Microstructural evolution in austenitic stainless steels biomaterials during processing under industrial continuous cooling conditions: Effect of the soaking temperature and interpasse times

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Austenitic stainless steels are extensively used in orthopedic implants. So far, the F138 is the most used. However, due to its high nickel content, low strength in the annealed condition, susceptibility to localized corrosion [1], the high-nitrogen Nb-bearing ISO 5832-9 is being used as a substitute to the F138. Several factors determine the microstructural conditioning. Ultimate materials' properties rely on the combined action of chemical composition and thermomechanical processing [2], both of which impose recrystallization conditions that control final grain sizes and resulting final mechanical properties. Therefore, processing route must be considered. Consequently, the number of deformation passes and processing temperatures must be thought. Determining the correct reheating temperature for processing microalloyed steels is of considerable interest because it defines initial grain sizes, amounts of solid-solution, and volume fraction of precipitates prior processing. Controlling reprecipitation is crucial because size, distribution and volume fraction of new precipitates contribute to grain refinement. During thermomechanical processing, there is competition between recovery, recrystallization, precipitation and solid solute effect. Understanding effective mechanisms can assist obtaining materials with fine and homogeneous microstructures and good properties.

This work aimed to study the impact of the reheating temperature and interpass-times on the microstructural evolution of two austenitic stainless steels (the F138 and the ISO 5832-9), processed under industrial continuous cooling conditions. Both steels were reheated to 1200 oC. The ISO 5832-9 was also heated to 1250oC for comparison. The soaking time was of 300 s. Then, they were cooled down with the rates of 240, 60 and 24oC/min. Samples were deformed with a pass-strain of 0.3, strain rate of 1 s-1, and interpass times of 50, 20 or 5 s. Optical microscopy, Scanning and transmission electron microscopy, and Electron backscattered electron diffraction were used to describe the microstructure. Additionally, microhardness and corrosion tests were also performed. Results revealed that, for 1250 oC, large Z-phase is dissolved preceding the ISO deformation. Some precipitates of TiNbN were not dissolved after reheating. Fine reprecipitation occurred when decreasing the temperature. Hence the steel is likely to behave as a microalloyed steel because precipitates smaller than 50 nm will inhibit recrystallization. Precipitates of Z-phase (CrNbN) and (Cr,Nb)N were observed after processing. Shorter interpass times produced finer grains and precipitates. For 1200 oC, second phases are not dissolved. Large Z-phase were broken while processed, acting as matrix reinforcement in the ISO 5832-9 steel. Processing load increased minimally, thus not compromising equipments. Both steels recrystallized in all passes, producing a more homogenous microstructure and larger grain refinement than in the ISO 5832-9 processed at 1250 oC. The ISO 5832-9 exhibits higher microhardness and better corrosion resistance than the F138 in any processing condition. However, in the case of ISO 5832-9 steel, surely the processing temperature can be decreased, thus reducing operating costs and a material with improved corrosion and mechanical properties.

References:

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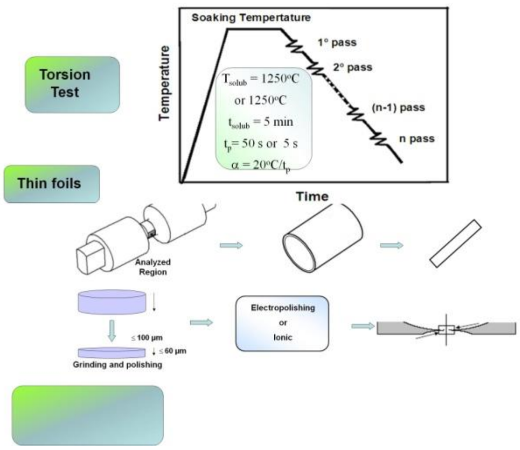
PERIMENTAL PROCEDURE



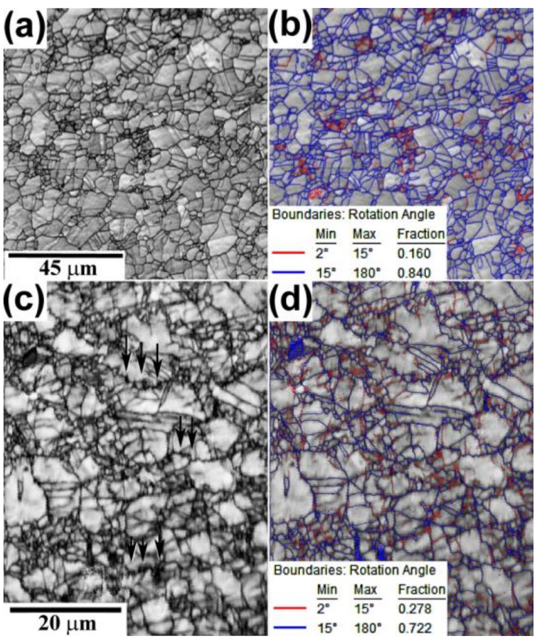


Figure 1 - EBSD from samples with 13 passes, interpass time of 5 s. (a) and b) for F138. (c and d) for ISO (1200°C) with interruption immediately after the straining. Image quality map: (a and c). Orientation Image Mapping (OIM) showing high angle (grains - θ > 15º - blue lines) and low angle (subgrains - 2 < θ < 15° - red lines) grain boundaries: (b and d).

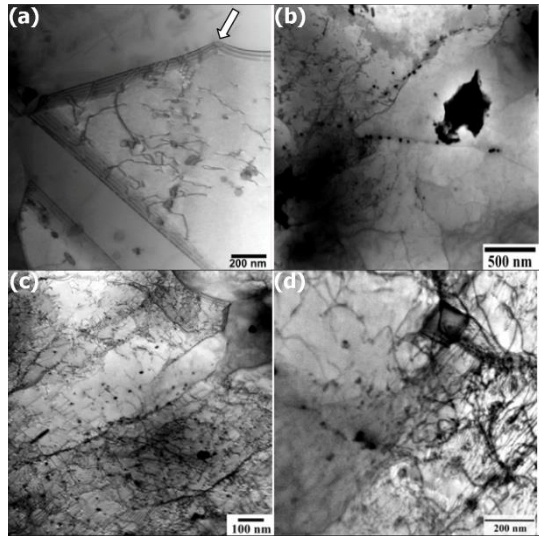


Figure 2 - Thin foils TEM analysis of ISO 1250oC after 13 passes with 20 or 50 s of interpass time: displaying the interaction of the precipitates with grain boundaries (a) and (b); dislocations (c) and (d).

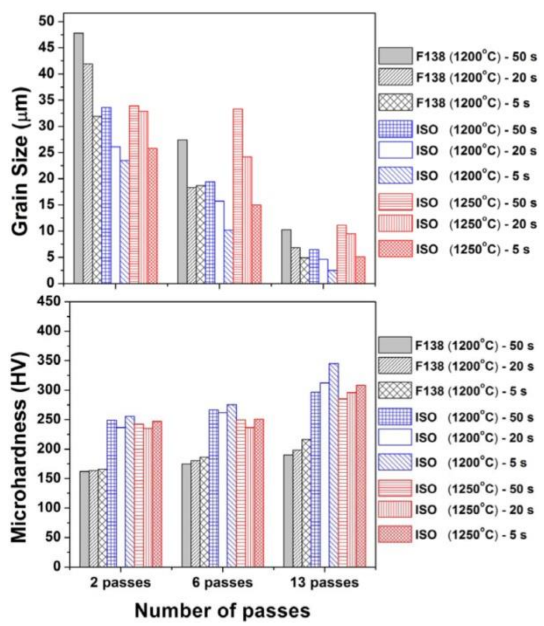


Figure 3 - Grain size evolution (upper) and microhardness (lower) dependence on the pass number and interpass times for F138 and ISO 5832-9 steels