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ORGINAL ARTICLE

Quick fabrication of aeronautical complicated structural parts based on stereolithography

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Abstract Investment casting based on stereolithography (SL) has the characteristics of short production cycle and low cost, which is especially suitable for fabricating complex aeronautical parts without metal dies. But there are some problems during the fabrication process, such as low surface accuracy caused by the staircases of resin prototype, shell cracking caused by higher thermal stress during the sintering process and so on. Taking an engine turbine stator as a fabrication example, the surface accuracy of resin prototype under the effect of coating method was investigated using the laser confocal microscopy; what's more, both theoretical analysis and finite element analysis (FEA) were combined and compared to reveal the thermal stress field of ceramic shell during pyrolyzing and sintering process under different situation. It was founded that the surface staircases of the resin prototype was eliminated and the surface quality was improved after coating process, the thermal stress was decreased and shell cracking was avoided by sintering the ceramic shell with the inner hollow resin prototype under the heating rate of 5 °C/min. The result showed that, the metal turbine stator had high dimensional accuracy of CT4-CT6 and had a good surface finish within R_a 3.2.

1. Introduction

Engine turbine stator is the key part of aero-engine and gas turbine, which is generally fabricated through investment casting, and the metal dies are an essential tool to

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Nomenclature

H	layer's thickness (unit: mm)
L_w	width of laser beam (unit: mm)
C_d	resin's curing depth (unit: mm)
R_a	arithmetical mean deviation of profile (unit: mm)
T	thermodynamic temperature (unit: K)
b	radius of resin prototype (unit: mm)
a	radius of ceramic shell (unit: mm)
t	wall thickness of ceramic shell (unit: mm)

Greek letters

α	angle between upper surface of part and level (unit: rad)
θ	angle between actual profile line and normal line of upper surface (unit: rad)
γ	staircase's height which is the distance between actual contour line's nadir and theory contour line (unit:mm)
δ	stress (unit: MPa)
τ	coefficient of thermal expansion (unit: W/($m^2 \cdot K$))
σ	bending strength (unit: MPa)
v	Poisson ratio
G	shear modulus (unit: Pa)

Subscripts

δ_r	radial stress (unit: MPa)
δ_β	hoop stress (unit: MPa)
σ_{slim}	bending strength of ceramic shell (unit: MPa)
τ_1	coefficient of thermal expansion of ceramic (unit:W/($m^2 \cdot K$))
τ_2	coefficient of thermal expansion of resin (unit: W/($m^2 \cdot K$))
G_1	shear modulus of ceramic (unit: Pa)
G_2	shear modulus of resin (unit: Pa)

make wax pattern for investment casting. With the improvement of engine comprehensive performance, the structure of turbine stator is becoming more complex, and the corresponding structure of metal dies also has to be changed. Resulting in many problems during fabrication process of complex part based on investment casting, such as long production cycle, high cost and low yield. Therefore it cannot quickly meet the market's needs for new complex metal parts in single and small batch production [1].

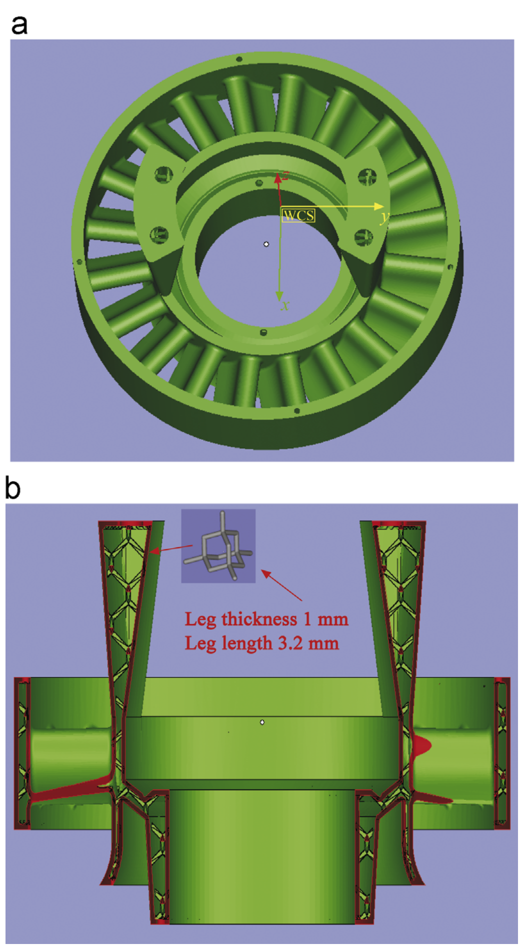

Figure 1 CAD model of turbine stator. (a) CAD model and (b) internal web structure.

Stereolithography (SL) is a new technology based on layered manufacturing which is the most common among all the RP techniques. Owing to the SL's characteristic of layer forming mechanism, complex parts can be fabricated directly in a short time without metal dies which can be used to replace wax pattern in investment casting. Therefore the quick casting (QC), which combines stereolithography and investment casting, has many advantages in producing complex parts in single and small batch production, such as short production cycle, low cost and simple process, which is especially suitable for fabricating complex metal parts in small series production [1,2]. During the QC process, the wax patterns are replaced by resin prototypes and complex metal parts are obtained after coating resin prototypes with

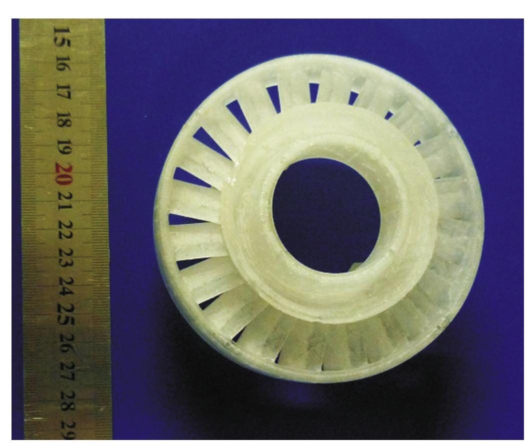

Figure 2 Resin prototype of turbine stator.