Materials Science Forum
ISSN: 1662-9752, Vol. 857, pp 179-182
doi:10.4028/www.scientific.net/MSF.857.179

Submitted: 2016-01-18
Accepted: 2016-01-25
Online: 2016-05-20

Development Of Seamless Pipe Based On Al/Al_2O_3 Composite Produced By Stir Casting And Centrifugal Casting

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Keywords: Aluminum Composite, Billet Al.6061, Al_2O_3 Ceramic Particles, Stir Casting, Centrifugal Casting

Abstract. Aluminum with Al_2O_3 material has high strength and light weight. In this study, the aluminum is used with Al_2O_3 material as an alternative material seamless pipe. The making of this material seamless pipe is through the stir casting process and centrifugal casting process. The results show that the addition of reinforcing and spin method increases the mechanical properties of the cast. Influences of process-variables are analyzed using the microstructure observation. The observations show that there formed a new phase, i.e. MgO and $MgAl_2O_4$. The new phase will improve wettability and mechanical properties of the composites. The hardness value of composites growing with the increasing of the Vf% Al_2O_3 and the centrifugal process. The highest hardness is achieved by 47 HRB with 5%Vf Al_2O_3-3 wt% Mg. Expected results of aluminum composite with ceramic particles reinforcement design is to obtain a composite material, which have superior mechanical properties, such as strength, hardness, high temperature resistant and light weight. The material can be applied as an alternative material for tube and pipe products. Initially, the product materials are made of steel and now can be replaced using composite Al/Al_2O_3.

Introduction

Metal–matrix composites (mmcs) are most promising materials in achieving enhanced mechanical properties Such as: hardness, young's modulus, yield strength and ultimate tensile strength due to the presence of micro-sized Reinforcement particles into the matrix [1]. Commercial Aluminum Metal Matrix Composites (AMMCs) possess much higher specific strength and stiffness, improved high temperature properties, higher wear resistance and lower thermal expansion coefficient in comparison on to their base alloy matrixes due to the incorporation of suitable particles or fibers into the matrix metal [2].

Aluminum alloy 6061 possesses very high corrosion resistance and excellent extricable in nature and exhibits moderate strength and finds much applications in the fields of construction like building and highway, automotive and piping, marine applications [3].

The conventional centrifugal casting method can be used for making functionally graded metal matrix composites. This process involves synthesis of MMC by stir casting method followed by centrifugal casting to form the gradient in micro-structure due to centrifugal force. When particle-containing slurry is subjected to centrifugal force, two distinct particle enriched and depleted zones are formed. Depending on the density, the lighter particles segregate towards the axis of rotation, while the denser ones move away from axis of rotation [4]. The thickness of particle enriched zone decrease with increasing pouring temperature and speed of rotation. Many studies have been reported on the use of centrifugal casting method as an efficient technique for making wide range of functionally graded metal matrix composites [1].

The present investigation is on characterization of functionally graded composites based on Al.6061 wrought aluminum alloys reinforced with Al_2O_3 particles of 63 μm average particle size processed by liquid metal stir casting followed by horizontal centrifugal casting.

Experimental Method

In the manufacture of pipes made from metal composite Al/Al_2O_3 through two stages, with the stir casting process followed by centrifugal casting method. Before the stir casting process, ceramic particles with (3, 5, 10) % Vf Al_2O_3 (97.1% purity, spherical shape, average diameter of 63 μm) were heated at 1100 ^oC for 1 hour. Aluminum alloy was heated at a temperature of 800 °C and held for 2 minutes in an aluminum melting conditions. Inert gas (Ar) was flowed into the molten aluminum for 2 minutes afterwards. Furthermore, the mixing between Al_2O_3 and aluminum molten using the method of stirring at a speed of 800 rpm. Stirring was continued for 2 minutes. After that, the molten of composite was poured into the mold tube and rotated at a speed of 300 rpm.

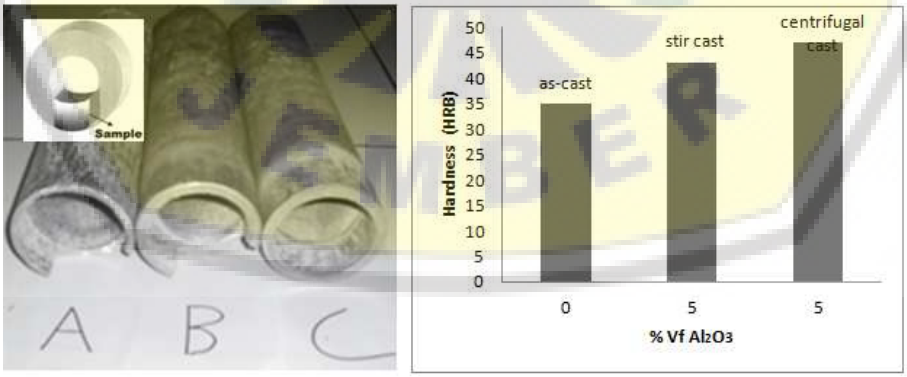
Result And Discussion

Powder Characterization, In Figure 1, the observation of the morphology of Al_2O_3 particles by using SEM. From the observation, shown the size and shape of the Al_2O_3 particles are not uniform. The Figure, it appears the particles agglomerate. In addition, the particles tend to agglomerate with a rough surface.

Fig 1. Shape and particle size distribution of Al_2O_3

The size of Al_2O_3 particles is shown in Figure 1 (a) through Figure 1 (d). Based on the measurement results obtained that Al_2O_3 particles have a size range between 58.53 μm to 117.79 μm.

Hardness, In figure 2, displayed image the pipe of composite products and results of comparison testing between composite hardness in as-cast condition, stir casting condition and centrifugal casting conditions.

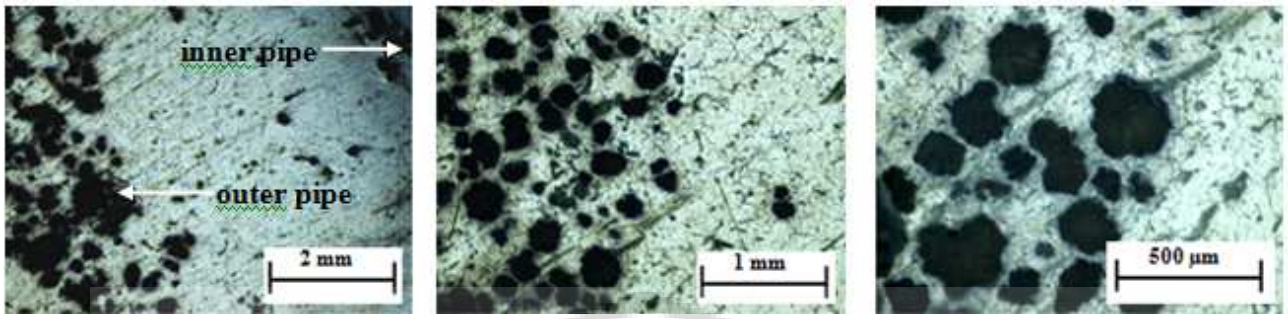


(a) (b)

Fig. 2. Based on: (a) prototype of composite pipe, (b) hardness of Al/Al_2O_3 composite

Figure 2 (b) shows that the hardness of composite increased by 8.5% in centrifugal casting conditions. It occurs because the centrifugal casting method will generate a centrifugal force that holds the ceramic particles to remain in its position. While the stir casting method, after stirring was stopped will cause the ceramic particles fall down due to gravity force. From figure 2 (b), it is seen that by using a centrifugal casting will increase the hardness of composite to 47 HRB.

Struktur Mikro, In figure 3, seen the difference between the content of alumina particles inside the pipe and outer pipe section.

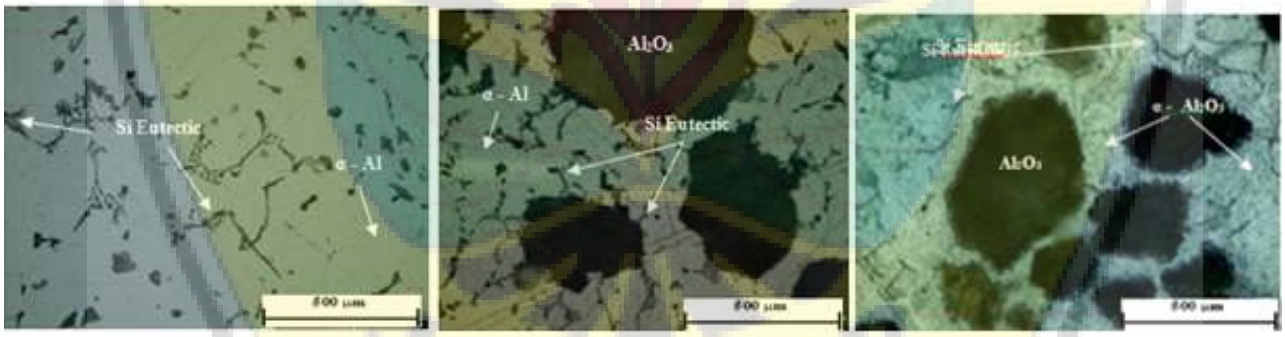


(a) (b) (c)

Fig. 3. Microstructure of Al/Al_2O_3 composite with centrifugal casting method, magnification: (a) 50 x, (b) 100x, (c) 200x

The microstructural features of the matrix alloy also vary from outer to inner periphery. This variation in microstructure is caused by different phenomena taking place during solidification under centrifugal force. Centrifugal force the resulting during centrifugal casting process will result in the separation of the ceramic particles. Ceramic particles will move towards the edge of the pipe. So, the middle part of pipe will experience a vacancy of ceramic particles. It will be result in a high hardness value differences between the edge and the middle of the composite pipe.

The observation of the optical microscope in figure 4, are shown the aluminum alloy Al-Mg-Si without reinforcement. The other major observation in the matrix microstructure is the presence of higher amount eutectic silicon phase at the inner periphery of the casting [4]. Microstructure consists of the α-Al and Si Eutectic.



(a) (b) (c)

Fig. 4. The matrix microstructure of Al-Mg-Si and Al/Al_2O_3 composite, with conditions: (a) matrix of Al-Mg-Si, (b) stir cast Al/Al_2O_3 composite (c) centrifugal casting Al/Al_2O_3 composite

FE SEM-EDX, Figure 5, from FE SEM-EDX observation of the composite results from stir casting process, there appear to be matrix phase, reinforcement phase and interphase ($MgAl_2O_4$) phase. From the EDX data in figure 5, at **point 1** may be indicated as an Al_2O_3 particles in the composite reinforcement. This case can be inferred based on two dominant elements contained in the phase that is Al and O. At **point 2** looks composition of the matrix elements aluminum alloy Al-Mg-Si. This was indicated by the percentage of aluminum which reach 91.00%. Whereas, at **point 3,** indicates the formation of $MgAl_2O_4$ phase. This is reinforced by the percentage of 09,25% Mg and 11,13% O. Therefore it, These phase when viewed in terms of the composition of an intermediate phase or phase transition closer to the MgO phase [5].

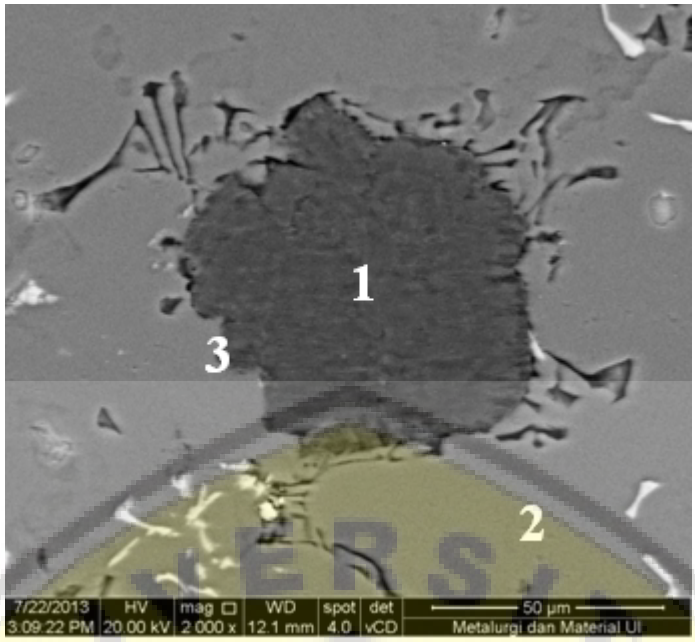


Fig. 5. FE SEM and EDX stir cast Al/Al_2O_3 composite

Summary

Centrifugal casting is an easy way to produce seamless pipe made from aluminum composite. The addition of alumina and centrifugal casting will improve the composite hardness.

The highest hardness value is 47 BHN, i.e the condition by using centrifugal casting. Centrifugal force produced during the centrifugal casting process, will push the ceramic particles into the edge of the pipe, so that the center of the pipe will experience a vacancy of ceramic particles.

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