11th International Conference on Advanced Materials
ICAM 2009
Rio de Janeiro Brazil
September 20 - 25

Influence of deformation conditions on dynamically recrystallized grain size of ASTM F 138 austenitic stainless steel biomaterial

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Abstract – Samples of F 138 austenitic stainless steel, used in the manufacture of orthopedic prosthesis by hot forging, were deformed by hot torsion tests at elevated temperatures and strain rates. The flow stress curves displayed a characteristic shape of materials that softening by dynamic recrystallization after some amount of work hardening and dynamic recovery. The microstructure observed in samples water quenched after large deformations indicates that the average dynamically recrystallized austenitic grains size (D) obeys a relationship of the type: $D = AZ^n$, where A and n are constants and Z is the Zener - Hollomon parameter ($Z = (\dot{\varepsilon}.\exp(Q/RT))$).

During hot forging of components with complex shapes, the deformation is not homogeneous, coexisting strain hardening and dynamically recrystallized regions. In the arrest time between deformations, the recrystallized grains grow while the strain hardened regions recrystallize, generating microstructural gradients [1]. The aim of this work is to study the effect of deformation conditions on the dynamically recrystallized grain size of F 138 austenitic stainless steel. Isothermal hot torsion tests was carried out over temperature range 900 to 1200 ^oC and strain rates of 0.01, 0.1, 1.0 and 10 s^{-1}. The samples were heated to 1200 ℃, maintained in this temperature for 300 s, cooled to the test temperature and strained to $\varepsilon = 4.0$. The dynamically recrystallized average grain size was measured in samples water quenched immediately after the end of deformation. The flow stress curves displayed in Figure 1 indicate that the stress increases with the deformation until a maximum, after which the stress level decreases to a steady state. This is the typical behavior of materials that softening by dynamic recrystallization. However, it is worth noticing that the decrease of stress level after the peak is small; at low temperatures the flow stress attains almost a steady state next to the maximum stress point. Calculations of the apparent activation energy for hot working using the relationship $Z = [\sinh(\alpha\sigma)]^n$, where A, α and n are constants, gave Q = 473kJ/mol. This value is slightly superior to that found for AISI 316 stainless steel (436 kJ/mol), which has a very close chemical composition to F 138 [2]; steel F 138 is equivalent to AISI 316 LVM - low carbon vacuum melting. Figure 2 shows the dependence of the dynamically recrystallized average grain size with Z parameter. It can be seen in this figure the average grain size decreases with the increase of Z, that is, with the decrease of deformation temperature and increase of strain rate. The experimental data fit to equation $D = 2.1x10^3(Z)^{-0.14}$, that is similar to that found for other metallic alloys [3]. Taking into account that the average grain size after reheating to 1200 ℃ was close to 80 µm and the ave rage dynamically recrystallized grain size obtained after deformation at T = 900 ºC with $\dot{\varepsilon} = 1.0\ s^{-1}$ was close to 2 µm, the grain refinement attained by dynamic recrystallization is very large and superior than that reached by static recrystallization.

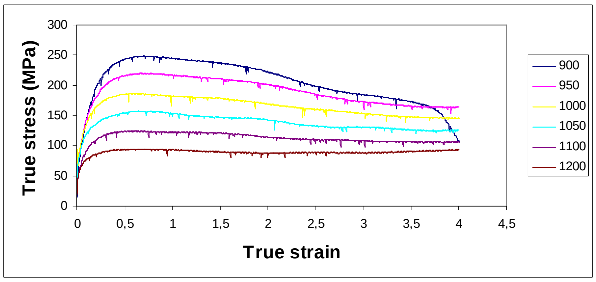

Figure 1: Some flow stress curves obtained by hot torsion tests with $\dot{\varepsilon} = 1.0\ s^{-1}$.

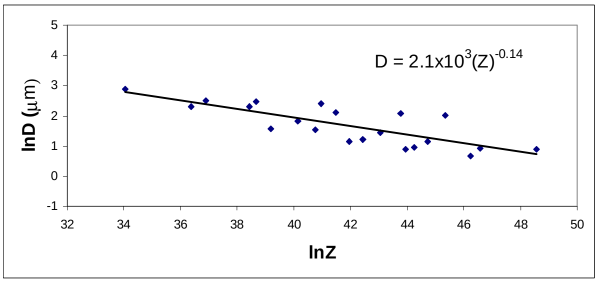

Figure 2: Dependence of average grain size with hot deformation conditions.

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