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Accumulative Roll Bonding for Improvement mechanical properties of Aluminum based Composite

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Abstract— The Aluminum has special properties such as light weight, ductile and a lower melting point. It has very suitable for applied as composite material, with ceramic as reinforcement. Accumulative roll bonding (ARB) is part of technology of Severe Plastic Deformation (SPD) that has been developed of manufacturing process for metals, alloys and composites as well. It has a potential becoming an industrial process to produce composite and ultrafine-grained (UFG) metal sheets. In this research, the development of aluminum-based composites is made by SPD technology using the ARB method on aluminum plate sheets with boron carbide (B_4C) as reinforcement, is expected to improve its mechanical properties along with the rules of microstructure analysis. To get of the UFG metallic materials where the mean grain size must be smaller than 1μm are expected can be exhibit excellent mechanical properties. The ARB process consists of multiple cycles of rolling, cutting, stacking and solid-state deformation bonding. Two plates were prepare for the ARB sample process, cleaning uses acetone liquid to prevent attachment of dust and dirt on the surface to be made in contact with other samples. Acetone and grinding to produce a rough surface to facilitate the surface binding process between samples, B_4C powder is sprinkled between the centers of aluminum plate surface and stacked going together.

Keywords—Aluminum, B_4C, Severer Plastic Deformation (SPD), Accumulative Roll Bonding (ARB) and Composites.

I. INTRODUCTION

Aluminum is the non-ferrous of metals for very wide applications. It has special properties such as being light weight, ductile and a lower melting point compared with many other common engineering materials. Aluminum is very suitable for applied as composite material, with ceramic as reinforcement [1-2]. Composite is a combination of two or more materials to improve the mechanical and physical properties. Strengthening and improvement of mechanical and physical properties on element of metal matrix and ceramic reinforcing materials can be applied by new technology of manufacturing process, namely Severe Plastic Deformation (SPD) [3]. Accumulative roll bonding (ARB) is part of technology of SPD that has been developing for manufacturing processed. It has a potential for becoming an industrial process for producing composite and ultrafine-grained (UFG) metal sheets [4]. Generally UFG materials have higher mechanical properties than conventional materials, which have grain sizes larger than of micrometers. A UFG polycrystalline material is defined as the material having grains with an average size of less than 1μm [3-4]. The ARB process has several advantages over other than another processes, such as: High forces forming facilities, not needed expensive mold, high productivity rate and the amount of material to be produced is not limited. However, ARB process limitations are only used for sheet-shaped products [5]. In the present study the effect of ARB used to get high mechanical properties of aluminum/B_4C based composites. Using one cycle is expected to increase the mechanical properties and by observation of TEM on microstructure, it will be traced how the grain boundary and diffusive process between aluminum as matrix and B_4C as the reinforcement was investigated. The morphology of the reinforcement–matrix interphase and mechanical properties of the composites were studied. EDS testing is done to find out the elements in aluminum as received and aluminum based composites process by ARB. The element that is present of aluminum as received compare with aluminum after adding an reinforcement (composite) is traced to distinguish what percentage is in the materials.

II. MATERIALS AND PROCEDURE EXPERIMENT

In the development of composite materials processed by ARB, used aluminum as matrix and B_4C as reinforcement. Combination of high stack of roll-pressing capable of producing better properties material. ARB process for get of high-strength aluminum based composite, the addition of B_4C elements and microstructural control give a effect on enhancing of hardness. To get of the UFG metallic materials where the mean grain size must be smaller than 1μm are expected to exhibit excellent mechanical properties. ARB process consists of multiple cycles of rolling, cutting, stacking and solid-state deformation bonding. It is one of the effective SPD processes which can produce UFG metallic material massively. The sample form preparation shown in fig. 1.

Two plates were prepare for the ARB sample process, by cleaning the surface area used a wire brush to remove residual oxides and impurities. Cleaning uses acetone liquid to prevent attachment of dust and dirt on the surface to be made in contact with other samples. After being given acetone and then grinding to produce a rough surface to facilitate the surface binding process between samples, B_4C Powder is sprinkled between the centers of the Aluminum plate surface and stacked going together. Then do pre-heating by temperature of 300-450ºC, with 60 minutes holding time used muffle furnace. After the pre-heating then the sample was done by cold rolled process with 50% reduction. The

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schematic illustration of the ARB process for manufacturing of composite is shown in Fig. 2.

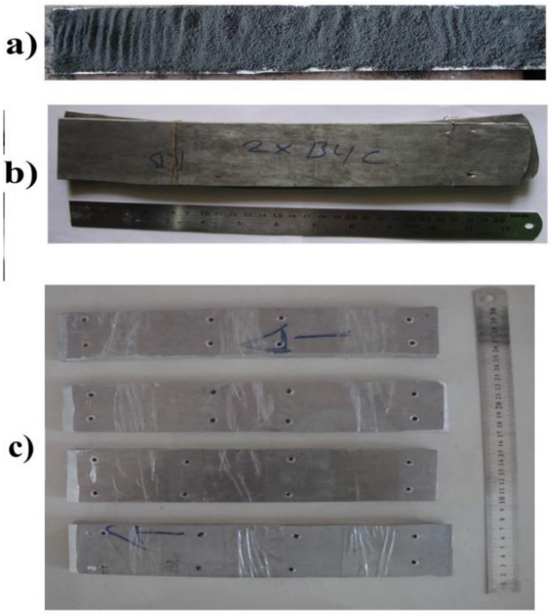

Fig 1. The aluminum/B_4C based composite form preparation: a) The B_4C is poured onto the surface of the aluminum plate b) Stacking 2 aluminum plates c) Result of Composite based on aluminum/B_4C.

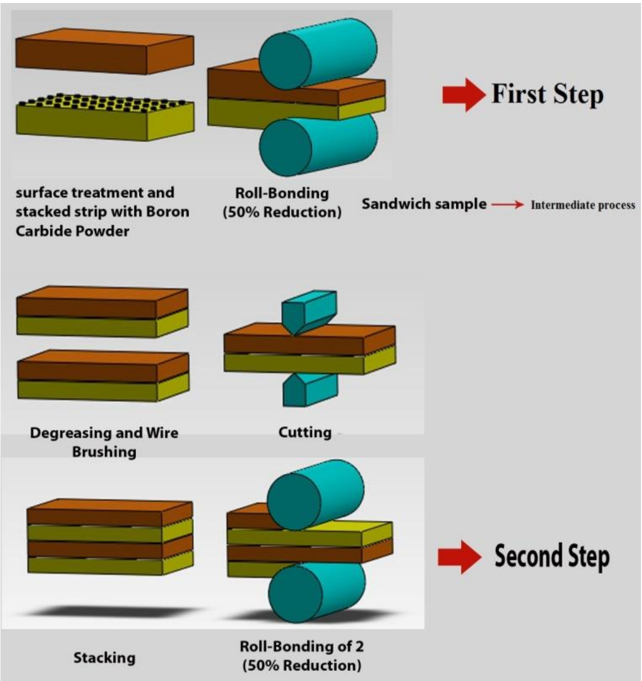

Figure 2. Schematic of ARB process on Aluminum-based composite material

III. Microstructure Analysis

The microstructure of Scanning Electron Microscope (SEM) on the ARB process can be seen in Figure 3. a) As a result of the ARB process without reinforcement, there has not been any effect on the grain, not yet seen the morphological changes of the grains. In figure 3. b) there is the addition of B_4C on aluminum, there is a macro crack in the middle interface area. Some of area find diffusion that binds between Al as matrix by B_4C as a reinforced at the edge on the interface boundary, this is evidenced by the TEM results in the Fig 3.c) which is a contact field of B_4C powder as an reinforce against on aluminum plate. Diffusion on technology of SPD does not require melting point and wetting agents as well, for surface binding processes. However, in a combination of several high forces it can produce inter-diffusion in aluminum as a matrix, since some of the deformation of forces on the aluminum surface will produce bonds between aluminum as the matrix on B_4C becomes strong.

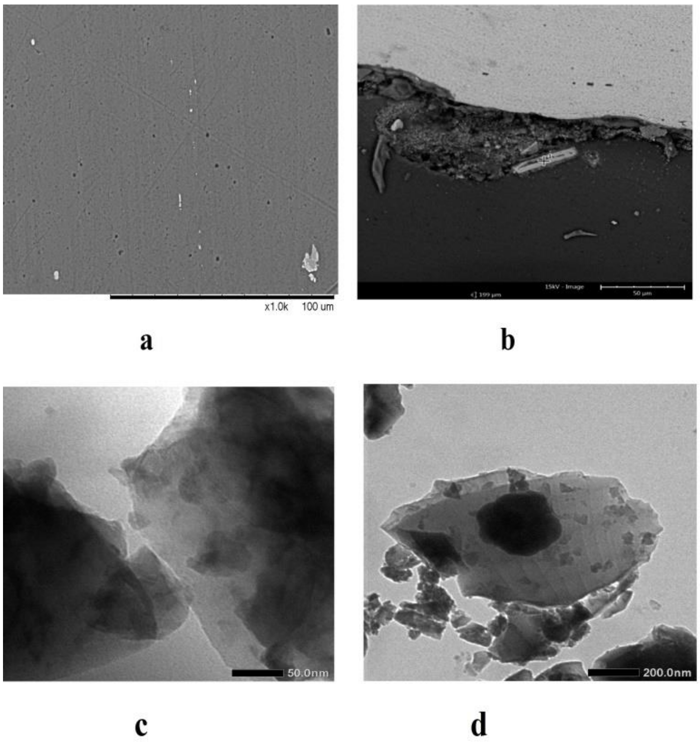

Figure 3. Result of Microstructure a) SEM aluminum as received b) SEM Composite of Al/B_4C c) TEM the contact area of Al/B_4C d) Indication of the diffusion part, B_4C attached on Aluminum surface.

Cycle of the ARB processes introduces a significant plastic deformation of the mating surfaces between stacking of Aluminum of plates, which leads to the fragmentation of the reinforced on the powder form [4]. In figure 3.d) show black B_4C powder attached to the surface of the aluminum plane plate, it indicates an inter-diffusion to the matrix and reinforcement. The diffusion of the ARB process is preceded by a particle shift or referred to as delamination. The refinement of nano-fibers is accompanied by the reduction of the porosity of composites, different mechanical properties of the matrix and reinforcement result in the fracture of the

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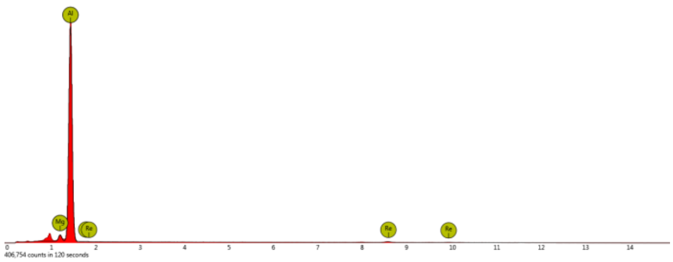
alumina layer, followed by the separation of fragments of alumina during plastic deformation. Plastic deformation and compacting temperature above recrystallization results in the grain growth. The delamination and development of defects in the cold region occur due to the excessive shear strains in the material during ARB. The reinforcement was blocks the contact area of the roll accumulation can lead to exfoliation at the interface area so that this gives rise to a uniform porosity as small pores in the interfacial region.

In EDS analysis, aluminum dominates compositions in materials, driven by magnesium, copper and carbon, the elements are alloyed in aluminum. B_4C is a compound, so in a carbon read search as an element. The element mapping reveals the distribution of elements in the sample, the carbon element fairly uniformly distributed based on the powder element interrupting the movement of the grains in the rolling process, as it leaves the crack in the process. Visible on elements mapped at pixel resolution showing elements present in aluminum-based composites.

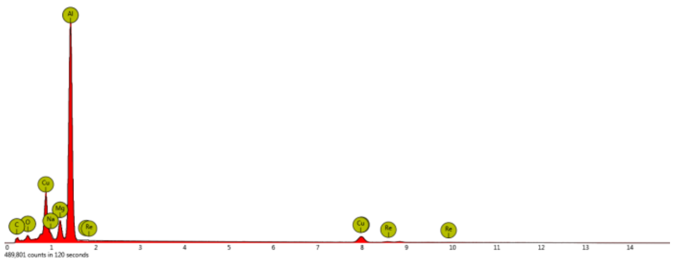
TABLE I
THE RESULT EDS OF ALUMINUM NO REINFORCEMENT



Element Number	Element Symbol	Element Name	Confidence	Concentration	Error
13	Al	Aluminium	100.0	85.0	0.2
12	Mg	Magnesium	100.0	3.3	1.4
75	Re	Rhenium	50.0	11.7	3.5

TABLE 11

THE RESULT EDS OF ALUMINUM BASED COMPOSITES WITH B_4C AS REINFORCEMENT



Element Number	Element Symbol	Element Name	Confidence	Concentration	Error
13	Al	Aluminium	100.0	64.6	0.2
12	Mg	Magnesium	100.0	7.3	0.9
29	Cu	Copper	100.0	10.6	1.2
11	Na	Sodium	100.0	5.2	1.5
8	O	Oxygen	100.0	6.1	2.6
6	C	Carbon	100.0	1.2	3.6
75	Re	Rhenium	50.0	5.0	4.2

Aluminum as received (no-reinforcement) produces smooth surface bonding, after addition of reinforcement, contact area between aluminum and B_4C, partly leaving porosity and producing several agglomerations of particles in the composite matrix produced by the ARB process by pre-heating [9]. Table I shows 85% aluminum composition with a mixture of Mg and Rhenium, there is no alloy in the microstructure as a composite reinforcement, so the composition is minimal, after the addition of B_4C type reinforcement, aluminum composition decreases by 64.6% resulting in the addition of other compositions such as: Copper, Sodium, Oxygen, Carbon and Rhenium are shown in table II. Addition of B_4C as reinforcement to aluminum-based components will result in improvements in properties [10]. Compared with similar studies [6], composites by ARB process with Al_2O_3 as reinforcement produced a hardness of 103.2 HV10 while B_4C as reinforcement on aluminum processed by ARB increased mechanical properties of 107.3 HV10, this was accompanied by a finer grain refining of 1.1µm while Al_2O_3 of reinforcement amounting to 1.3µm. In another study [9] B_4C was able to smooth matrix grain which could improve of mechanical properties.

IV. MECHANICAL PROPERTIES ANALYSIS

The hardness Aluminum no-reinforced was 50.5 HV10 corresponding with theoretical density is 2.89 gr/mm^3 presented in table 1. After the addition of B_4C as reinforcement hardness going up to 107.5 HV0 accompanied by a decrease in density till 2.76 gr/mm^3. Compared composites by Al_2O_3 as reinforcement [6], the hardness down to up 103.2 HV10 with density 2.79 gr/mm^3. The decline of hardness is accompanied by a decrease in density and a decrease in grain size.

TABLE II
TABLE MECHANICAL PROPERTIES

Materials	Hardness (VH10)	Density (gr/mm^3)	Grain Size (µm)
Aluminum as received	50.5	2.89	1.4
Al/B_4C	107.3	2.76	1.1
Al/Al_2O_3	103.2	2.79	1.3

The hardness will be optimum if the roll area is affected by heat zone, because in the hot region, the delamination mechanism will change the morphology of the grains, so as to make the matrix and reinforcement grains have stronger binding interfaces. Mechanical properties, hardness are affected by the bond interphase. The study of the microstructures revealed some differences in the size and morphology of the defects at the interphase of hot and cold regions [4-5]. In cold regions then the hardness will tend to decrease because it does not occur grain binding and produce porosity and cracks that will reduce the mechanical properties, especially hardness [6-8].

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V. CONCLUSION

Diffusion on technology of SPD does not require melting point and wetting agents as well, for surface binding processes. However, in a combination of several high forces it can produce inter-diffusion in aluminum as a matrix, since some of the deformation of forces on the aluminum surface will produce bonds between aluminum as the matrix on B_4C becomes strong.

Aluminum dominates compositions in materials on EDS measurement, driven by Mg, Cu and Carbon, the elements are alloyed in aluminum. B_4C is a compound, so in a carbon read search as an element. The element mapping reveals the distribution of elements in the sample, the carbon element fairly uniformly distributed based on the powder element interrupting the movement of the grains in the rolling process.

Addition of B_4C can increase the hardness significantly reaches 107.5 HV10, compared to Alumina type reinforcement which only reach 103.2 HV10, Increased hardness accompanied by density decrease and decreasing grain size. The Mechanical properties, hardness are affected by the bond interphase. The study of the microstructures revealed some differences in the size and morphology of the defects at the interphase of hot and cold regions. In cold regions then the hardness will tend to decrease because it does not occur grain binding and produce porosity and cracks that will reduce the mechanical properties, especially hardness.

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