of oxidation resistance [4]. The metal oxide layer is resulted from the oxidation of the metal bonding layer under high temperature, whose main component is Al_2O_3, taking the role of oxidant resistance, but it also affects the life of thermal barrier coatings [5, 6]. The outermost layer of the thermal barrier coatings is the ceramic layer, whose main function is heat insulation and reducing the operating temperature of the substrate.

The main component of ceramic layer is ZrO_2, and the pure powder of ZrO_2 at a normal temperature environment is monoclinic phase [7], having a high melting point and chemical inertness. However, monoclinic ZrO_2 is easily corroded, and in the process of phase transformation from monoclinic phase to tetragonal phase, volume expansion from 5 % to 8 % will be generated, which leads to the cracking of coatings. Therefore, some stabilizers, such as Y_2O_3, should be added for the purpose of replacing monoclinic phase with tetragonal phase of ZrO_2 and improving its chemical stability. Although the ceramic layer has good wear resistance and heat insulation, it also has high brittleness and low shock resistance, which is the key factor for crack initiation. In order to exploit the potentiality of zirconium ceramic layer, nanometer-level yttria-stabilized zirconia (YSZ) powder was used. It has higher hardness,

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Finite Element Analysis of Coating-matrix Interface Crack

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Keywords: coating, interface crack, finite element analysis, stress intensity factor.

Abstract. The finite element method combined with the singular element was adopted to study the effects of thickness ratio of the coating-matrix, elastic modulus ratio of the coating-matrix, and the ratio of ensile stress and shear stress on the coating top on the stress intensity of the interface crack on the coating-matrix. Through calculations, results show that elastic modulus ratio of the coating-matrix has little effect on stress intensity factor of interface crack, while the thickness ratio and the tensile stress and shear stress ratio on the coating top have a great effect on it, which should be controlled in the coating-matrix structure design.

Introduction

Many kinds of coating technology have been widely applied in aerospace, coal-fired boiler, mechanical component repair and many other fields [1-3]. Coatings in fields of aerospace and utility boiler are mainly used to improve the wear resistance of the components, so most of the coatings are ceramic coatings and metallic-matric ceramic coatings with high hardness. There are defects in the coating interior such as stomata and the coating is the porous material, so its fracture is mainly brittle fracture. The safety of component depends mainly on the integrity of the coating and the base metal matrix, and the bonding strength of the coating is regarded as one of the important targets to evaluate its applicability. The bonding strength of the coating includes two aspects: one is the internal bonding strength of the coating, the other is the bonding strength between coating and the base metal (matrix). The bonding strength between coating and matrix is a hot spot that is paid a large amount of attention, so it's an important design parameter to evaluate coating life [4-6]. The coating stripping often begins from micro crack or defect on the interface between coating and matrix, then under the external load crack is extending until the coating is stripped from matrix. Therefore, it is necessary to measure the bonding strength on the interface with interfacial fracture mechanics methods, and find suitable interface fracture control parameters. Obviously, this is an interface problem of bi-material or multi-materials. Williams analyzed interface crack problems in isotropic bi-material earliest [7], and drew a conclusion that type I and type II crack tip stresses had oscillatory singularity, so the crack tip stress field and stress intensity factor were very complex on bi-material interface. In addition, many researchers used bending test to measure the fracture toughness of interface between coating and matrix [8-12]. The critical interface stress intensity factor or the critical interface energy release rate (Cc) is suitable for hard elasticity coating / hard elasticity matrix system. If the matrix is very soft, when the interface crack extends, large range yielding will occur in the matrix near the interface crack tip. In this paper, the finite element method is used to study the relationship between interface energy release rate of coating-matrix and its thickness ratio, elastic modulus ratio, tensile stress and shear stress ratio, which will provide theoretical guidance for coating-matrix design.