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Influence of Rare Earths Additions on the Microstructure and Hardness of Heat-treated Nanostructured Superalloy Inconel 718.

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The superalloy Inconel 718 is greatly employed in high-temperature applications due to its principal characteristics: high resistance to oxidation and excellent mechanical performance at elevated temperatures; hence, its main uses are in aeronautics and aerospace engines, nuclear power generation and petrochemical industries [1-2]. Recently, research on the effects of rare earth in superalloys has obtained important progress. The employment of these elements like rhenium, hafnium, tantalum, niobium, and ruthenium has increased lately, owing to the need to develop alloys with higher mechanical and microstructural properties. The significant effects on the hardening mechanism by the solid solution of cerium and yttrium have been reported by research works because these elements provoke a lattice mismatch and favor the modification of eutectic phases and carbides, improving the work temperature applications of the superalloys. Other yttrium essential uses have been in research fields such as metallurgy, chemistry and surface engineering. Nevertheless, the use of cerium, lanthanum, neodymium and praseodymium in superalloys has not been thoroughly investigated, even though investigations have reported that these elements possess great potential to enhance the mechanical and microstructural properties in superalloys [3].

The Inconel 718 alloyed with small additions of rare earth (RE) was processed by the mechanical alloying route. The burr of a commercial Inconel 718 alloy and the mixture Misch metal with a purity of 99 % and content of Ce:La:Nd:Pr: 50-55:30-35:5-10:5-10: wt% were employed to form the modified alloys with 0.1, 0.2 and 0.3 wt% of RE elements. A Spex 8000 Mill with a milling device and milling media from hardened steel was used to produce the alloys with 5 h of milling time. The process control agent utilized in the millings runs was N-heptane and argon as an inert milling atmosphere. A ball-to-powder ratio of 5:1 was employed and the powder mass used was 8.5g. The compaction of the obtained powders was carried out in a hydraulic press machine with a compaction pressure of 1.56 GPa for 5 min. The consolidation of the powders was carried out in a Carbolite tubular furnace at 1300 ºC for 3 h in vacuum-sealed quartz ampoules. The standard heat treatment was carried out to the sintered samples: Solution treatment at 980 °C for 1 h with quenched in water at room temperature. Furthermore, two-step aging treatment was made at 720 °C for 8 h, cooling up to 620°C with a cooling ramp of 55°C and holding at 620 °C for 8 h before air cooling to room temperature. The characterization of the samples was made by a Panalytical X'Pert PRO x-ray diffractometer, JSM-7401F Field Emission Scanning Electron Microscope, and LM300 AT Vickers microhardness tester.

Fig. 1 shows SEM-BSE micrographs of the nanostructured Inconel 718 with and without RE additions. The images illustrate rounded (white) and irregular (grey) morphologies phases homogeneously distributed in the γ matrix. The microstructure of Inconel 718 is typically composed of a homogeneous and refined microstructure with oxides, carbides and δ-precipitates (Ni_3Nb) with acicular morphology. The micrographs show that higher RE content favors the significant refinement of the rounded particles (white). The hardness graph of Fig. 2 shows the highest hardness values in all alloys modified with RE additions for all conditions. However, a higher value is observed with 0.2 wt% RE in the aged condition.

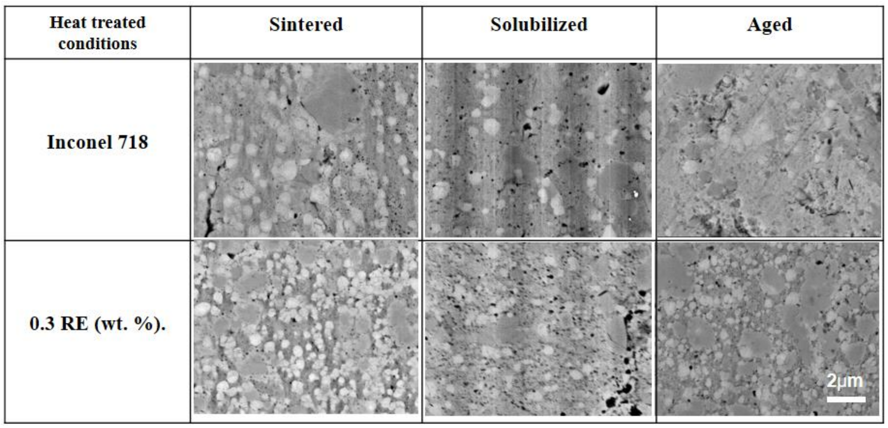

Figure 1. SEM-BSE Micrographs of Inconel 718 and those alloy with 0.3 RE (wt. %) additions in sintered, solubilized and aged conditions.

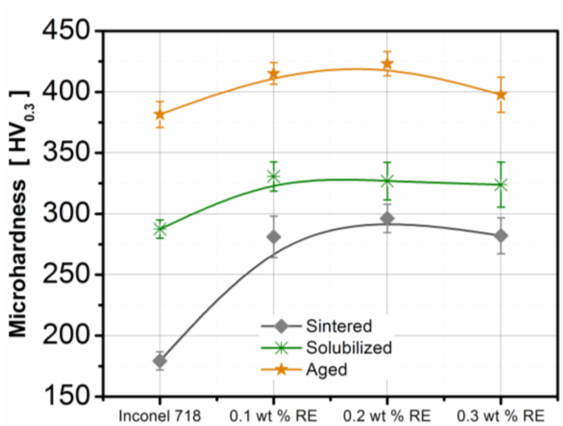

Figure 2. Vickers microhardness values in Inconel 718 and those alloys modified with RE elements additions in sintered, solubilized and aged conditions.

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