MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AA2219 ALLOY TURBINE IMPELLER MANUFACTURED BY INVESTMENT CASTING

A. Chennakesava Reddy
Department of Mechanical Engineering, JNTU College of Engg., Hyderabad 500 072.

Abstract: AA2219 alloy was employed to fabricate turbine impeller using investment casting process. The mechanical properties are good. Turbine impeller generally machined by CNC machining which is time-consuming and high manufacturing cost. This can be replaced by the investment casting to fabricate turbine impeller with good precision. Fatigue strength is 105 MPa.

Keywords : Investment casting, AA2219 alloy, colloidal silica binder, zirconia.

1. INTRODUCTION

Manufacturing of turbine blades, which are of complex geometry, is generally carried out using CNC machining and investment casting process. As the tips of the blades are very fragile the cost of CNC machining is very high due to long manufacturing lead time. On the other hand, the investment casting can generate a highly precise parts characterized with added complex geometry [1-9]. Al alloys was used for impeller due to lightweight, high strength to weight ratio, high corrosion resistance and excellent mechanical properties. Compressor turbocharger that operates on conditions similar to Organic Rankine Cycle (ORC) turbine impeller, used Al-(1-2) Mg-(2-3) Cu (wt %) with addition of titanium [10].

The aim of the present work is to manufacture turbine impeller by investment casting. The turbine impeller was made from AA2219 alloy.

2. EXPERIMENTAL PROCEDURE

In the present work, the colloidal silica binder was used to fabricate the ceramic shell moulds from zirconia as reinforced filler material. 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. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made. The AA2219 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 [11-20].

Figure 1: Cast turbine impeller in investment shell moulds.

3. RESULTS AND DISCUSSION

Turbine impellers were found free of macro defects, such as misruns, macro porosity, and surface cracks (figure 2). Figure 3 shows microstructures free from shrinkage porosity. A backscattered SEM image of polished surface is shown in figure 4. The image in figure 4 shows the presence of gas porosity on the polished surface.

The image in figure 4 also shows the presence of a lighter contrast phase that lies at the boundaries between the interlocking grains. The lighter contrast in the backscattered SEM image is indicative of this phase being of a higher atomic number element. Spot EDX analyses taken from the areas in figure 4 showed that area 'A' comprised of predominantly 'Al' and 'O' peaks suggesting it to be aluminum oxide. The lighter contrast phase 'B' at the grain boundaries were found to be highly rich in 'Cu' and such could have come from the copper precipitates of the substrate alloy that do not participate in the oxidation process. These could be attributed to $CuAl_2$ and $CuMgAl_2$ formed in this alloys due to higher Cu content. Different amount of in $CuAl_2$ and $CuMgAl_2$ phase caused significant differences in mechanical properties. The darker phase 'C' was found to be rich in 'Si' content.

Figure 2: Turbine impeller.

Figure 3: Microstructure of AA2219 alloy used for turbine impeller.

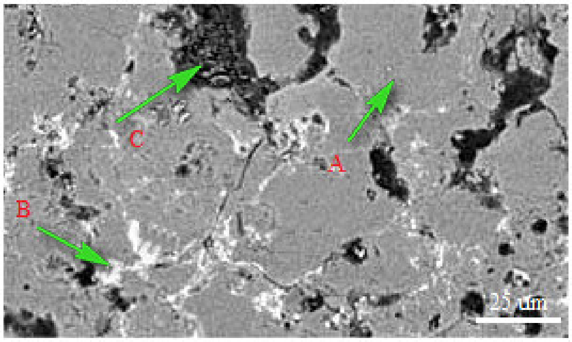

Figure 4: SEM backscattered image of a polished surface of AA2219 alloy A - Al_2O_3; B - Cu containing phase; C – Si containing phase.

The physical and mechanical properties are as follows:

- Density: 2.84 g/cc
- Tensile strength: 415 MPa
- Tensile yield strength: 290 MPa
- Fatigue strength: 105 MPa
- Brinell hardness: 118

Modulus of elasticity: 73.1 GPa
Shear modulus: 27 GPa.

4. CONCLUSIONS

The turbine impeller manufactured by the investment casting is free from macro defects such as misrun, macro porosity and shrinkage. It contains micro gas porosity. This alloy contains 5.5 wt. % Cu giving the hardness of 115 HRB and fatigue strength of 105 MPa.

REFERENCES

1. A. Chennakesava Reddy, K.M. Babu, P.M. Jebaraj and M.P. Chowdaiah, Accelerator for faster investment shell making and its effect on the properties of investment moulds, Indian Foundry Journal, 41,1995, pp.03-08.
2. A. Chennakesava Reddy, H.B. Niranjan and A.R.V. Murti, Optimization of investment shell mould using colloidal silica binder, Indian Journal of Engineering & Materials, 3, 1996, pp.180-184.
3. A. Chennakesava Reddy, V.S.R.Murti and S. Sundararajan, Regression modeling approach for the analysis of investment shell moulds from coal-flyash, Foundry Journal, 9, 1997, pp.36-40.
4. A. Chennakesava Reddy, V.S.R. Murti, S. Sundararajan, Some aspects of reducing sediments rate of refractory fillers in the investment casting process, Journal of Engineering Advances, 10, 1998, pp.61-63.
5. A. Chennakesava Reddy, V.S.R. Murti and S. Sundararajan, Control factor design of investment shell mould from coal flyash by Taguchi method, Indian Foundry Journal, 45, 1999, pp. 93-98.
6. A. Chennakesava Reddy, V.S.R.Murti and P.M.Jebaraj, A new technique for measurement of the strength of ceramic shells in the precision casting process, Journal of Testing and Evaluation, 28, 2000, pp. 224-226.
7. A. Chennakesava Reddy, V.S.R. Murti and S. Sundararajan, Bonding mechanism in the coal-flyash ceramic shells, Indian Foundry Journal, 47, 2001, pp.21-25.
8. A. Chennakesava Reddy, and V.S.R. Murti, Studies on Lost-Wax Process Using Silox Binder, X-ISME Conference on Mechanical Engineering, New Delhi, 09-11th December, 1996, pp. 82 – 86.
9. A. Chennakesava Reddy, Characterization of ceramic shells fabricated using yttria as reinforcing filler, National Conference on Advanced Materials and Manufacturing Technologies, Hyderabad, 5-7th December 1997, pp.125-129.
10. Furukawa-Sky Aluminum Corporation Chiyoda-Ku Tokyo (Jp), Cast Aluminum Alloy Compressor Wheel for a Turbocharger, European Patent Application, 2005.
11. A. Chennakesava Reddy, Characterization of ceramic shells using rutile (titania) as reinforcing filler at casting temperature, National Conference on Advanced Materials and Manufacturing Technologies, Hyderabad, 5-7th December 1997, pp. 130-134.
12. A. Chennakesava Reddy, V.S.R. Murti, and S. Sundararajan, Development of a Ceramic Moulding Process from Coal Flyash for Investment Casting, 18th AIMTDR Conference, Kharagpur, 21-23rd December 1998, pp.118-122.
13. P. Martin Jebaraj and A. Chennakesava Reddy, Prediction of thermal shock of ceramic shells using fused silica as reinforcing filler at casting conditions, National Conference on Advances in Production Technology, Bangalore, 7-9 February 1998, pp.52-56. 3
14. H.B. Niranjan and A. Chennakesava Reddy, Investment shell moulds using graphite filler to prevent dimensional instability and metal-mould reaction of Ti-alloy castings, National Conference on Advances in Production Technology, Bangalore, 7-9 February 1998, pp. 57-62.
15. A. Chennakesava Reddy, S. Sundara Rajan and V.S.R. Murti, Dampening of Noise Parameters for Developing Ceramic Shell Process from Coal Flyash by Taguchi Method, CEMILAC Conference, Ministry of Defence, India, 20-21st August, 1999, pp.91-95.
16. Ch. Rajana and A. Chennakesava Reddy, Interfacial Reaction between Zirconium Alloy and Zirconia Ceramic Shell Mold, National Conference on Advanced Materials and Manufacturing Technologies, Hyderabad, 18-20 March 2000, pp. 212-217.
17. S. Madhav Reddy and A. Chennakesava Reddy, Interfacial Reaction between Magnesium Alloy and magnesia Ceramic Shell Mold, National Conference on Advanced Materials and Manufacturing Technologies, Hyderabad, 18-20 March 2000, pp. 218-222.
18. A. Chennakesava Reddy, Development of Alumina Investment Shell Molds to Cast 7075 Al-Alloy, National Conference on Advances in Manufacturing Technologies (AMT-2001), Pune, 9-10 March 2001, pp. 102-104.
19. A. Chennakesava Reddy, Thermo-Physical Properties of Fused Silica Investment Shell Moulds at Preheat Conditions of Steel Casting, National Conference on Advanced Materials and Manufacturing Techniques, Hyderabad, 08-09th March 2004, pp.342-346.
20. A. Chennakesava Reddy, Structure and Morphology of Recycled Iron-Rich Al-Si Alloys Cast in Thin-Walled Investment Shell Moulds, National Conference on Advanced Materials and Manufacturing Techniques, Hyderabad, 08-09th March 2004, pp. 347-349.