GRAVITY AND CENTRIFUGAL INVESTMENT CASTING OF NEAR-GAMMA TiAl TURBOCHARGER TURBINE WHEELS

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Experimental work was carried out in a vacuum induction furnace (IS2/I HERAEUS) fitted with a crucible of Y_2O_3 (oxygen content in castings ~ 0.1 wt%). Castings of turbine wheels of 55 – 152 mm in diameter were cast in Ti46Al7Nb0.7Cr0.1Si0.2Ni (at.%) – *Fig. 1*. In the course of experimental work two types of casting defect appeared in gravity castings:

1. Misrun – as a result of the loss of fluidity of alloy prior to complete filling of the mould.

2. Surface shrinkages – as a result of the appearance of unfavourable temperature field in the casting during solidification.

The appearance of misrun defect is the result of inappropriate combination of the temperature of ceramic shell mould, pouring temperature, and forces acting on the melt in the course of casting, for a given wall thickness of the casting. If for the sake of improved running property the TiAl alloy is poured into a mould of high temperature, then, due to slow cooling, large grains of alpha phase with long lamellae will appear. Large, fully lamellar grains lead to reduced ductility, large scatter of properties, and increased tendency to cracks in the casting below yield point. Experiments were therefore carried out to improve the running property of TiAl alloys via centrifugal casting. For these experiments, the HERAEUS IS2/I vacuum induction furnace was fitted with centrifugal casting machine with vertical rotation axis and stepless control of revolutions in the range 0 – 300 r.p.m.

In centrifugal casting, the melt surface is in the shape of paraboloid of revolution. The maximum utilizable number of revolutions for a given configuration of ceramic shell mould is limited by the height of paraboloid of revolution (*Fig. 2*), which for a given radius must not exceed the upper rim of the pouring cup of shell mould. The height of melt level in still state halves the height of the paraboloid of revolution for the given number of revolutions. In practice the height of still melt is given by the height of level required for efficient riser feeding. The maximum number of revolutions can then be determined experimentally, using water (the shape of paraboloid is not a function of liquid density).

Experiments were conducted on two configurations of ceramic shell moulds. In both cases, the ceramic shell mould was placed in a steel box and poured over with quartz sand. In the casting given in *Fig. 3* on the left the axis of centrifuge rotation was identical to the symmetry axis of the turbine wheel (diameters 110 and 152 mm). Maximum revolutions for the required height of level in the riser were determined with the aid of water – the frequency of the supply current for the motor was 20 Hz, which corresponds to 120 r.p.m. In the castings in *Fig. 3* on the right the rotation axis was not identical to the turbine wheel axis (diameter 55 mm). Maximum revolutions were again determined for the required height of level in the sprue with the aid of water – the frequency of the supply current for the motor was 25 Hz, which corresponds to 150 r.p.m. In both cases, the centrifuge revolutions are reduced immediately after pouring to make the melt level in the riser fall. Preliminary results show that macroscopically sound castings can be fabricated in both cases – *Fig. 3*.

While castings of 55 mm in diameter were cast without problems, in dia 152 mm castings made by gravity and centrifugal casting large surface shrinkages began to appear at the riser/casting transition (*Fig. 4*). The mould configuration is evident from *Fig. 5a)*. These defects were found, to a lesser degree, also on castings of 110 mm in diameter. An analysis of potential reasons for these defects led to the conclusion that the high pouring temperatures used (ca. 1700 °C) intensify the radiant heat transfer from riser level to such a degree that two solidification fronts advance through the casting: one goes from the casting upwards and the other goes from the riser downwards. This is attested by columnar grains growing from the riser surface downwards – *Fig. 6*. At the point where the two fronts meet the above-mentioned defect appears. This assumption was proved via simulation of turbine wheel casting, dia 152 mm, using the ProCast software – *Fig. 7a)*. It is evident from *Fig. 8* that the cooling rate of untreated riser level is comparable with the cooling rate of thin turbine blades.

The treatment of riser level in the case of titanium alloys is complicated because of the titanium auto-ignition temperature, which is 1200 °C. Thus it is impossible to admit air into the vacuum furnace and apply insulating or exothermic materials to the riser immediately after pouring. It was therefore proposed to reduce radiant heat transfer from the riser surface by means of a radiation shield, with which the ceramic mould is closed after pouring – *Fig. 5b)*. This was experimentally tested and the solidification vs. time for casting with the radiation shield is obvious from *Fig. 7b)*. Using the radiation shield, it was possible to shift the surface shrinkages as well as inner shrinkages into the riser and obtain a perfect casting – *Fig. 9*.

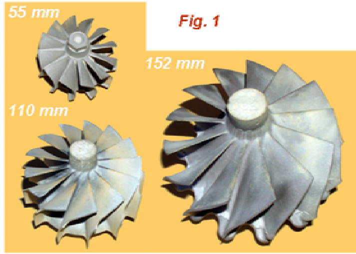

Fig. 1

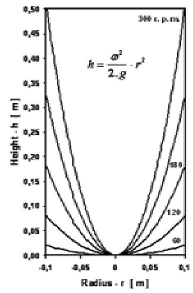

Fig. 2

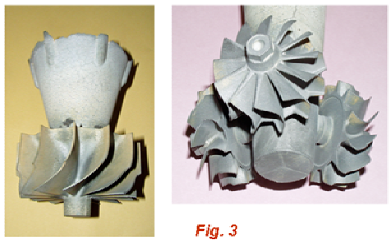

Fig. 3

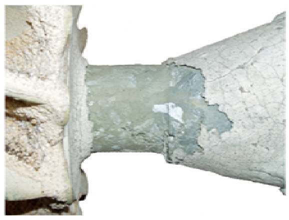

Fig. 4

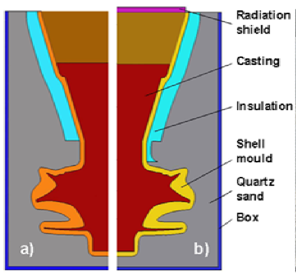

Fig. 5

Fig. 6

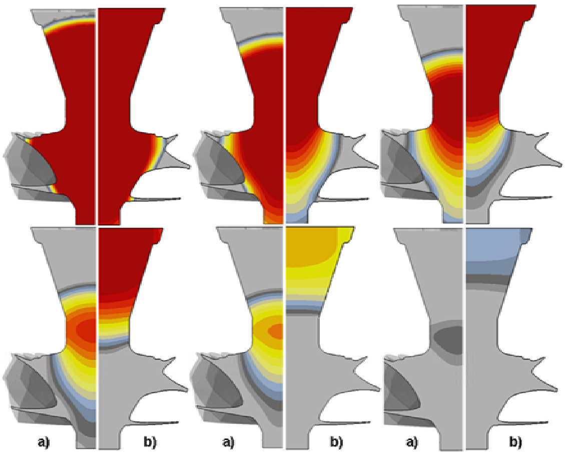

Fig. 7

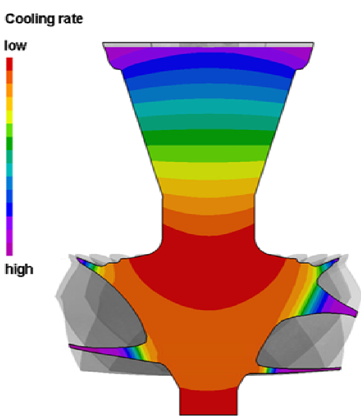

Fig. 8

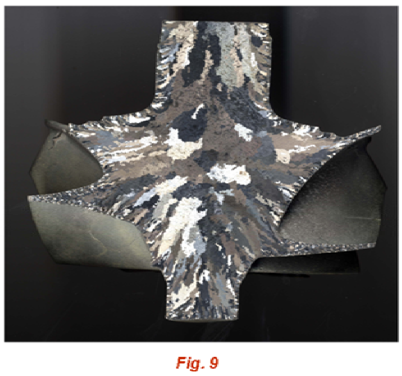

Fig. 9

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