AMMT – 2004
National Conference on Advanced Materials and Manufacturing Techniques, March 08-09, 2004
JTNTU College of Engineering, Hyderabad and CITD, Hyderabad

THERMO-PHYSICAL PROPERTIES OF FUSED SILICA INVESTMENT SHELL MOULDS AT PREHEAT CONDITIONS OF STEEL CASTING

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ABSTRACT: Investment casting shells are subjected to a number of heating cycles during pattern removal, firing, preheating before pouring and finally during solidification. The thermo-physical properties of the shell play an important role during these processes. The investment shell moulds were prepared with fused as a filler material along with colloidal silica binder. The phase transformations of fused silica have remarkable influence on the thermo-physical properties in investment shell moulds at high temperatures.

Keywords: *Investment casting, fused silica, colloidal silica binder, thermal expansion, thermal conductivity, specific heat capacity.*

1. INTRODUCTION

The investment casting process has been used widely for the production of small and medium sized precision castings with complex geometry [1-10]. The investment shell moulds are preheated between 700 and 1000°C just before pouring to keep the metal liquid, allowing complete filling of complex geometry parts. During solidification phase transformations take place in the investment shell mould, which results in small changes in volume leading to cracking of the shell [11-12]. This phenomenon helps in breaking the castings out of the investment shell moulds. Also, the porosity in the shell structure accounts for the considerable variation in the thermo-physical properties of the investment shell moulds. Therefore, it is essential to understand the thermo-physical properties of investment shell moulds before the liquid metal will cast in them. The important properties are coefficient of thermal expansion, thermal conductivity and specific heat capacity of the investment shell moulds.

This research work deals with the measurement of coefficient of thermal expansion, thermal conductivity and specific heat capacity at temperatures ranging from 800 to 1200°C of different compositions of investment casting shells.

Figure 1: Fused silica investment shell mould and specimens for testing.

2. EXPERIMENTAL PROCEDURE

The investment slurry used for making investment shell moulds plays a major role in determining final properties of the mold such as thickness of the shell, permeability and strength. The colloidal silica binder was used to fabricate the investment shell moulds from fused silica 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. The thickness of shell moulds were 10 mm. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made [14-20].

The measurement techniques used in this study are thermo-mechanical analyzer (TMA), differential scanning calorimeter (DSC) and laser flash thermal conductivity. TMA 4000 thermo-mechanical analyzer (TMA) is designed to accurately measure small changes in the dimensions of a sample as it is heated over a programmed temperature range. The TMA measures the expansion of the sample as a function of its temperature. DSC is used to measure specific heat capacity. DSC (ASTM E1269) measures the amount of energy absorbed or released by a sample when it is heated or cooled, providing quantitative and qualitative data on endothermic (heat absorption) and exothermic (heat evolution) processes [21]. In the laser flash method, a laser pulse of 1ms width or less is used to momentarily heat the front side of a 5-10 mm diameter, 2mm thick discoid sample, and the back side temperature change is measured.

Figure 2: TMA analyzer for the measurement of thermal expansion of investment shell moulds.

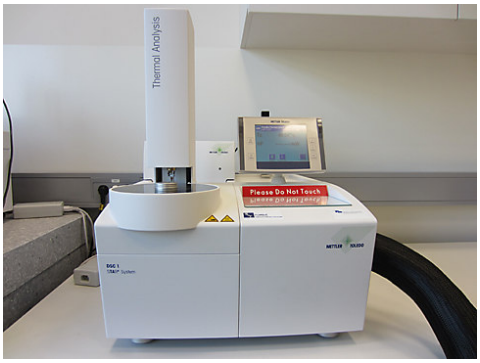


Figure 3: DSC analyzer for the measurement of specific heat capacity of investment shell moulds.

Figure 4: Laser flash method for the measurement of thermal conductivity of investment shell moulds.

3. RESULTS AND DISCUSSION

Parameters like binder content, finder to filler ratio, type stucco sand, porosity and sintering can have a noteworthy effect on thermal expansion, specific heat capacity and thermal conductivity. Thermal expansion (figure 5), thermal conductivity (figure 6) and specific heat capacity (figure 7) increased for all investment shell moulds with the increase in the temperature.

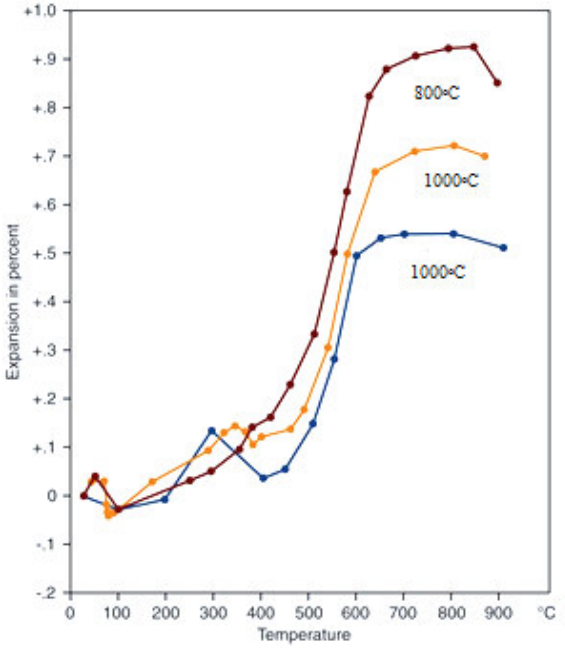


Figure 5: Thermal expansion of investment shell moulds.

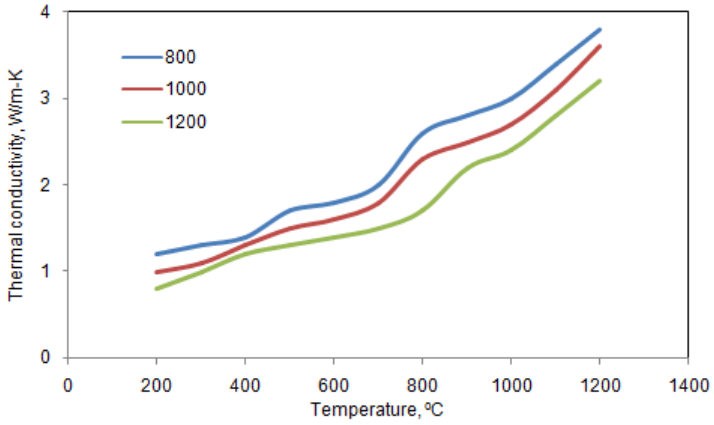


Figure 6: Thermal conductivities of investment shell moulds.

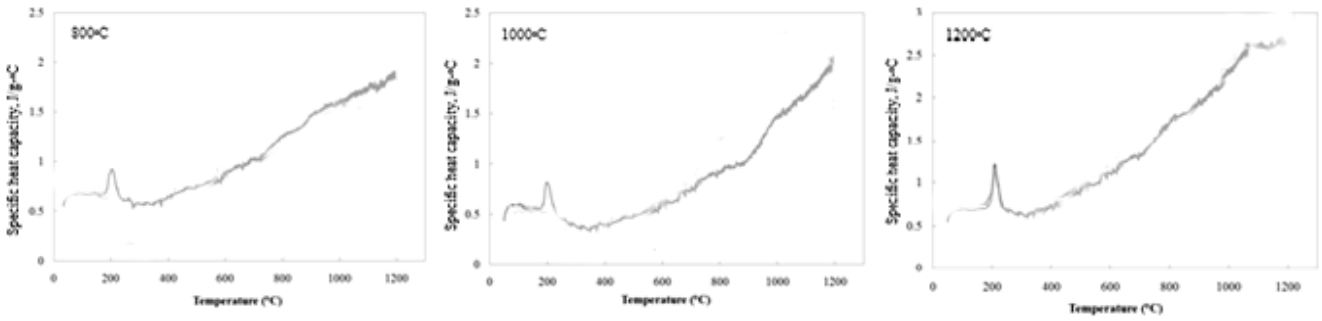
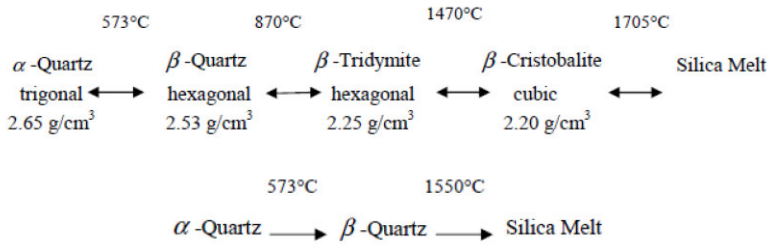


Figure 7: Specific heat capacities of investment shell moulds.

Changes in the thermal expansion and heat capacity of the fired investment shell moulds can be elucidated using silica phase transformation. At atmospheric pressure, α-quartz will transform to hexagonal β -quartz at 573°C, upon further heating it will transform to hexagonal β-tridymite at 870°C and then to β-cristobalite at 1470°C and at 1705°C it melts. If quartz crystal is heated quickly then α-quartz will get converted to β-quartz but after that β-quartz will directly melt. The stability of β- quartz is less than β-cristobalite at melting temperature and hence its crystal structure is easily broken up.



4. CONCLUSIONS

The thermo-physical properties of investment casting shells at high temperatures were successfully measured using the TMA analyzerm laser flash test and differential scanning calorimetry. The phase transformations of fused silica have an important influence on thermo-physical properties of fused silica investment shell moulds.

REFERENCES

1. 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.
2. 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.
3. 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.
4. 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.
5. 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
6. 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.
7. 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.
8. 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.
9. 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.
10. 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.
11. M.J. Hendricks, D.R. Engelhardt, Thermal Conductivity and Heat Transfer Measurement for Ceramic Shell Molds, 8th World Conference on Investment Casting, 28-30 June 1993, London Hilton, Vol. 2, paper # 11.
12. H. Huang, J.T. Berry, X.Z. Zheng, T.S. Piwonka, Thermal Conductivity of Investment Casting Ceramics, 37th Annual Technical Meeting : Investment Casting Institute 1989.
13. 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.
14. 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.
15. 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.
16. 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.

17. 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.
18. 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.
19. 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.
20. ASM Handbooks, Vol. 15 Castings, Investment Casting, Design Advantages of Investment Castings.