The microstructure of a Ni-Cr-Fe alloy after welding processes

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The Ni-Cr-Fe alloy is an austenitic nickel-base alloy which has been used in applications with a combination of excellent mechanical properties and corrosion resistance for the construction of aircraft; thermoelectric turbines; components for chemical reactors, radiation detectors and nuclear reactors [1-2]. Now, efforts occurs in fusion welding processes of this alloy to enhance and maintain good properties when in service. This work shows some aspects on the microstructure observed by TEM obtained in different fusion welding processes, TIG, Plasma - Arc and LASER, applied in a Brazilian Ni-Cr-Fe alloy samples (flat pieces, without adding material, in top unions and single pass) who was initially 91% cold worked and then annealed at 1150 ^{0}C for 30 minutes.

A complete work for the microstructure evaluation was employed optical and electron microscopy (SEM; TEM) and electron microanalysis techniques in the welded zones (WZ) and in the heat-affected zones (HAZ) of the samples. The cracking surfaces (electron fractography) of stress-strain test samples was also investigated by scanning electron microscopy and EDS microanalysis. Some significant differences in structure concerning the three welding processes was observed: After the application of TIG and also Plasma - Arc processes in the Ni-Cr-Fe alloy samples, fine dendritic formations with elongated grain in the welded zone and equiaxed grains in the heat - affected zone was observed, by optical microscopy. After the LASER welding process in the annealed Ni-Cr-Fe alloy samples, very fine grains and a very fine dendritic formation in the welded zone and equiaxed grains in the heat - affected zone was observed, by optical microscopy and the extension of the WZ and HAZ is shorter and with better mechanical properties as compared with the other two earlier mentioned processes.

The transmission electron microscopy (200kV) help us to understand some special details of the final microstructure. The figure 1-a shows some "clusters", most of them, matrix with carbide precipitation, inside a grain of a Ni-Cr-Fe alloy sample after the plasma - arc process, that was observed in the welded zone but, also, near the heat - affected zone. The figure 1-b shows a dislocation network near carbide precipitates inside a grain, after the plasma - arc process, in the heat - affected zone, of a Ni-Cr-Fe alloy sample. In the figure 2, a dislocation network and some carbide precipitates inside and in the grain boundary is shown in a sample of Ni-Cr-Fe alloy submitted to a TIG process in a welded zone of this sample. Normally in a Ni-Cr-Fe alloy sample after a LASER welding process is observed the following situations: Formation of subgrains with a intense dislocation network and some carbide precipitates in the welded zone (figure 3-a). Several crystalline defects including precipitates inside a grain (figure 3-b) and elongated dislocations and fine chromium-carbide precipitates near a grain-boundary (figure 3-c), in a typical region of heat - affected zone was found.

References

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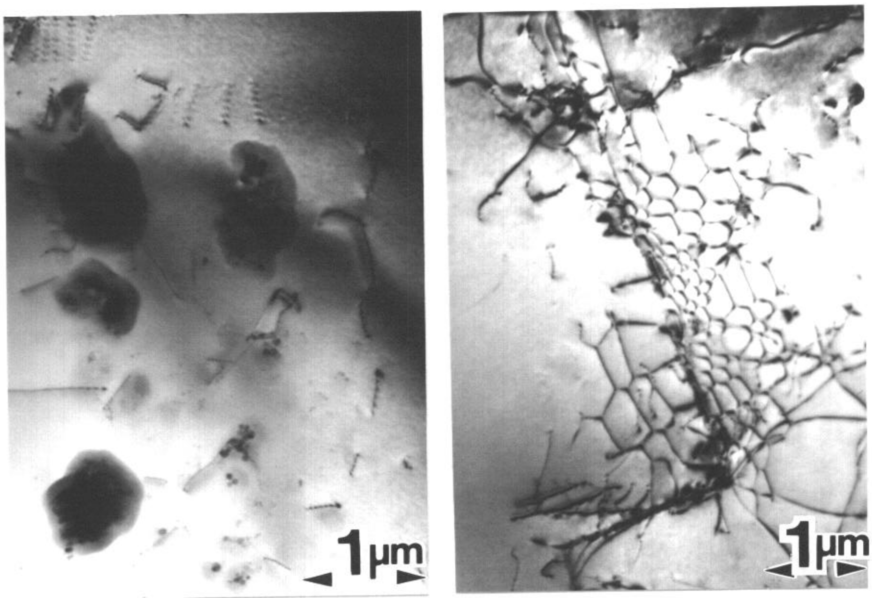

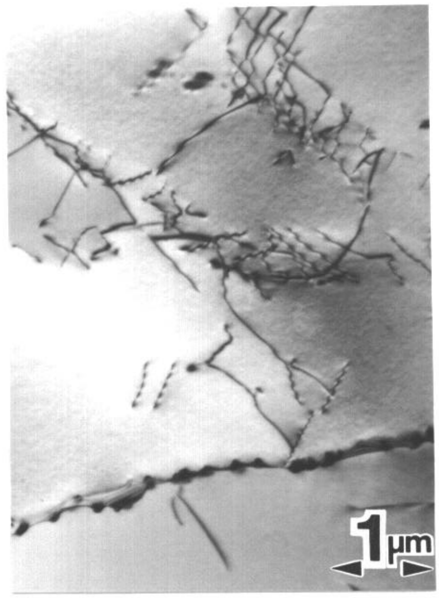

FIG.1- Ni-Cr-Fe alloy welded by plasma-arc process (TEM; 200 kV; Bright Field); (a) Clusters of matrix and carbide precipitates, Zone Axis = (001), (WZ); (b)- Dislocation tangles and carbide precipitates, Zone Axis ≈ (011), (HAZ).

FIG.2- Dislocation network interacting with carbide precipitates and also precipitates in grain boundary of a Ni-Cr-Fe alloy welded by TIG process, Zone Axis = (011), (WZ). TEM; 200 kV; BF.

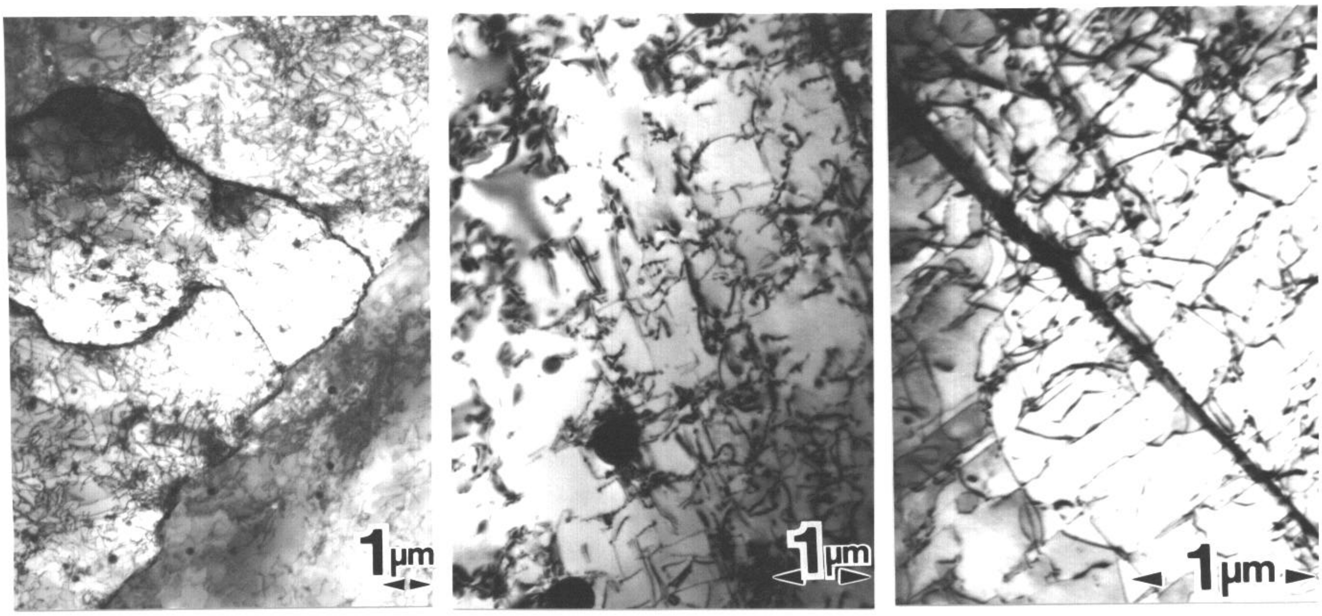

FIG.3- TEM (200 kV, BF) observations of a Ni-Cr-Fe alloy welded by LASER process:

(a) Formation of subgrains; dislocation network interacting with fine carbide precipitates, Zone Axis ≈ (013), (WZ); (b) Crystalline defects inside the grain, Zone Axis = (011), (HAZ); (c) Elongated dislocations and fine chromium-carbide precipitates near a grain-boundary Zone Axis of both grains ≈ (011), (HAZ).