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Microstructural Changes in Aluminum Mechanically Milled Sintered by Conventional Method and Induction

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Aluminum (Al) is widely used in the aerospace and automotive industries due its mechanical properties and low density [1]. One way to improve the mechanical performance of pure Al is by cold work and grain size reduction. The last one can be achieved using high-energy ball milling, this process involves different events such as: particle deformations, cold welding and fracture, resulting in a notable crystal size reduction [2]. In order to obtain solid specimens is necessary some additional processing: conventional sintering (CS) requires high temperature and longer processing time; this generates an adverse increment of grain size [3] or high frequency induction sintering (HFIS) wherein some authors have reported high densification levels with not significant changes of grain size [4].

This work deals with the study of microstructural changes observed in pure Al samples mechanically milled before and after two sintering processes: CS includes cold compaction and pressure-less sintering in a furnace for extended periods of time (hours). In contrast our alternative method deals with induction heating and uniaxial compacting simultaneously reaching high densities in minutes.
The first step was the high-grain refined Al powders preparation using a SPEX-800M mixer/mill during 2 hours in a hardened steel vial. The milled powders were subsequently sintered using the two routes above mentioned: with CS the samples were compacted under 900MPa pressure and sintered at 550°C with a heating rate of 10°C/min for 4 hours and by HFIS where the samples were compacted and sintered (450MPa - 450°C) at the same time for 3 minutes, following a heating slope of 158°C/min.

In the Fig. 1 the micrograph (A) exhibits the refined microstructure obtained from the powders after milling and compaction. With CS process (B) and HFIS (C) the samples porosity is drastically reduced. After HFIS, the refined microstructure obtained after high-energy milling is kept as a result of short processing time and lower temperature use (C). In contrast, using long sintering time and high temperature, the refined microstructure is almost eliminated (B).

TEM specimens were prepared by focused ion beam (FIB), the Fig. 2 presents some micrographs showing a refined microstructure in green sample (a) and sub-micrometric grains. After HFIS, the refined microstructure remains in the material (c). On the contrary, with samples sintered by the conventional method (b) grain size become larger and the refined microstructure is almost eliminated due the long period of sintering time and high temperature use.

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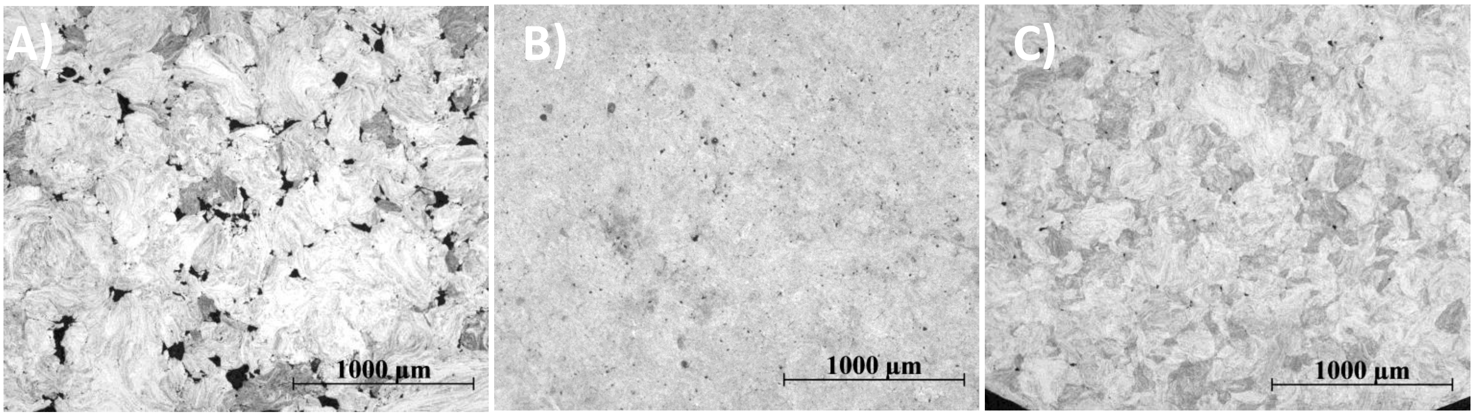

Figure 1.- Optical micrographs of compacted milled Al powder without sintering process (A), CS method (B) and HFIS (C).

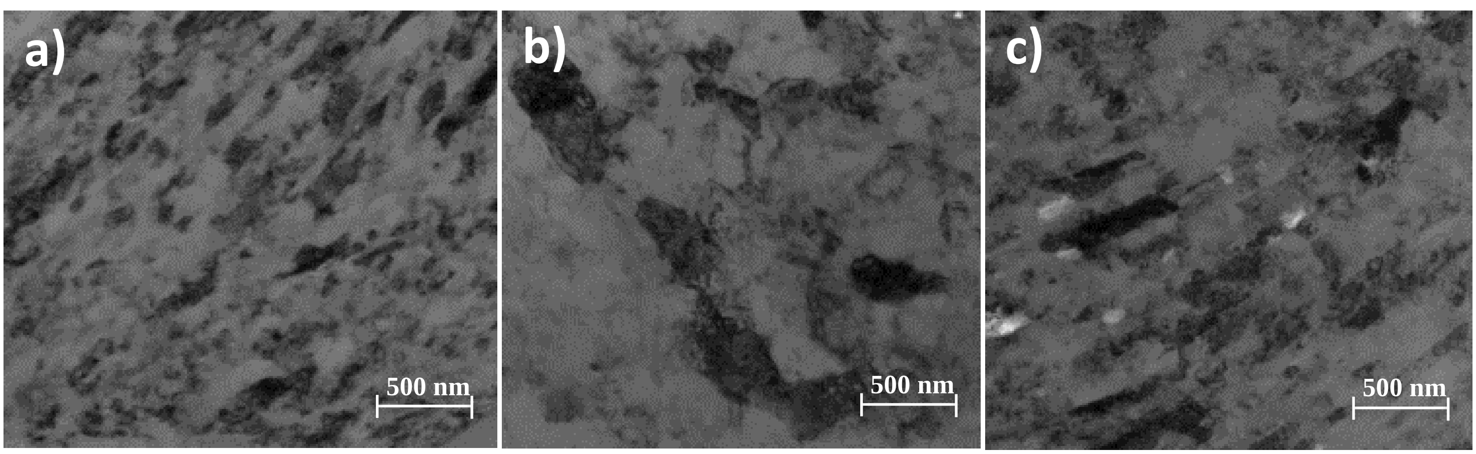

Figure 2.-TEM micrographs of samples prepared by FIB of compacted milled aluminum powder without sintering process (a), conventional method (b) and induction (b).

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