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Assessment of Compressive Strength and Hardness of Al-Gr Composites Produced Using Liquid Homogenization Followed by Cold-Press and SPS

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1- Introduction

There is a controversy over the influence of graphite in aluminum composites on mechanical properties. While many papers report the positive effect of the addition of graphite on mechanical properties of aluminum composites, some believe the reverse.
It is clear that the uniform distribution of reinforcing phase in matrix of a composite is essential to obtain the optimum properties. Reinforcing particle agglomeration causes the loss of mechanical properties. So various processes are used by researchers to distribute reinforcing particles in the composite matrix more uniformly.

In this study, a new method for mixing aluminum and graphite powders, called liquid homogenization, is used. The mixing method prepares homogeneous and uniform composite components in an organic solvent by an ultrasonic device. The objective of this study is to investigate the mechanical properties of aluminum-matrix composites reinforced by different amount of graphite particles prepared by liquid homogenization. Compaction and sintering were performed by two ways: spark plasma sintering (SPS) and cold-press and sintering in a vacuum furnace.

2- Experimental

To produce aluminum composites reinforced by graphite, different content of graphite was added. Aluminum powder was added slowly to the suspension and ultrasonic operation was continued for 4 hours. Pressing and sintering operations were performed on the resulting dried powder in two ways: SPS method and the method of cold-press sintering in a vacuum furnace.

Compression test was performed on the specimens using a Zwick / 2250 according to the standard ASTM E9 with height to diameter ratio of 1.5 at strain rate of 0.03 s^{-1}. Hardness of the specimens was measured by Brinell hardness under a load of 5 kgf. The mean value of five measurements was reported for each sample.

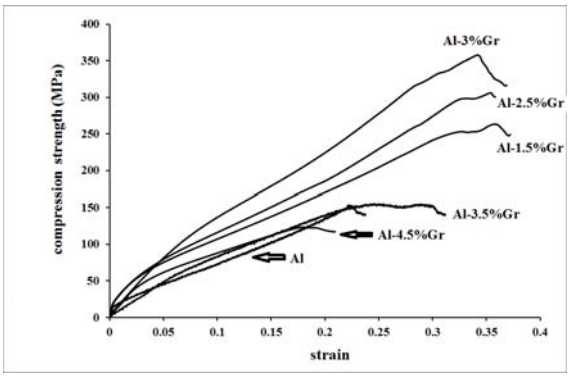
3- Results and Discussion

By the liquid homogenization method used in the current study, it was possible to increase the graphite percentage in the matrix up to 3wt.% without agglomeration. While, the optimum amount of graphite added to aluminum composites by other production methods (1wt.%) is much lower than the optimum value achieved by this method. Above the optimum content, graphite uniformity in the matrix decreases.

Microstructural study of the composites produced by cold-press sintering and SPS indicates that more uniform distribution of graphite particles is obtained by SPS relative to the cold-press sintering.

Results of compression tests for samples fabricated with different percentages of graphite at 590□ and pressure of 28 MPa are presented in Fig. 1a. As can be observed, compressive strength increases with the addition of graphite up to 3 wt.%. The strength decreases with more addition of graphite. The reason can be attributed to the agglomeration of graphite particles and the more porosity and stress concentration sites produced during fabrication of the composites.

Compression test was also performed on the samples produced by liquid homogenization and cold-press in 500 MPa and sintered at 500 °C for 6 hours in vacuum atmosphere (Fig. 1b). According to the results the maximum compressive strength is occurred at 2.5 wt.% graphite content. In other words, the maximum graphite content which can be added to aluminum matrix by cold-press and sintering process (2.5 wt.%) is lower than the amount added to the matrix by SPS process (3 wt.%).



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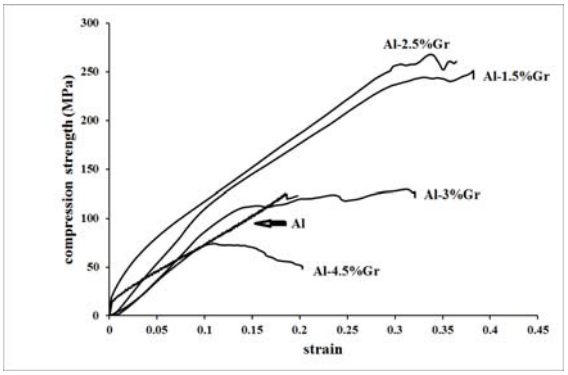

Fig. 1 Compression test curves of pure aluminum and composite samples produced by homogenization in liquid and: a) SPS at a pressure of 28 MPa and b) cold-pressed at a pressure of 500 MPa and sintered at 500 °C

Hardness test results of samples manufactured by SPS at pressure of 28 MPa and manufactured by cold press - sintering in a vacuum furnace are presented in Fig. 2. According to the diagram, it is observed that hardness of the composites increases with increasing graphite content to the optimal value and then decreases. The reason is that in the pressure of 28 MPa, since the distribution of 3 wt.% graphite in aluminum are uniform and homogeneous without agglomeration, the mechanical properties such as hardness are increased. With the increase of graphite over the optimal value, accumulated graphite and agglomeration are growing.

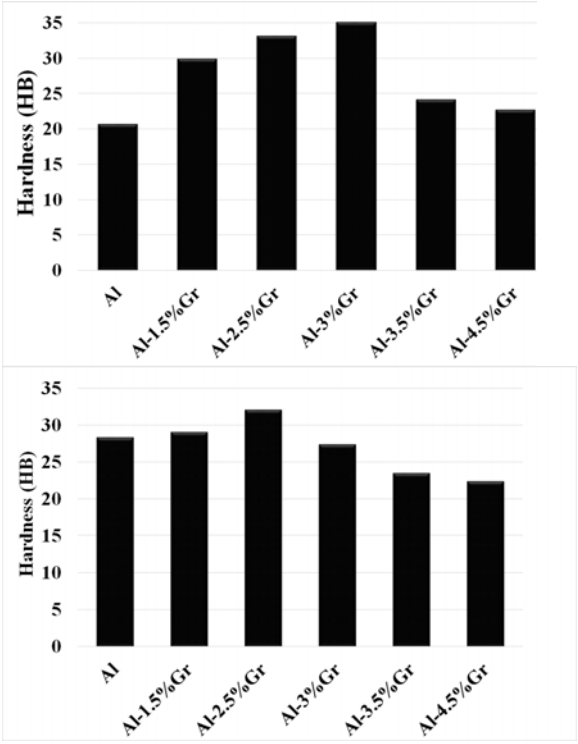

Fig. 2 Hardness of Al-Gr composites with different percentages of graphite produced by homogenization in liquid and: a) SPS at a pressure of 28 MPa and b) cold-press sintering

4- Conclusions

1. Using the method of liquid homogenization and SPS, a uniform distribution of graphite at the optimum content of 3 wt.% was achieved which improved the mechanical properties.
2. Increasing the percentage of graphite to the optimal value (3 wt.%), enhanced hardness value 69.6%, compared to pure aluminum.
3. With the increase of graphite to the optimal value, compressive strength increased to about 206.17% relative to aluminum.
4. Comparison of SPS with cold-press and sintering method showed the efficiency of SPS in producing high density composites with improved mechanical properties.