Effect of Refractory Filler Materials on Defect Formation in Investment Cast Ni-Base Super Alloy

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Abstract: Ni based super-alloys are used to manufacture turbine blades. The refractory filler materials used in the present work are graphite and zirconia. Casting trials were performed to develop a relation between the mechanism driving formation of shrinkage and refractory filler material. It was observed that zirconia shell mould is significant to achieve a steeper thermal gradient which is essential in order to minimize the width of the mushy zone. It was also observed that a slower cooling rate along with a steeper thermal gradient at the metal-mold interface not only helps to avoid shrinkage porosity but also increases fillability in thinner sections.

Keywords: Investment casting, Ni-base super alloy, colloidal silica binder, zirconia, graphite.

1. INTRODUCTION

During the solidification of alloys, a mushy zone is formed at the solidification front [1]. In nickel-base super alloys usually the solidification interval is large which leads to formation of an extended mushy zone. In the investment casting of complex geometries, the solidification front grows from different directions and meets at intersections or along the centerline. The areas where solidification fronts meet usually are more prone to the interdendritic shrinkage. The materials used to build the investment shell mould, especially binders and refractories, play a vital role in the production of quality castings [2-8]. Using different refractory filler materials can affect the ability of the shell mould to absorb heat and maintain a critical thermal gradient.

The present work was designed to investigate the relation between refractory filler materials and thermal gradient and thus shrinkage porosity of Ni-base super alloy.

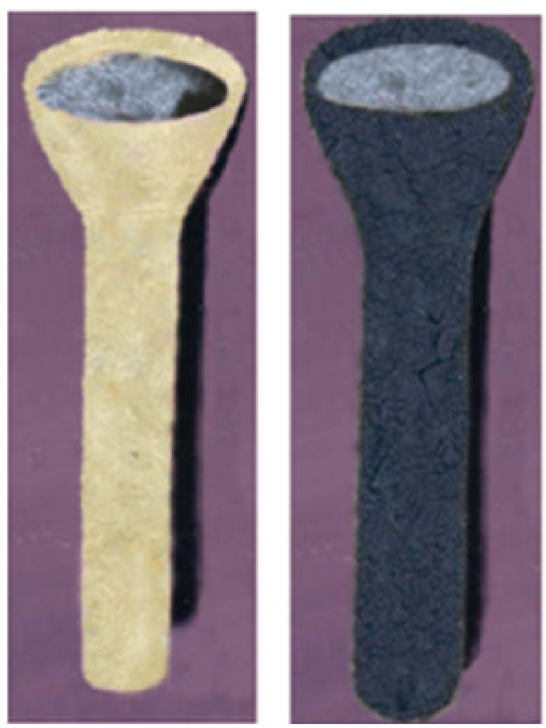

Figure 1: Investment shell moulds.

2. MATERIALS METHODS

The chemical composition of Ni-base super alloy is given in table 1. In the present work, the colloidal silica binder was used to fabricate the ceramic shell moulds from zirconia and graphite as reinforced filler materials. The silica content in the colloidal silica binder was 30%. Two grades (primary and backup sands) of stuccoing sand were employed in the present investigation. Finer grade silica sand having AFS grain fineness number 120 was employed for primary coats. This is synthetic sand. This sand was used for first two coats, called prime coats to get good surface finish and every detail of the wax pattern. Coarser grade sand having AFS grain fineness number 42 was employed for back up coats. This is river sand. The backup sand was employed to develop more thickness to the shell walls with minimum coats. The thickness of shell moulds were 12 mm. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made. The Ni-base super alloy was melted in an induction furnace under vacuum. The liquid alloy was gravity poured into the pre-heated investment shell moulds. The shell moulds were knocked off by hand hammer after solidification of the molten (figure 1). The castings were cleaned with soft brush and visually inspected for pins and projections [9-23].

Table 1: Chemical composition of Ni-base super alloy

Element	Ni	Cr	Co	Mo	Fe	Ti	Al	B
%wt	54.09	18	15	3	4	3	2	0.01

3. RESULTS AND DISCUSSION

Refractory filler materials were observed to have very significant effect on porosity. The effect of refractory filler materials is presented in figure 2. It was observed that the area of the porous zone reduced for zirconia shell moulds at all four casting temperatures. It was observed that the use of zirconia filler material not only minimized shrinkage and columnar grain formation but also eliminated surface defects. The area of the porous zone increased for graphite shell moulds at all four casting temperatures. The shrinkage and columnar grain formation were high in the castings produced from the shell moulds prepared from the graphite filler material. The surface defects were also observed on the castings produced from the graphite shell moulds. Casting temperature and refractory filler material appeared to be key process parameters for eliminating shrinkage porosity, misruns and non-uniform grain structure. At higher temperature i.e. 1560^{o} C shrinkage porosity was low due to the prolonged feeding of melt. However, high casting temperature resulted in coarse grains.

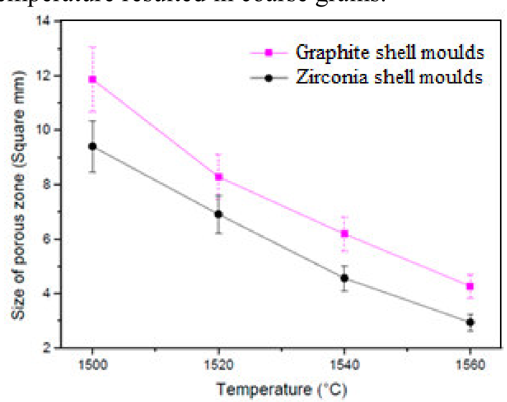

Figure 2: Effect of casting temperature on porosity with two refractory filler materials.

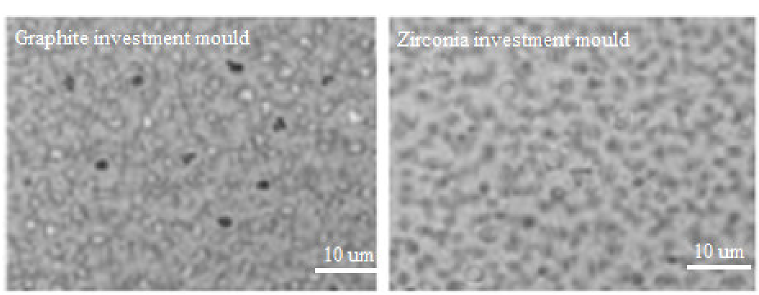

Figure 3: Microstructure if Ni-base super alloy.

The specific heat capacities of graphite and zirconia are, respectively, 188 J/kg/^{o}C and 540 J/kg/^{o}C. The thermal conductivities of graphite and zirconia are, respectively, 90 W/m/^{o}C and 2.7 W/m/^{o}C. At initial phase of solidification, increasing the capacity of the mould to absorb heat leads to a steeper thermal gradient at the metal/mould interface. The growth of dendrite arms and improved the fillability in the thin sections and feed of metal to the shrinkage pores in the zirconia shell moulds. Grain size appeared to be dependent on available heat mass and cooling rate. In the zirconia shell moulds, presence of extra heat mass resulted in slower cooling and thus larger grains resulted in the castings (figure 3). On other hand, fine grain structure is observed in the castings produced from the graphite shell moulds due to gradual thermal gradient.

4. CONCLUSIONS

It has been observed that the refractory filler materials of the ceramic shell mould strongly influences shrinkage. The heat absorbing capacity of ceramic is determined by refractory filler material, which is critical for casting of thin, complex shapes.

• Increasing the heat absorbing capacity of ceramic shell helps to maintain a high thermal gradient between melt and mold for a longer time interval. The width of mushy zone decreases with increasing thermal gradient making possible feed of metal to shrinkage pores.

• The conditions achieved through the higher thermal gradient and slower cooling rate keeps the width of mush shorter which allows metal feed through growing dendrite arms for a longer distance and thus helps to reduce shrinkage not only at points where solidification front meets but also between the growing dendrites.

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