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Dear Pakdell Noghabi, H., Babakhani, A., Sajjadi, S.A.

We appreciate your active participation in the CCFA-4, also thank you for presenting your paper in this conference, entitled:

**Using Liquid Homogenization in Order to Produce Al-Gr Composite with SPS and Cold Pressed-Sintered in Furnace and Investigation of Microstructure**

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# Using liquid homogenization in order to produce Al-Gr composite with SPS and cold pressed-sintered in furnace and investigation of microstructure

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**Abstract**
To produce aluminum matrix composite reinforced with graphite particles, mixing of pure aluminum and graphite powders by a new method, called homogenization in liquid phase, was performed. The graphite content was chosen from zero to 4.5wt.%. First, the graphite powder was poured into acetone, and was mixed by ultrasonic. The aluminum powder was added to the solution and ultrasonic was continued. Then the filtered mixture was dried in vacuum, with suitable temperature and time. Composite samples were produced using the dried powder by two ways: spark plasma sintering (SPS) and cold pressing and thereafter sintering in a vacuum furnace under different pressure, temperature and time. The microstructure was investigated by OM and SEM. To calculate the porosity and density of the samples the Archimedes method was used. Brinell hardness test were used. Compared to other methods, using this method caused significant improvement in the distribution of graphite particles in the matrix and finally the increasing the hardness .The optimum wt.% of graphite to distribute uniformly in the aluminum matrix and to obtain the highest hardness and lowest prosity was 3wt.%.

**Keywords:** Aluminum matrix composite, Graphite, liquid phase homogenization, SPS - investigation of microstructure.

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# Using liquid homogenization in order to produce Al-Gr composite with SPS and cold pressed-sintered in furnace and investigation of microstructure

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***Keywords*** - Al/Gr composite, liquid phase homogenization, SPS, investigation of microstructure.

## I. Introduction

After steel, aluminum more than any other metal used. Because of the wide variety of industries [1]. However, the use of aluminum for high abrasion resistance and low yield strength is limited [2]. For this reason, the use and production of aluminum based composites (AMC) as an excellent alternative material to achieve better mechanical properties has been expanded [3]. In order to achieve the desired mechanical properties, the reinforcement should be used very fine particles [4]. Decreasing particle size, have a positive influence on composite properties. The need for a composite to show its high efficiency, uniform distribution of the reinforcing phase. Reinforcing particle agglomeration, the reduction in mechanical properties [5,6]. In the SPS, the pressure and sintered powders are done simultaneously. Compared with other methods is done in a shorter period and lower temperatures and extremely high efficiency of this method. In the present study, for mixing powders Al / Gr, a new method was used. I called this method, the method of homogenization in the liquid. This is the first time I got in the Faculty of Engineering, Ferdowsi University of Mashhad. This method is a powder metallurgy method. The preparation and mixing of powders in liquids by ultrasonic devices were used. The composite strength by reinforcing particles is dependent on the following factors: type and particle size, morphology, volume fraction, distributed. Using homogenization method allows uniform distribution of particles in the liquid phase exists.

## II. Experimental Procedure

The as received Al powder with purity of 99.9% and average particle size of 45 μm and Graphite with an average particle size of 10μm that used in this study was. The concentration of graphite in the composites was 0, 1.5, 3 and 4.5% by weight. First, the graphite was dispersed in acetone using ultrasonic with the frequency of 50 kHz for 1 h. Then, the Al powder was slowly added into the solution and sonicated for 4 h to obtain a homogenous mixture. The mixtures were filtered and dried at 90°C for 6 h to form the powder. The mixed powders filled in cylindrical graphite dies with 6 mm diameter and after placing the die inside the SPS apparatus, uniaxial pressure of 28 MPa was applied to the samples. The pressure was exerted to the samples during entire sintering time. Sintering was carried out by applying a pulsed DC current with 7 A/mm² current density for 390 sec under high vacuum ($10^{-2}$ Torr). The temperature variations of die during the process was measured by a placing the thermocouple inside the die and sintered at temperature of 590°C. After sintering, the DC current was turned off and samples cooled naturally. The sintered compact cylindrical sample had a diameter of 6mm and a length of 10 mm. Also, using other method, The mixed powders was pressed at 500 MPa for 5 min to make a cylindrical shape with the ratio of 1:1 between diameter and height. The pressed samples were sintered at 500°C for 6 h in the furnace. The prepared composites were observed by OM and SEM to recognize the distribution of graphite within aluminum. To calculate the porosity and density of the samples the Archimedes method was used. Brinell hardness test were used.

## III. RESULTS AND DISCUSSION

According to observations by OM and SEM (Figure 1), it can be concluded that: In this way, the addition of graphite to an optimal value, the aggregate does not occur. and distribution will be uniform. But with the addition of graphite over the optimum, uniform distribution declined. But yet again the uniformity and homogeneity in comparison with similar samples generated by other methods more. The optimal amount of graphite (graphite aluminum with three percent) are much more efficient than the same graphite composites produced by other methods (in other production methods, optimal value, 1%.).

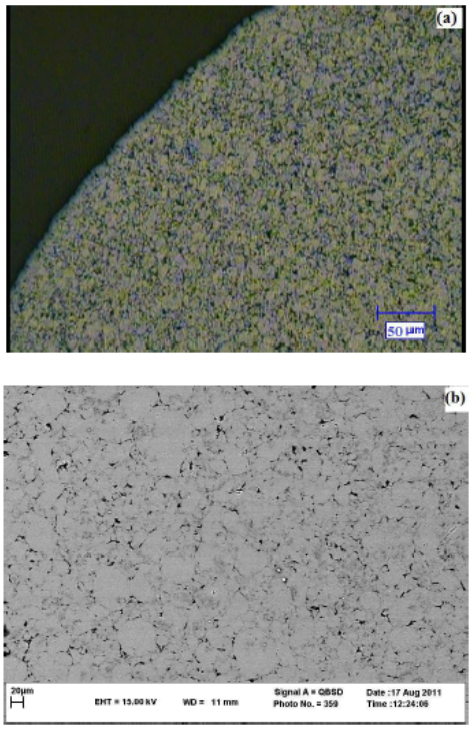


Fig. 1: (a) OM of sintered composites Al-3%Gr by SPS. (b) SEM of sintered composites Al-1.5%Gr by cold pressed-sintered in furnace.

The smaller, more uniform distribution of bulk graphite contributed to the improved mechanical properties. Hardness and porosity values (obtained from measurements and calculations of the density of the Archimedes method), that for pure aluminum and composite samples were obtained, an endorsing optimized content and low porosity (see Table 1 ).

TABLE I: BRINELL HARDNESS DATA FOR THE VARIOUS MATERIALS AND CONDITIONS.

| Material | Condition | Brinell hardness (HB) | Porosity (%) |
|---|---|---|---|
| Al-0%Gr | SPS | 20.7 | 1.77 |
| | furnace | 28.4 | 2.5 |
| Al-1.5%Gr | SPS | 29.9 | 1.4 |
| | furnace | 29.1 | 1.75 |
| Al-3%Gr | SPS | 35.1 | 0.85 |
| | furnace | 32.1 | 1.42 |
| Al-4.5%Gr | SPS | 22.7 | 1.68 |
| | furnace | 22.4 | 4.53 |

As was observed from 1.5 to 3% graphite porosity decreased. Then with the addition of graphite, the porosity increased. It is clear that the size of the aluminum powder, graphite powder has nearly quadrupled in size. Thus, up to three per cent, of graphite in aluminum powders are homogeneously distributed. And pretty much fills the gaps between the aluminum powder. And porosity decreases. But from 3 to 4.5 percent graphite, increasing porosity. Such as graphite began to lump it. As noted earlier, the optimal distribution of approximately three percent.

## IV. CONCLUSIONS

using graphite particles homogenization of liquid and powder metallurgy method can achieve uniform distribution of graphite, which improves the mechanical properties. Also, with the addition of graphite to the optimal value, the hardness is increased. For amounts greater than the optimal value, the reverse process occurs. Also, with the addition of graphite is greater than the optimal value, larger spherical masses of graphite was observed. As is the site of stress concentration. And a decrease in mechanical properties. Also, Compared with other methods, this method eliminates casting defects (such as separation) occurs. And compared to milling, as well as an increase in the uniform distribution of graphite was observed. Which increases the mechanical properties. Also, with the addition of graphite to the optimal value, Porosity decreased. And more than this optimum, increased.

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