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Investment Casting Of Torpedo Nozzle

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Abstract - Investment Casting is also known as Lost Wax process. Investment casting process is generally used to produce intricate and complex shaped products. The primary objective of the project work is to produce Torpedo Nozzle by investment casting. Nozzles are manufactured by investment casting process consisting of wax injection, ceramic coating, wax removal, metal casting, and finishing. The creep strength of the product should be enhanced as we go to higher temperature application. Super Alloys (Ni-based) satisfy the above condition and are hence used for the production of components used at elevated temperatures. Earlier IN 718 was used in the manufacture of Torpedo nozzles by mechanical working and machining the alloy to obtain the final product. Machining of the nozzle was difficult as it involved intricate shape internally and also as found to be eroding during its service. This alloy also can not be used above 700°C because the strengthening precipitates will coarsen. Hence, we produced the nozzles by Investment Casting process, using CM 247 to overcome the limitations of IN 718. CM 247 can withstand higher temperatures (1000°C - 1100°C) and has better mechanical properties over IN 718. The focus of this experimental work was on the several stages of investment casting process and the microstructures were also studied.

Keywords- torpedo,investmentcasting,cm 247lc,inc 718

1. INTRODUCTION

A.Investment Casting

Investment (lost wax) casting is a widely used casting technique in which a pattern usually made of wax is formed by introducing a molten wax composition into a mold having the shape of the finished part and by cooling it until solidification. In the ceramic shell method, the pattern or a cluster of such patterns is/are gated to a wax sprue. Then the sprued pattern or patterns is/are invested with ceramic slurry which is then solidified to build a shell around the wax pattern. The pattern wax is then removed from the mold by melting or burning. The resulting refractory shell is further hardened by heating and filled with molten metal to produce the finished part. In this process, surface and dimensional characteristics of the pattern are transferred to the ceramic shell and so to the final casting. (Refer to the figure1)

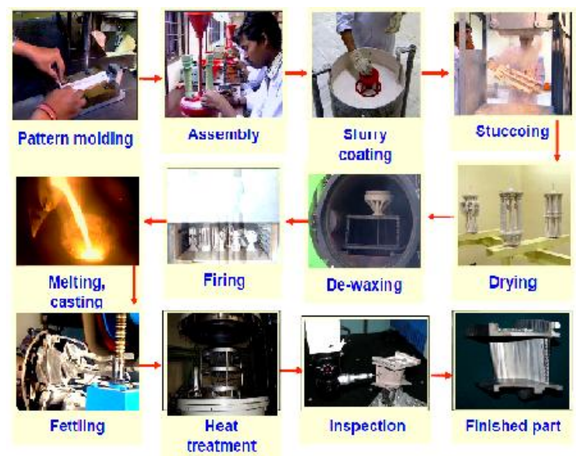

Fig. 1: Steps in the investment casting process

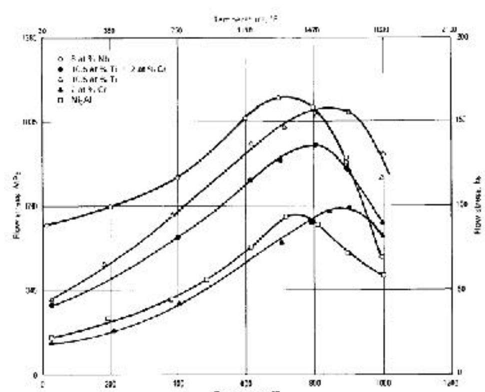

Fig. 2: Flow stress peak in gamma prime & influence of several solutes

3.1 Manufacture of Torpedo Nozzle

Investment casting of the torpedo nozzle involves the following steps:

- Pattern Making
- Pattern Assembly
- Slurry Coating
- Drying
- Dewaxing
- Firing & Inspection
- Melting
- Fettling
- Finished Product

Table 1: Specifications of Injection molding machine

Parameter	Value
Wax Chamber Temperature	65.2°C
Nozzle Temperature	80°C
Dwell Time	1-2 min
Suction	0.5s
Pressure	280psi

Fig 3: Nozzle (wax) patterns

3.1.2 Pattern Assembly

Clustering of the patterns produced was done. Three different gating ratios i.e, 12mm, 15mm and 18mm were maintained while assembling the patterns. Two different clusters were prepared using the 8 patterns produced .Each contained 4 nozzle patterns.

Slurry Coating

The cluster was then coated thoroughly and dried completely before each coating. Totally 8 coatings were given to each cluster prepared. The composition of the coatings is tabulated in the tables 3 and 4.

Ingredient	Quantity	Quantity of Ingredient Required
Colloidal Silica	10 lit	12.10 kg
Zircon Flour (-200mesh)	5 lit	50 kg
Wetting Agent	25ml	0.25%
Antifoam Agent	50ml	0.50%

Table 2: Primary Slurry coating Composition

Fig 4: Slurry Coating

Ingredient	Quantity	Quantity of Ingredient Required
Colloidal Silica	25 lit	30.25 kg
Zircon Flour (-200 mesh)	5.01 lit	125 kg

Table 3: Back-up slurry coating composition

Coating Number	Particle size (mm)
First	0.10-0.20
Second	0.20-0.30
Third	0.30-0.50
Fourth	0.50-0.75
Fifth	0.75-1.00
Sixth	0.75-1.00
Seventh	0.75-1.00
Eight	1.00-1.50

Table 4: Stuccoing particle size for each coat

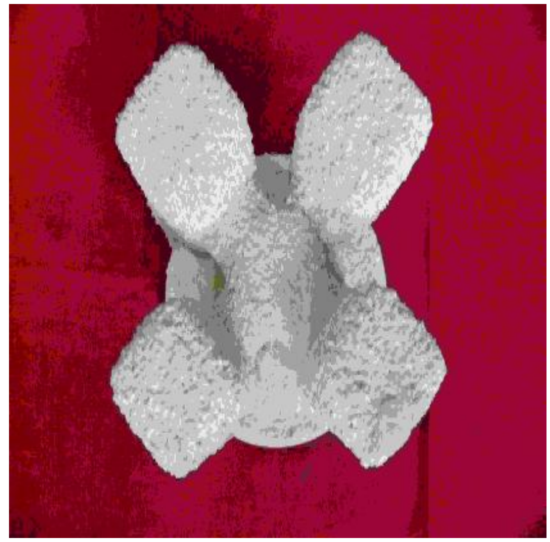

Fig 5: Slurry coated nozzle patterns

3.1.4 Drying

Drying of the coated clusters was done carefully and thoroughly after each coat at room temperature. No specific arrangements or machinery was used to dry the coated clusters. Coating was done only after the previous coat is completely dried. The clusters were allowed to dry for a longer time after the last coat was given.

3.1.5 De-waxing

De-waxing of the dried clusters was done carefully in an autoclave. As the thermal co-efficient of expansion of wax is on a higher side, the wax present in the shell was removed from the autoclave. The wax was removed within 4 min, as longer exposure might result in the cracking of the shell. The autoclave was maintained at 200°C.De-waxing was done rapidly to avoid cracking of the shell.

3.1.6 Firing & Inspection

After de-waxing, the shell was fired in an induction furnace to remove the left over wax. Firing was done by maintaining the temperature at a range of 950°C - 1000°C. At this temperature, the wax that was left inside the shell got evaporated .After firing, the shell was subjected to inspection by ink – test. For this, ink was mixed with water and poured into the shell and inspected for any internal cracks present. They were no cracks as there was no appearance of the color on the shell.

3.1.7 Melting

Melting of the super alloy (CM 247) ingot was done in an induction furnace. Before pouring of the liquid metal the shell was preheated up to 900-950°C because they shouldn't be any significant thermal gradient between the shell and the liquid metal. The shell is placed in the furnace before being lifted above the graphite suseptor. The metal ingot that is melted is poured into the shell via a tundish. The shell is withdrawn slowly from the furnace for directional solidification to take place.

3.1.8 Fettling

Fettling of the shell can be done by hammering and knockout. We have done the fettling by manually hammering it. Complete removal of the shell was done successfully by hammering.

3.1.9 Finished Product

The finished products (torpedo nozzle) were successfully obtained after the removal of the shell. Part of the nozzle was sectioned and the microstructures were studied.

3.2 Metallography

Small pieces that were obtained after machining were taken and mounted using bakelite powder in a mounting machine. After mounting the sectioned parts were polished. Initially rough polishing was done with emery papers 180, 220, 320, 400 and 500; rough polishing was done to remove the level difference and scratches present onto the specimen to maximum extent. Later, final polishing was done on 9 µm and 1 µm to give a mirror finish to the sectioned part. After the final polishing is done the sectioned parts are cleaned with acetone to remove any minute dust particles.

After polishing, the microstructures were observed under an optical microscope. Later, the specimens were etched with Kalling's reagent and the resulting microstructures were observed again after etching.

Chemical	**Quantity**
Copper Chloride	2-5 g
Hydrochloric Acid	40 ml
Methanol	40 ml

Table: 5

SPECIMEN	**LIFE**	**ELONGATION**	**TEMPERATURE**	**STRESS**
INCONEL 718	**195 hours**	**25%**	768°C	585 Mpa
CM 247	**303 hours**	**4.50%**	768°C	585 Mpa

4. RESULTS AND CONCLUSIONS

1. The torpedo nozzle having a complex internal passage was produced successfully by investment casting process.

2. The investment casting process facilitated manufacture of this component in CM 247 LC having higher temperature capability as compared IN 718 from which it was made originally.

3. The part made by IN 718 was reported as failing prematurely at the thin edge at the exit.

4. The stress rupture strength of CM 247 is higher than that of INCONEL 718.

5. The component made of CM 247 LC alloy by investment casting as been performing very satisfactorily.

6. Thus, a part made by machining and fabrication route has successfully converted into an integral part by investment casting giving advantage of cost as well as high performance.

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LOAD	VICKER'S HARDNESS
30 kg	394
30 kg	395.6
30 kg	395.2
AVERAGE HARDNESS	394.93

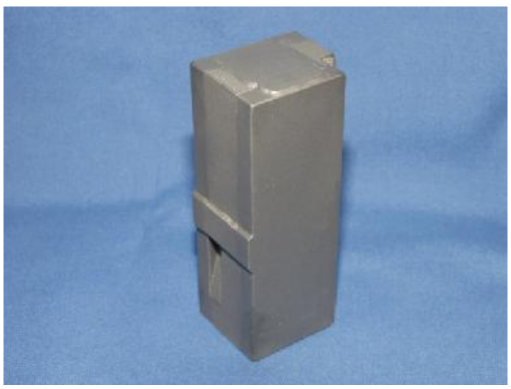
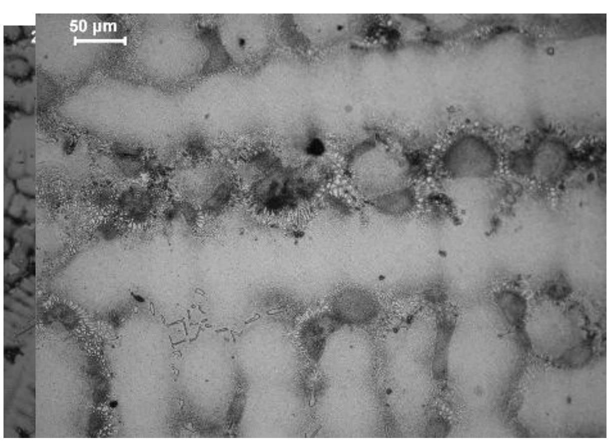


Fig: 6 Torpedo Nozzle manufactured

Microstructures

The as-cast microstructure is shown in the figures below. The as-cast structure at low magnification (50X) shows the dendritic structure. At slightly higher magnification (200X), eutectic pools at inter dendritic regions are seen. At 500X and 1000X magnification the as-cast γ' phase is visible.



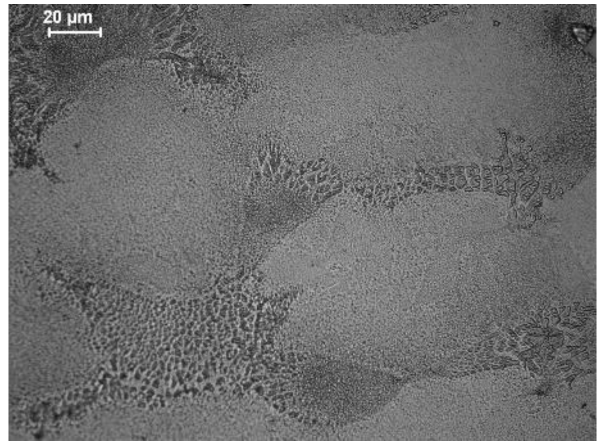


Fig 12 & 13: Microstructure of CM 247 (50X) &(200X)

Fig 14: Microstructure of CM 247 (500X)

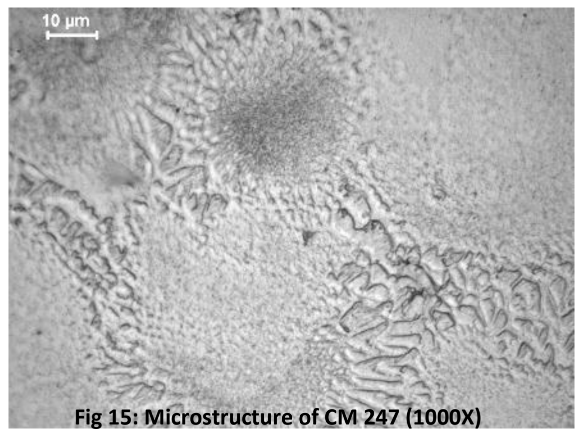


Fig 15: Microstructure of CM 247 (1000X)

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