Evaluation of Mechanical Properties of Aluminum Alloy (Al-2024) Reinforced with Carbon-Coated Silver Nanoparticles (Ag$_C$NP) Metal Matrix Composites

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Aluminum matrix composites (AMCs) are emerging as advance engineering materials due to their strength, ductility and toughness. The aluminum matrix is getting strengthened when it is reinforced with the hard ceramic particles like SiC, Al2O3, and B4C etc. Aluminum alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes. The alloys primarily utilized today in transport aircraft are 2024-T4 and the alloys having still higher strength (2014-T6, 7075-T6, 7079-T6 and 7178-T6). Aluminum alloy 2024 has good machining characteristics, higher strength and fatigue resistance than both 2014 and 2017. It is widely used in aircraft structures, especially wing and fuselage structures under tension. It is also used in high temperature applications such as in automobile engines and in other rotating and reciprocating parts such as piston, drive shafts, brake- rotors and in other structural parts which require light weight and high strength materials [1]

Raw materials were Al2024 alloy as the metal matrix and AgC nanoparticles with a mean size of 15 nm as reinforcement agent. Initial Al2024 burhs were produced by machining a commercial solid bar. These coarse powders were mixed with AgcNP in differents concentrations, chemical composition of Al2024 is shown in Table 1 and the addition of the reinforcement particles are show in Table 2. The mechanical milling of powder mixture was performed in a high-energy horizontal attritor mill (ZOZ CM01 Simoloyer), under an inert atmosphere of pure argon gas. The milling container was made of stainless steel and milling media was made of hardened chrome steel, 2 ml of methanol was used as a process control agent to avoid excessive cold-welding of the powder particles. The Al2024-AgCNP composite powders used to prepare the extruded rods were ball milled for 10 hours. A blank (reference) sample without any reinforcement addition was produced under the same conditions for comparison purposes. The milling ball-to-powder weight ratio was set at 20:1.

The behavior of tensile test is presented in Fig. 1, the composites with nanometric particulates exhibited a higher yield and tensile strength compared with Al2024 reference alloy observed tendency is that yield strength and UTS values of samples increases as AgCNP content increases. The experimental values obtained in extrusion condition are higher than those obtained after solution treated at 495°C and water quenched, due extrusion process and because the solution treated does not provide an increase in

resistance to aluminum alloy 2024, a similar behavior was found in the UTS, with the subsequent aging process, the yield strength and UTS value of the composite was higher than that other two conditions due to formation of precipitates $\theta'(S')$.

Figure 2 shows the morphology, distribution and amount of such precipitates in the composites reinforced after aged processing. These small needles are homogeneously dispersed into the alloy matrix; this could indicate that the nucleation of the $\theta'(S')$ precipitates was induced by the aging treatment.

References:

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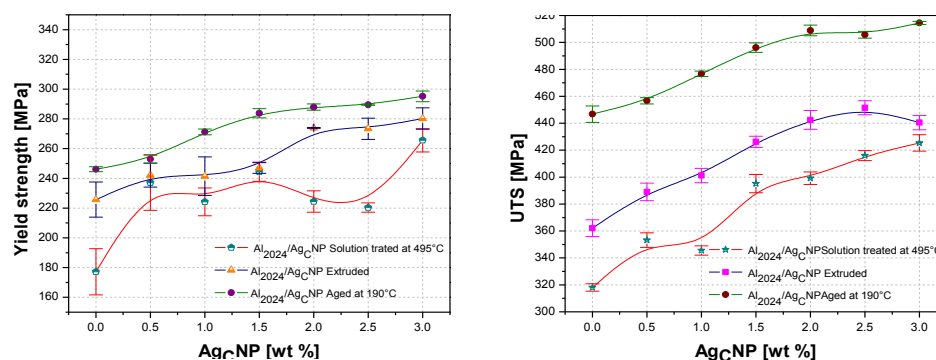

Figure 1. Variation of ultimate tensile strength (UTS) and yield strength of the pure Al2024 alloy and prepared composites as a function of Ag$_C$NP concentration in the three conditions.
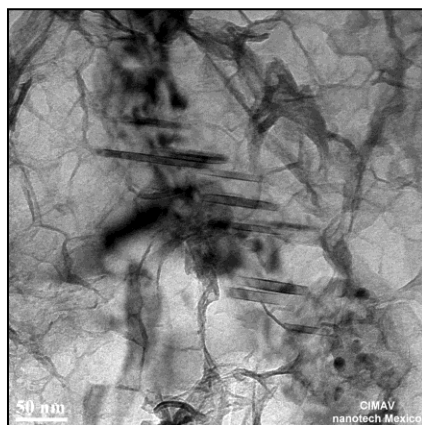

Figure 2. TEM micrograph shows the precipitates $\theta'(S')$ interacting with Ag$_C$NP.