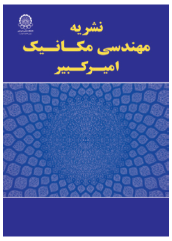

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Investigation of the Microstructure and Mechanical Properties of Aluminum/Brass Composite Produced by Accumulative Roll-Bonding Process

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ABSTRACT: Accumulative roll-bonding process that is one of the severe plastic deformation processes is investigated by the authors in order to fabricate ultrafine grained aluminum/brass composite. In this study, the aluminum composite is reinforced with brass in seven cycles of accumulative roll-bonding at room temperature and without any heat treatment. Tensile strength and hardness of the composite increase strongly in the first cycle. These mechanical properties do not change significantly with increasing the number of cycles. After seven cycles of the process, tensile strength and hardness of the composite compared to the initial Al sheet respectively increased to 46% and 85%. Also, elongation of the composite decreases strongly in the first two cycles and slightly increased in the following cycles. These changes in the mechanical properties during the accumulative roll-bonding process are due to the strain hardening and cold working mechanism in the primary cycles and the grain refinement in the final cycles. The microstructure results of the composite shows that the average values of grains reach 250 nm and the distribution of brass particles in the composite become more uniform with increasing the accumulative roll-bonding cycles.

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1- Introduction

Materials with very fine grains whose crystalline grain size is less than one micron have special mechanical properties and are highly regarded by researchers. Severe plastic deformation techniques are the proper processes for producing nanoscale grain materials [1]. Accumulative Roll-Bonding Process (ARB) process, by applying high strain on the metal sheets, results in the formation of superficial microstructure and high strength [2, 3]. In this process, first, the surface of two sheets of metal with the same dimensions, brush and degrease. Then these two sheets are placed together and rolling is done by reducing the thickness by 50%. The sheet is then cut into two equal parts in a longitudinal direction and these steps are repeated up to several cycles. Since the thickness of the sheet in the process is constant, it can be repeated to high strains to reach sheets of very fine and high strength [4]. Microstructural and macroscopic studies of multilayer metal systems are more complicated than single-metal systems. Due to the difference in mechanical properties, plastic instability in one of the layers occurs earlier and the deformation of the layers further leads to nailing and eventually the hardening of the phase becomes harder [5, 6]. The purpose of this study was to construct aluminum/brass composite with nanoscale grain size and to study the mechanical properties and microstructure of the composite in the ARB process.

2- Methodology

In this study, aluminum alloy 1200 (99.85 wt% Al- 0.48 Fe- 0.33 Mg) with 1 mm thickness and brass alloy 70/30 (70.32 wt% Cu- 29.59 Zn) with 0.5 mm thickness were used as raw materials, the mechanical properties of these materials are given in Table 1. Also, the microstructure of them is shown in Fig. 1.

In order to make aluminum and brass composite with ARB process, the samples were cut in a 200 mm length and 50 mm wide. Then the sheets were decreased in the acetone bath and the brushing operation on the sheet surfaces was performed to create a scratched and rough surface using a circular brush with 0.3 mm diameter of steel wires.

Table 1. Mechanical properties of raw materials

Material	Hardness (Micro Vickers)	Elongation	Ultimate strength (MPa)
Al 1200	85	4.8	246
Brass 70/30	120	70	327

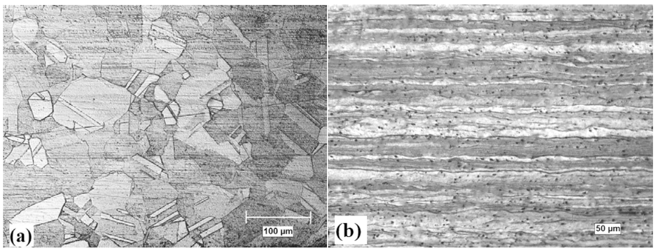

Fig. 1. The microstructure of brass and aluminum sheets used in ARB process (a) brass and (b) aluminum

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Then to produce the first multi-layered composite, the sheets under the rolling process were reduced the thickness of the layers from 2.5 to 1 mm (60% reduction). The composite of the first few layers was cut in the middle and evenly, and the previous steps involve washing with acetone to remove the fats and contaminants present on the surfaces, to brush off the depleted surfaces, to pierce the four corners of the sheets, and to tie them together with the copper wire was carried out, but this time rolling operations were performed by reducing the thickness of 50% to the initial composite. ARB operation was repeated with a rolling machine of 20 tons with rollers of 140 mm diameter at a speed of 67 rpm at room temperature and without heat treatment between cycles for up to six cycles. In order to investigate the mechanical properties of the produced sheets, the samples were cut to standard ASTME8/E8M and an uniaxial tensile test was performed at ambient temperature with a strain rate of 0.01 s-1 using a SANTAM STM250 machine. The Micro-Vickers hardness test was performed by the KOOPA machine under a force of 100 grams and the time of applying 10 seconds on the longitudinal plane of the samples in the rolling direction. The composite microstructure was also studied by TESCAN MIRA3 field scanning electron microscopy.

3- Discussion and Results

According to Fig. 2, after ARB process, the brass layers in the fifth and seventh cycles were distributed uniformly in the aluminum field and a proper bond between the aluminum and brass layers was created. After composite construction, the samples were cut in the direction of rolling and after Electro-etching, they were examined by scanning electron microscopy to determine the grain size. According to Fig. 3, in the fifth cycle, new thresholds have been created due to the application of severe plastic strain and increased dislocation under ARB process, and in the seventh cycle, these thresholds are more orderly and produce grain sizes of an average of 250 nm.

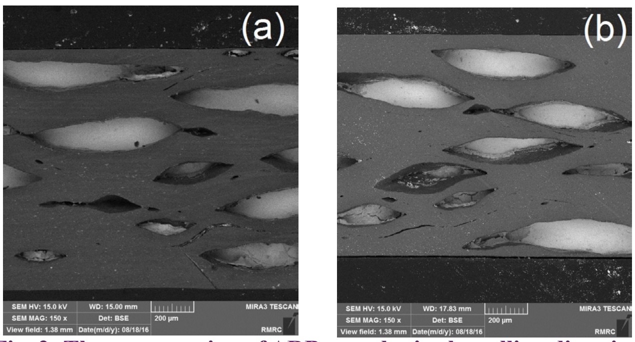

Fig. 2: The cross-section of ARB samples in the rolling direction after (a) 5 and (b) 7 cycles

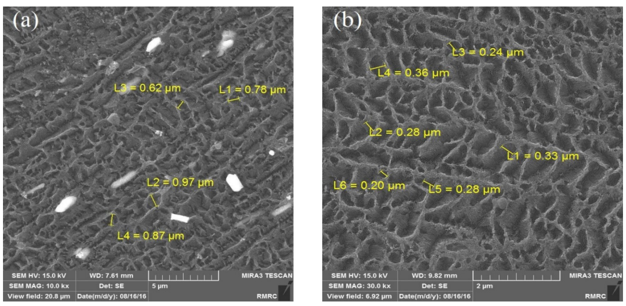

Fig 3: The grain size of the ARB sample after (a) 5 and (b) 7 cycles

The uniaxial tensile test results are shown in Fig. 4. As shown in Fig. 5, the composite strength increased during the first cycle with a high rate and subsequently fluctuated, and eventually increased by 46% in the seventh cycle compared to the aluminum raw material. In the early stages of the ARB process, the increase in strength is due to the high rate of material hardness. As shown in Fig. 6, the percentage of elongation in the first and second cycles was sharply reduced, followed by fluctuations and finally reached 3.48%, compared to the raw aluminum sample of 27.5 percent fell. As the results show, the variations in the tensile strength and elongation are influenced by the two principal mechanisms of strain hardening and grain refinement. According to Fig. 7, Composite hardness increased significantly in the early stages and at the seventh stage ARB process reached its highest level at 158 VHN; it increased about twice as much as the raw aluminum sheet. Work hardening only has an impact on the hardness in the early stages and has little effect on increasing the process steps.

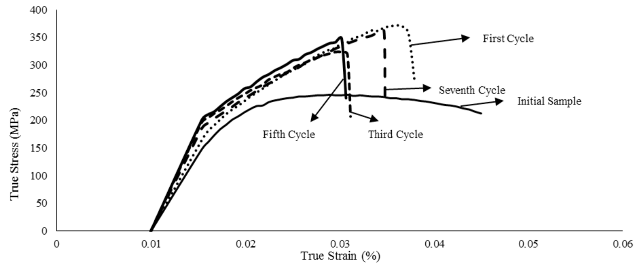

Fig. 4: True stress-strain curves of ARB samples

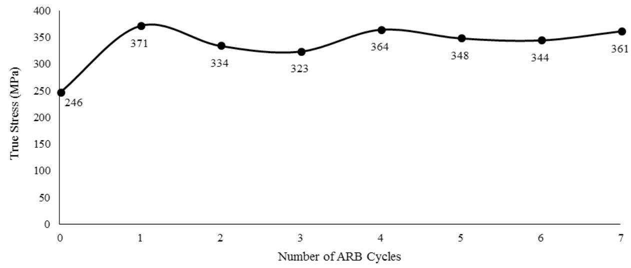

Fig. 5: Tensile strength variations in ARB samples

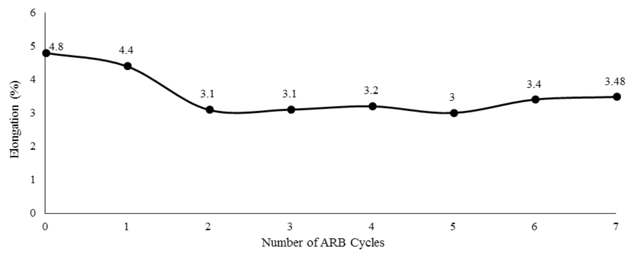

Fig 6: Elongation variations in ARB samples

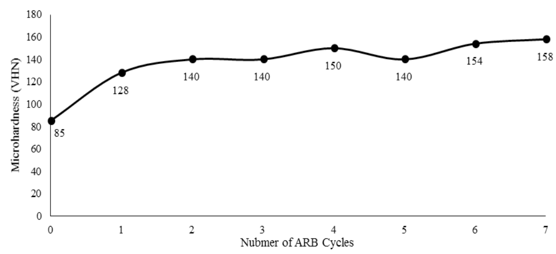

Fig. 7: Hardness variations in ARB samples

4- Conclusion

1. After seven cycles, the ARB process of the aluminum/brass composite with a nanoscale microstructure with an average grain size of 250 nm was constructed.

2. With increasing cycles of ARB, the brass layers are broken and after seven cycles, composites with aluminum and small brass reinforcement layers are distributed uniformly in the field.

3. With increasing cycles of ARB process, tensile strength increases. In the initial cycle, the rate of increment is high and in the subsequent cycles, tensile strength increases at a lower rate. In the seventh cycle of the process the tensile strength reach 361 MPa which is 46% higher than the raw aluminum sheet.

4. The elongation in the first and second cycles decreases steeply and then increases with a slight increase, which is due to the changes in strength. The elongation at the end of the seventh cycle reaches 3.48%, which is 12% higher than the second cycle.

5. Hardness has also changed similar to the tensile strength, with increasing ARB cycles, it increases in the first cycle at higher rates and in subsequent cycles with lower rates and eventually reached 158 VHN in the seventh cycle which is about 85% higher than the raw aluminum sheet.

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