Effect of Mold Temperature on Microstructure and Hardness of an As-cast Biocompatible Cobalt Base Alloy

H. Ghazvinizadeh, M. Meratian, A. Kermanpur, M.H. Fathi.
Department of Materials Engineering, Isfahan University of Technology, 8415683111, Isfahan, Iran.

Statement of Purpose: The Co-28%Cr-6%Mo (ASTM F-75) alloy is widely used as a biocompatible alloy in medicine for manufacturing implants. Mechanical properties of this alloy are strongly related to the microstructure (C. Montero-Ocampo. Metal. Mat. Trans. A. 1999;30A: 611-620.). In this study, effects of mold preheating temperature on as-cast microstructure of this alloy were investigated in the solid investment casting process. The size, morphology and fraction of secondary phases in microstructure of this alloy were investigated.

Methods: The samples were prepared in rectangular shape with dimension of 3x12x12 mm by solid investment casting process. Several mold preheating temperatures of 550, 700, 850 and 1000 °C were selected in a given superheat. The samples were then characterized by optical microscopy, electron microscopy and macro hardness test. Quantitative determination of grain structure and carbide size was carried out using the Image Tool program.

Results: Figure 1 shows the as-cast microstructure of this alloy. The alloy in as-cast condition presents a microstructure consisting of a strongly cored dendritic matrix with a distribution of dispersed carbides that presented three different morphologies.

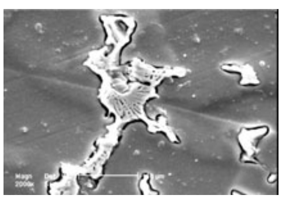

Figure 1. SEM micrograph of as-cast ASTM F-75 alloys.

The eutectic carbide with lamellar morphology was formed at grain boundaries. This lamellar component was formed by interlayer plates of $M_{23}C_6$ carbide and possibly σ phase or both α and σ phases. The other carbide morphology is blocky and were found to have precipitated within the dendritic matrix. The last carbide morphology is the blocky one, but it is precipitated at the interface between the matrix and the eutectic carbide. The chemical composition of these carbides was similar to the $M_{23}C_6$ (M = Co, Cr and Mo) carbide.

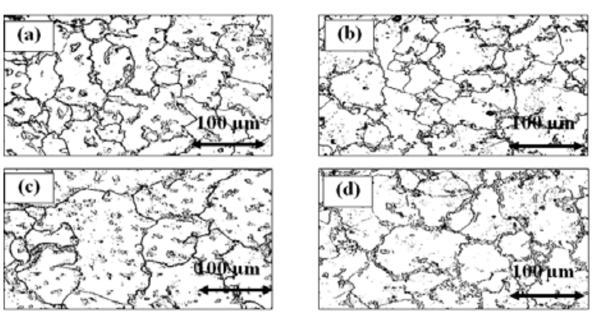

Figure 2. Microstructure of as-cast F-75 alloys after preheating at: (a) 550 °C, (b) 700 °C, (c) 850 °C and (d) 1000 °C.

Figure 2 shows microstructural changes induced by different mold temperature. As the mold temperature increases, morphology of carbides tends to blocky shape precipitating at both carbide-matrix interface and denritic matrix.

The change in precipitation morphology is probably as a result of the change in the nucleation and growth mechanisms responsible for the carbide precipitation reactions. The dependency of eutectic and blocky carbide volume fraction on mold preheating temperature is illustrated in figure 3. It may be associated with the increase in the number of nuclei activated by the higher undercooling caused by higher differences between the pouring temperature and the mold preheating temperature.

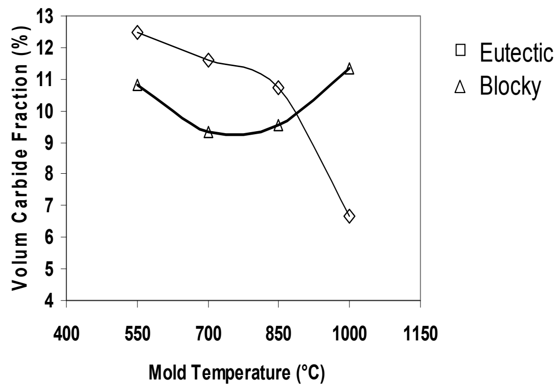

Figure 3. Effect of mold preheating temperature on the volume fraction of eutectic and blocky carbides.

Figure 4 shows the effect of mold preheating on the sample hardness. In general, the alloy hardness was increased with preheating temperature.

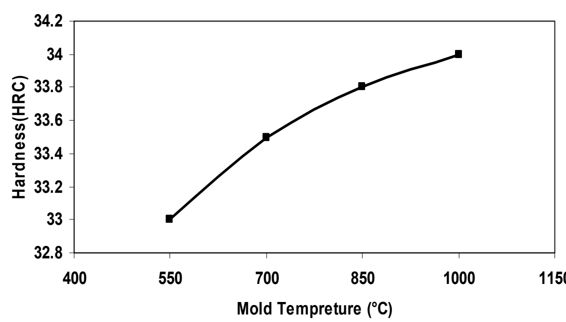

Figure 4. Effect of mold preheating temperature on the hardness of as-cast alloys

Conclusions: The main effects of mold temperature were manifested as a removal of the extensive interdendritic carbide precipitation and appreciable break up of the dendritic grain structure. This led to the development of a homogeneous equiaxial grained structure and the consequent improvement in hardness. The size of carbides also increases as the mold preheating temperature increases. The best microstructure with nearly fine grains and desirable mechanical property with homogeneous distribution of secondary phases was obtained in 850 °C mold temperature.