FABRICATION OF Al_2O_3 BASED CERAMIC MOLD FOR CERAMIC PROCESSING①

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ABSTRACT Fabrication of Al_2O_3 based ceramic mold was discussed in details. Powder additives(TiO_2 and MgO) and fine Al_2O_3 powders were used to decrease sintering temperature, special dewaxing method and careful control on sintering were explored to prevent cracking and distortion of ceramic mold. Through those efforts, qualified Al_2O_3 ceramic mold with complex inside shape was successfully fabricated, in addition, this process can also be applied to the fabrication of other ceramic component with complex inside shape.

Key words aluminia near-net shaping powder metallurgy

1 INTRODUCTION

For producing large components with complex shape, precision casting technique is always adopted. However, owing to unavoidable cast defects such as coarse crystals and segregation of dendrite crystals, the mechanical properties and service durability of these casting products are very low. Therefore, powder metallurgy—a promising technology for near-net shape high performance components, is facing more and more application.

Ceramic mold process—a new P/M technique for fabricating full density and complex shape components, was developed by Crucible inc. in late 1970s[1-3]. It is a combination of both HIP and Ceracon process, as described in Fig. 1[4].

Firstly, a ceramic mold is fabricated, whose inside shape precisely resembles the component to be produced. Secondly, the ceramic mold is filled with raw material powders through centrifugal method to ensure the powders being full charged every inside corners. The ceramic mold is then placed in a metal capsule, surrounded with secondary pressure media. After vacuumed, the assemble is HIPed. Under high pressure and high temperature, densification of raw material powders occurs inside ceramic mold and metal capsule. After the metal capsule and ceramic mold being stripped, a full-density component of near-net shape is obtained.

In this process, fabrication of ceramic mold with complex inside shape is a key point. Therefore, a detailed procedure of fabricating ceramic mold is investigated in this article.

2 FABRICATING CERAMIC MOLD

2.1 Composition determination

Raw materials for ceramic mold can be Al_2O_3, SiO_2, ZrO_2 and their mixed powders[1]. This article mainly concentrates on Al_2O_3 based ceramic mold, which has higher thermochemical stability and can be used at high temperature. As sintering temperature for pure Al_2O_3 is above 1 600 ℃, several constituents are added to decrease sintering temperature, such as TiO_2 and MgO. Sintering temperature can also decrease, while adopting fine raw material powders. The particle size distribution of Al_2O_3 is given in Fig. 2. The mean particle size of Al_2O_3 is 6.16 μm.

2.2 Coating

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Al_2O_3 based powder mixtures are then agitated with polyethylene alcohol aqueous solution. The ceramic slurry are then coated on die-cast wax pattern(Fig. 3), which precisely resembles the component to be produced. In order to prevent cracks, the first layer should be thin enough and after it completely dried, a second layer will be coated. In this way, Layer after layer, a ceramic shell of neccessary thickness and strength can be produced.

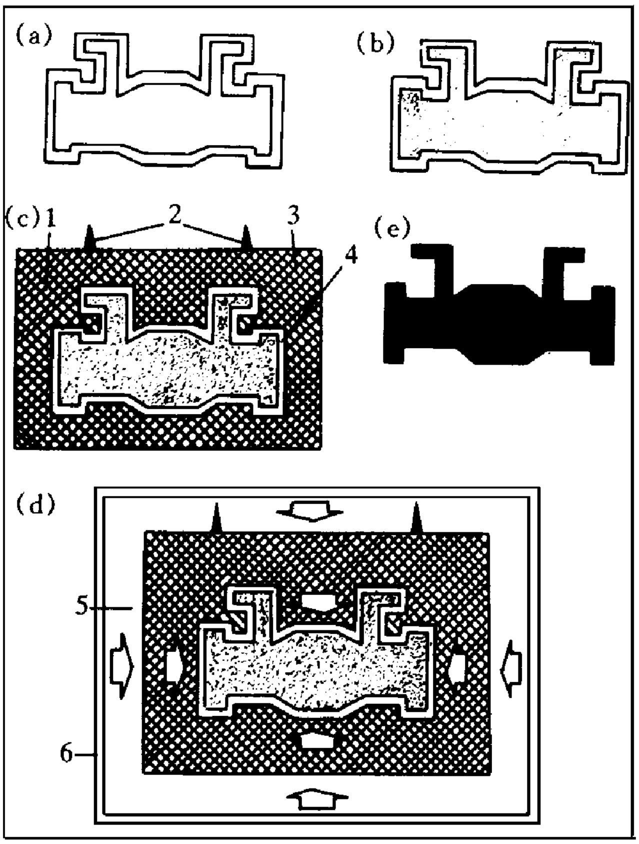

Fig. 1 Ceramic mold process for producing full dense complex components from powder[4]

(a) —fabricate mold; (b) —fill with powder; (c) —put in secondary metal can with secondary pressing media and be evacuated; (d) —hot isotatic press; (e) —finished part; 1 —secondary pressure media; 2 —evacuation slame; 3 —secondary can; 4 —ceramic shell; 5 —gas pressure; 6 —autoclave

At this step, other binders are available, such as sodium silicate, or ethyl silicate, which could have bring higher strength to ceramic shell. But sodium silicate and ethyl silicate can not be eliminated in subsequent sintering process, and will aggravate the deformability of ceramic mold in HIP; while polyethlene alcohol can be burned off in sintering process, exerting no influence on the subsequent deformability of ceramic mold. Therefore, polyethylene alcohol is always prefered.

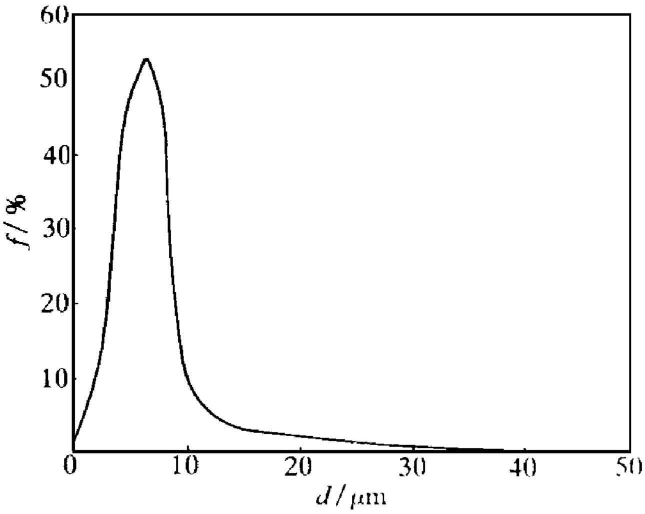

Fig. 2 Particle size distribution of Al_2O_3

Fig. 3 Wax pattern

2.3 Dewaxing

In precision casting, several methods can be adopted to eliminate wax core inside the ceramic shell. The wax core can be burned off by ethyne flame, or can be melted away in boiling water. However, because of lower strength of polyethylene alcohol binded ceramic shell, as temperature increases, the expanding stress of wax would bring about cracks in ceramic shell at dewaxing step. Furthermore, as polyethylene alcohol would volatilize above 200 ℃ and dissolve in boiling water, the ceramic shell would crash if polyethylene alcohol all runs off or dissolves, both ethyne flame and boiling water can not be used. Therefore, two essential principles should be followed at dewaxing step: one is that wax should be burned off quickly before it expands; the other is that dewaxing step should not last long time in case of polyethylene alcohol runs off completly. A simple method for quick dewaxing is described in Fig. 4. The ceramic shell is buried with Al_2O_3 powders in a metal or ceramic vessel, leaving an outlet for wax volatilizing. The vessel is then placed in a furnace, whose temperature has already been above 300 ℃. Because heat conductility of Al_2O_3 particles between vessel and ceramic mold is very low, heat flow firstly enters the ceramic mold from the outlet. Due to high temperature, the wax core in the outlet quickly volatilizes before it expands, while other part of it keeps cool. In this way, the wax core is gradually eliminated from outside to inside. The process last approximately 15 min, and only part of polyethylene alcohol around the outlet runs off, the ceramic mold keeps sufficient strength. This method is more applicable to ceramic shell with small wax, for large wax core, because longer dewaxing time leads to more volatilization of polyethlene alcohol, and because heat can gradually be transfered through Al_2O_3 particles and ceramic mold, leading to the expansion of wax, this method should be modified.

2.4 Sintering

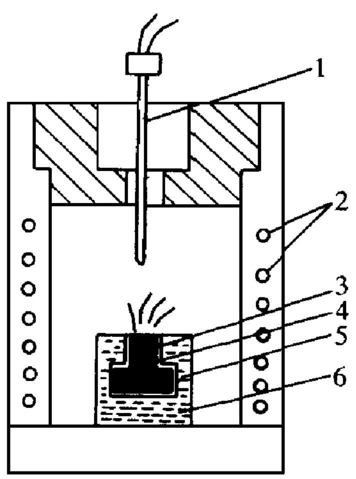

Fig. 4 A novel dewaxing method
1 —thermocouple; 2 —resister;
3 —ceramic mold; 4 —wax;
5 —Al_2O_3 particle; 6 —ceramic vessed

Ceramic mold needs not to be full density. As TiO_2 and MgO are adulterated and fine raw material powders are adopted, sintering temperature of Al_2O_3 based ceramic mold can be below 1 500 ℃. Due to complex inside cavitying, inhomogeneous shrinkage may lead to crack and deformation of ceramic mold during sintering process, therefore heating rate should be carefully controlled. When thermal stress caused by temperature difference in ceramic mold being considered, the dropping of temperature should also be carefully adjusted. A successfully sintered ceramic mold with perfect inside shape is shown in Fig. 5.

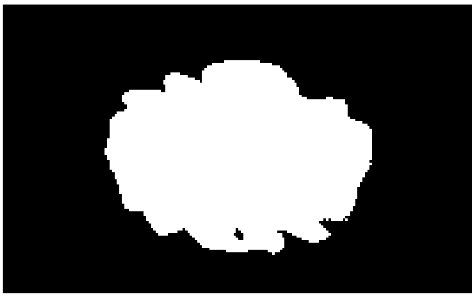

Fig. 5 Inside shape of sintered ceramic mold

3 CONCLUSION

The fabrication of Al_2O_3 based ceramic mold is such a complicated process that mistakes at any step would bring about defects in final product. However, this process can be applied instructively to the production of any large ceramic components with complex inside shape.

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