Castability of Biocompatible TNZT in Investment Shell Moulds

P. Janardhan Reddy
PG Student, Department of Mechanical Engineering, JNT University, Hyderabad

Under the Guidance of Dr. A. Chennakesava Reddy, Associate Professor, JNTUH College of Engineering, JNT University, Hyderabad.

ABSTRACT

Beta-titanium alloys are capable materials for load-bearing orthopaedic implants due to their outstanding corrosion resistance and biocompatibility, low elastic modulus and moderate strength. The most commonly used is Ti-6Al-4V alloy that belongs to $\alpha+\beta$ Ti-alloys. The main drawback of this alloy is toxic nature of vanadium. In addition, a high amount of aluminum interferes with cell viability, besides having a long-term cytotoxic effect in-vitro and in-vivo. In vitro refers to the technique of performing a given procedure in a controlled environment outside of a living organism. In microbiology in vivo is often used to refer to experimentation done in live isolated cells rather than in a whole organism, for example, cultured cells derived from biopsies. The $\alpha+\beta$ Ti-6Al-7Nb alloy has been developed to avoid the bad effect of vanadium. Another adverse property is too high elastic modulus (115 GPa of Ti-6Al-4V and Ti-6Al-7Nb alloys) that is higher than that of cortical bone (20 GPa). Too high elastic modulus causes stress shielding and consequent osteoporosis that results in decreased life-time of orthopaedis implant. In spite of reducing the elasticity modulus of titanium alloys without causing cytotoxic effects, new promising alloys that add niobium, tantalum, zirconium and molybdenum to titanium have been developed. These alloys represent a new class of titanium-based alloys, which are free of aluminum and vanadium, while exhibiting low values of the Young's modulus. Ti-35Nb-7Zr-5Ta (TNZT) alloy was developed in 1990s in USA and patented in 1999. The biggest current interest is focused on metastable β-titanium alloys with increased biocompatibility and decreased elastic modulus to avoid stress shielding and increase of life-time of an implant. The elastic modulus of TNZT alloy is 55 GPa. The mechanical properties of titanium-based alloys are directly related to their microstructure [5]. In fact, the strength and toughness of many β alloys are improved by the presence of the ω phase. The reason was attributed to the fact that α forms in a compositionally invariant way, having no long-range effect on the β matrix.

The purpose of this investigation was microstructural assessment of TNZT alloy cast by counter-gravity in Yttria-doped Titania investment shell moulds. The mechanical

properties with loading and unloading conditions, porosity levels and metal-mould reactions were also investigated.

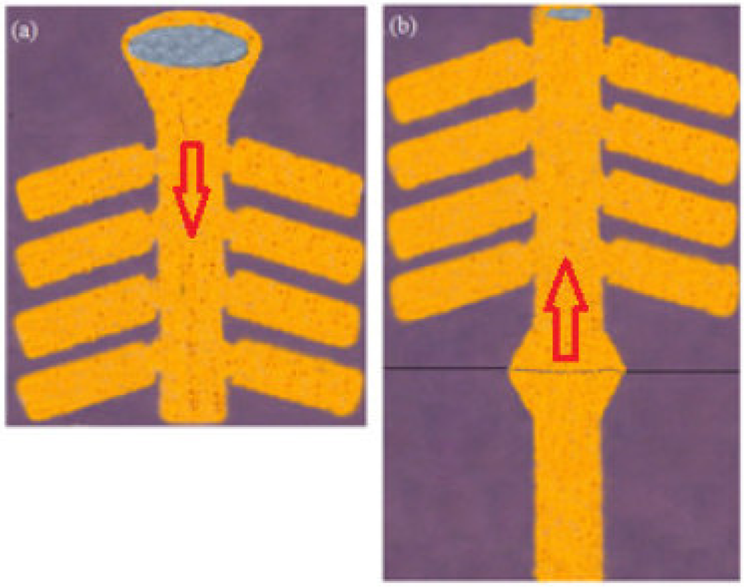

Figure 1: Investment shell moulds: (a) gravity poured and (b) counter-gravity poured.

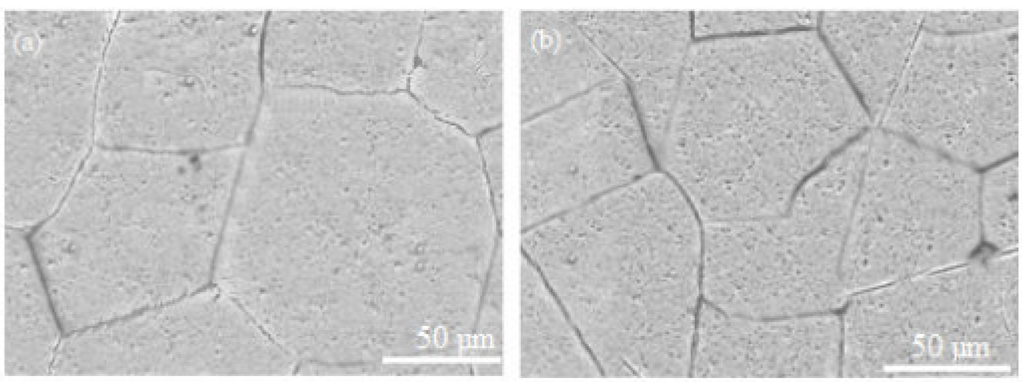

Figure 2: Optical microstructures of TNZT alloy: gravity poured and (b) counter-gravity poured.

The counter-gravity pouring of TNZT alloy in investment shell moulds has yielded fine grain structure in the castings. Also, the mechanical properties of TNZT alloy are superior with counter-gravity pouring. The tensile curves of TNZT alloys exhibit double yielding phenomenon. Gravity and counter-gravity poured TNZT alloy exhibited the modulus of elasticity 53.52 GPa and 55.96 GPa, respectively.

References:

1. A. C. 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, Vol.41, No.10, pp.3-8, 1995.

2. A. C. Reddy, H.B. Niranjan and A.R.V. Murti, Optimization of investment shell mould using colloidal silica binder, Indian Journal of Engineering & Materials, Vol.03, No.05, pp.180-184, 1996.
3. A. C. Reddy, Coal flyash – environmental impact and utilization: A review, Journal of Engineering Advances, Vol.9, No.2, pp.48-49, 1997.
4. A. C. Reddy, V.S.R.Murti and S. Sundararajan, Regression modeling approach for the analysis of investment shell moulds from coal-flyash, Foundry Journal, Vol.9, No.5, pp.36-40, 1997.
5. A. C. 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, Vol.10, No.8, pp.61-63, 1998.
6. A. C. Reddy, V.S.R. Murti and S. Sundararajan, Control factor design of investment shell mould from coal flyash by Taguchi method, Indian Foundry Journal, Vol.45, No.04, 93-98, 1999.
7. A. C. 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, Vol. 28, No.3, pp. 224-226, 2000.
8. A. C. Reddy, Reuse of coal- flyash in foundry, Journal of Technology Trends, Vol.2, No.1, pp.35-36, 2001.
9. A. C. Reddy, V.S.R. Murti and S. Sundararajan, Bonding mechanism in the coal-flyash ceramic shells, Indian Foundry Journal, Vol.47, No.4, pp.21-25, 2001.
10. A. C. Reddy, V.S.R. Murti, Studies on Lost-wax process using silox binder, X-ISME Conference on Mechanical Engineering, New Delhi, 09-11th December1996, pp.82-86.
11. A. C. Reddy, Characterization of ceramic shells fabricated using yttria as reinforcing filler, National Conference on Advanced Materials and Manufacturing Technologies, Hyderabad, 5-7 December 1997, pp.125-129.
12. A. C. Reddy, S. Sundararajan, Characterization of ceramic shells using rutile (titania) as reinforcing filler at casting temperature, National Conference on Advanced Materials and Manufacturing Technologies, Hyderabad, 5-7 December 1997, pp.130-134.
13. A. C. Reddy, V.S.R. Murti, 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.
14. P. Martin Jebaraj, A. C. 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.
15. H. B. Niranjan, A. C. 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.
16. A. C. Reddy, S. Sundararajan, V.S.R. Murti, Dampening of noise parameters for developing ceramic shell from coal fly ash by Taguchi Method, CEMILAC Conference, Ministry of Defence, India, 20-21st August 1999, B91-95.
17. V.V. Satyanarayana, A. C. Reddy, S. Sundararajan, Reduction of Casting Porosity in the Lost-wax process choosing right coating materials by response surface criteria, CEMILAC Conference, Ministry of Defence, India, 20-21st August 1999, B110-114.

18. Ch. Rajana, A. C. 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.
19. S. Madhav Reddy, A. C. 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.
20. A. C. 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.
21. A. C. Reddy, Fluidity and microstructural features of Al-alloy weld beads, Engineering Advances, vol. 15, no.3, pp. 28-32, 2003.
22. A. C. Reddy, V.S.R. Murti, S. Sundararajan, Characterization of dip-coating slurries from coal-flyash for investment vesting process, Foundry Magazine, vol. 18, no. 4, pp. 51-54, 2006.
23. P. Laxminarayana, A. C. Reddy, Design of top risers using parabolic metal flow concept during solidification, National Conference on Advanced Materials and Manufacturing Techniques, Hyderabad, 08-09th March 2004, pp. 51-54.
24. A. C. Reddy, Impact of Boron Coated Investment Shell Moulds on Surface Modification of Hypoeutectic Al-Si Alloys, National Conference on Computer Applications in mechanical Engineering, Anantapur, 21st December 2005, 324-326, 2005
25. G. S. Rao, A. C. Reddy, Fluidity of Al-Cu alloys in fused silica and cristobalite investment shell moulds, National Conference on Advances in Design Approaches and Production Technologies (ADAPT-2005), Hyderabad, 22-23 August 2005, pp. 52-56.
26. A. C. Reddy, S. Sundara Rajan, Analysis of hot ceramic shell behavior at casting conditions, National Conference on Investment Casting, Hyderabad, 28-29 December 2006, pp. 138-142.
27. A. C. Reddy, S. Sundara Rajan, Pattern of cooling contours in the flyash ceramic shell and Al-Mg alloy casting, National Conference on Investment Casting, Hyderabad, 28-29 December 2006, pp. 143-146.
28. Ch. Rajanna, A. Chennakesava Reddy, Effect of Refractory Filler Materials on Defect Formation in Investment Cast Ni-Base Super Alloy, 6th National Conference on Materials and Manufacturing Processes, Hyderabad, 8-9 August 2008, pp. 58-61.
29. P. Laxminarayana, A. Chennakesava Reddy, Quantification of Delta Ferrite in Austenitic Stainless Steel Cast in Investments Shell Moulds, 6th National Conference on Materials and Manufacturing Processes, Hyderabad, 8-9 August 2008, pp. 62-65.
30. S. Madhav Reddy, A. Chennakesava Reddy, Effect of Strontium on Surface Modification of Al-Si Alloys Cast in Investments Shell Moulds, 6th National Conference on Materials and Manufacturing Processes, Hyderabad, 8-9 August 2008, pp. 66-69.
31. A. C. Reddy, Counter-Gravity Casting of IN625 Alloy in Thin-walled Investment Shell Moulds, 6th National Conference on Materials and Manufacturing Processes, Hyderabad, 8-9 August 2008, pp. 54-57.
32. Ch. Rajanna, A. C. Reddy, Characterization of Elektron 21- an Aerospace Magnesium Alloy Cast by Counter-Gravity in Magnesia Mixed Fused Silica Investment Shell Moulds, 7th International Conference on Composite Materials and Characterization, Bangalore, 11-12 December 2009, pp. 126-129.
33. Ch. Rajanna, A. C. Reddy, Hydrodynamic Mode of Bronze Sleeve Bearings Cast by Counter-Gravity in Calcite Investment Shell Moulds, 7th International Conference on Composite Materials and Characterization, Bangalore, 11-12 December 2009, pp. 136-141.