Lamellar formation in Co-Cr-Mo-C Alloys by Discontinuous Reaction

R. Rosenthal[(1)*], I. S. Bott[(2)], R. B. Cardoso[(1)], R. Paranhos[(1)]

(1) LAMAV, Universidade Estadual do Norte Fluminense, Brasil, e-mail:ruben@uenf.
(2) DCMM, Pontifícia Universidade Católica do Rio de Janeiro, Brasil
* Corresponding author

Abstract: The formation of grain boundary carbide lamellar cells in Co-Cr-Mo-C alloy has been investigated. Cells of two main lamellae thickness have been observed (Figs. 1 and 2). It is proposed that they are formed by discontinuous rather than by eutectoid reaction. Aging heat treatments have been applied at different temperatures attempting to remove the cells by a receding movement of the grain boundary.

Cobalt alloys employed in the manufacturing of orthopedic implants were reported to present low ductility in the as-cast state, due to the presence of grain boundary lamellar carbides of possible eutectic or eutectoid origin [1, 2]. The lamellar structure could be suppressed by spheroidization followed by dissolution during high temperature exposure. However, the improvement in ductility could be to the expense of tensile strength, as the amount of blocky carbides would also decrease. The present work identified that the lamellar cells in Co-Cr-Mo-C alloy were formed by discontinuous reaction; in such case they could be possibly suppressed by a receding movement of the grain boundary during intermediate temperature exposure. Aging treatments at several temperatures have then been presently applied in order to identify a temperature range where a receding boundary movement would occur. The sample examination has been carried out by x-ray diffraction- XRD of extracted particles, scanning electron microscopy- SEM and energy dispersive x-ray microanalysis– EDS. For the SEM observation the samples were submitted to a metallographic procedure that preferentially etched the cobalt-base matrix.

The identification of the secondary phases present in the matrix by XRD revealed the presence of $M_{23}C_6$ carbide and σ phase. The examination of the as-cast alloy by SEM showed the presence at grain boundaries and adjacent regions of lamellar cells of both coarse and fine lamellae, as shown in Figs 1 and 2, respectively. At the present work it is proposed that such cells are formed by discontinuous reaction. Such proposition is in agreement with previous observation from directional solidification quenching experiments that revealed the presence of grain boundary lamellar aggregates if cooling rates were under 35°C/min, the formation occurring at a temperature below 990°C, and increasing in amount with the alloy carbon content [2]. The dependence of discontinuous phase formation on the cooling rate from casting had been previously established for other alloy system [3]. Differently from the eutectoid reaction, lamellar formation and growth in Co-Cr-Mo-C alloy would then be controlled by grain boundary rather than volume diffusion. The reasons for the formation of cells of different lamellae thickness have not been clearly established but could be the result of local composition; in Fig. 3, three different lamellae thickness are present at a small grain near a main grain boundary.

The initial results from the aging treatments applied to the cast alloy suggest that heat treating the alloy at the right temperature could lead to a receding grain boundary movement, and offer a way to suppress lamellar cells in order to improve the tensile properties.

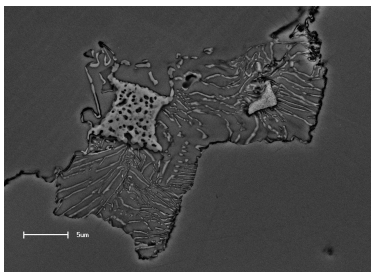

Fig. 1: Coarse lamellae cell formed at the grain boundary. Other features are also present.

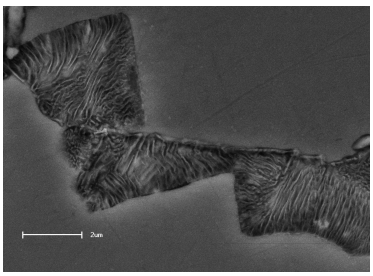

Fig. 2: Fine lamellae cell formed at the grain boundary. Growth apparently occurred at both sides of the boundary.

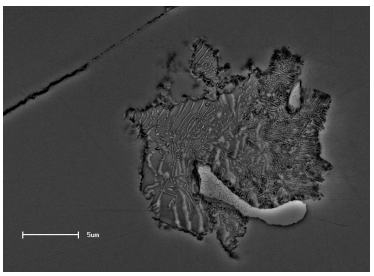

Fig. 3: Lamellae of three different thickness have developed at a small grain near the main boundary.

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