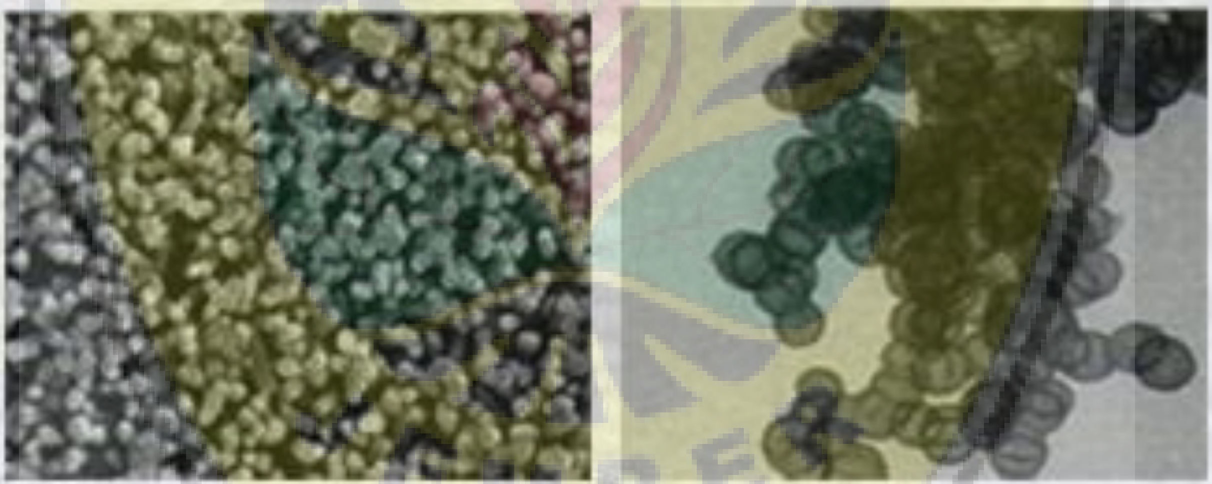
# Advances Materials Research

Vol. 789
ISSN: 1022-6680



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# Advanced Materials Research

ISSN 1022-6680, ISSN/ISO: Adv. Mater. Res.

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The periodical is available in full text via www.scientife.net

**Subscription Information:**

Irregular: approx. 150-250 volumes per year. First volume in 2013: vol. 601
The subscription rate for web access is EUR 1070.00 per year. Standing order price: EUR 108.00 per volume including online access, EUR 100.00 per volume for print only.
ISSN print 1022-6680 ISSN cd 1022-6680 ISSN web 1662-8985

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*Advanced Materials Research Vol. 789 (2013) pp 8-11*
*Online available since 2013/Sep/04 at www.scientific.net*


*doi:10.4028/www.scientific.net/AMR.0.8*

# The Influence Of Various Percentage Of $Al_2O_3$ By Using Vortex Method To Tensile Strength And The Distribution Of $Al_2O_{3p}$ Composite

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**Keywords** : Aluminum composite,billet Al.6061,$Al_2O_3$ ceramic particles,Vortex method (Stir Casting), volume fraction

**Abstract.** Aluminum composite reinforced ceramic particles can be created through stirring process (Stir Casting) so that the molten aluminum to form a vortex as a space for the reinforced of $Al_2O_3$ particles well distributed on the aluminum melt. Engineering ceramic particles and vortex formation process will determine the distribution of particles in molten aluminum metal. Mg was added during the melting and argon was flushed to improve wetting system and protect oxidation. In this study, billet Al.6061 was combined with various percentage of $Al_2O_3$ from 5Vf % to 20Vf%. The results showed that the optimum tensile strength obtained at 10Vf % $Al_2O_3$ with the value of 190 MPa.

## Introduction

The vortex method is one of the better known approaches used to create and maintain a good distribution of the reinforcement material in the matrix alloy. In this method, after the matrix material is melted, it is stirred vigorously to form a vortex at the surface of the melt, and the reinforcement material is then introduced at the side of the vortex. The stirring is continued for a few minutes before the slurry is cast [1].

While conventional stir mixing followed by casting is one of the most economical techniques available to produce large near-net shape parts from metal matrix composites [2]. Stir Casting (vortex method) is one of the manufacturing process of composite aluminum in liquid state using a stirrer,which performed at a temperature slightly above the melting temperature of Aluminum [3].

The development of materials technology, the alternative to create a wider variety of new materials. Important MMC applications in the ground transportation (auto and rail), thermal management, aerospace, industrial, recreational and infrastructure industries have been enabled by functional properties that include high structural efficiency, excellent wear resistance, and attractive thermal and electrical characteristics [4]. Currently it has developed a method to improve the mechanical properties of aluminum by adding reinforcement to the aluminum such as aluminum composite material with reinforcing ceramic such as silicon carbide (SiC), alumina ($Al_2O_3$), and Carbon.

One of the problems encountered in metal matrix composite processing is the settling of the reinforcement particles during melt holding or during casting. This arises as a result of density differences between the reinforcement particles and the matrix alloy melt. The reinforcement distribution is influenced during several stages including (a) distribution in the liquid as a result of mixing, (b) distribution in the liquid after mixing, but before solidification, and (c) redistribution as a result of solidification [4].

The purpose of this study was to determine the distribution of ceramic particles due to the influence of the vortex flow stir casting process with the content of $Al_2O_3$ ceramic particles are different. With the difference in the content of $Al_2O_3$ ceramic particles, it will be able to stream vortek know how to spread the ceramic particles into the aluminum matrix. Some of the steps taken in this research, including the preparation of Al.6061/$Al_2O_3$ composite constituent materials and stir casting method in order to produce a vortex flow in the hope of ceramic particles can be dispersed uniformly in the matrix of aluminum, so it will increase the strength of the composite.

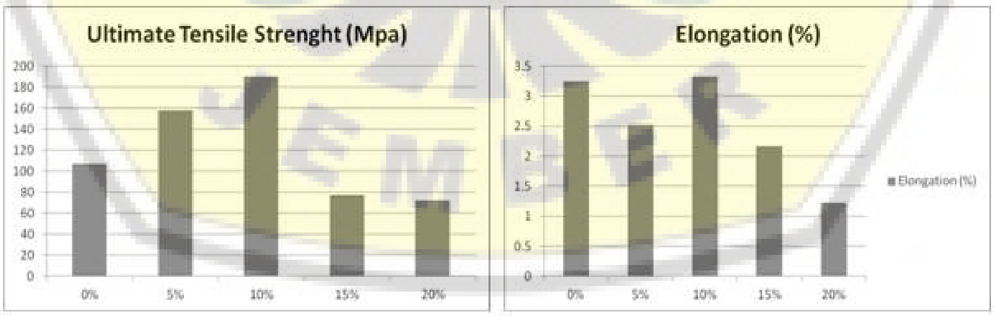
## Experimental Method

Al alloy 6061 billet was cut to (6x3x1) mm size and placed in the crucible. $Al_2O_3$ powder (with purity 97.1%, spherical shape, and average diameter 40 μm) were used. Prior to stir casting, alumina ($Al_2O_3$) ceramic particles in 5, 10, 15, and 20 % vf were heated at 1100$^o$C for 1 hour. The Al alloy was heated at 850°C and held for 4 minutes in order to get molten Al alloy. Inert gas (Ar) was inserted to the molten alloy for 4 minutes to adjust inert atmosphere. The $Al_2O_3$ and Mg (8 wt %) were further added to the molten alloy. The mixture was mechanically stirred at constant speed of 5000 rpm for 4 minutes to produce a perfect vortex flow.

After the mixing process was carried out, the mixture was poured into tensile test H13 steel mold at 750°C. Tensile strength test was performed according to ASTM B 108-03a and ASTM B557M-02a. The microstructure of samples was observed using scanning electron microscopy (Philips Type XL-40).

## Result And Discussion

**Tensile Strength Testing.** From Fig. 1 (a), it is showed that the volume fraction of reinforcement affect tensile strength of the composite. Ultimate tensile strength (UTS) tends to rise with increasing volume fraction from 0% to 10% and further decrease at 15Vf% and 20Vf%. The optimum strength was found at 10Vf% with the value of 190 MPa. The decrease in tensile strength was caused by poor condition of interface between matrix and reinforcement particles, i.e $Al_2O_3$. In addition to the above, several other important factors leading to decreased tensile strength values are uneven distribution of particles, the particles agglomerate and clustering reinforcement. On the clumping of particles will cause the particles were completely wetted by the liquid metal and potentially cause porosity around the interface [5].




(a) (b)

Fig. 1 $Al_2O_3$ Volume Fraction $Al_2O_3$ Versus: (a) Tensile Test and (b) Elongation

In Fig. 1 (b). seen that the elongation of aluminum 6061 with no reinforcement reach 3.25%, while aluminum composite 6061 with $Al_2O_3$ by 10Vf% to reach 3.33%. This value indicates that the addition of $Al_2O_3$ increased elongation of aluminum. The addition of 10Vf% $Al_2O_3$ effective enough to wetted by the matrix. Because the particles on the reinforcement will divide the tension matrix so well that makes the extension into high. While with a higher volume fraction resulted in decreased extension [5].

**Optical Microscopy.** Al.6061/$Al_2O_3$p composite microstructure is shown in Fig 2. $Al_2O_3$ reinforced with a volume fraction of 5%, 10%, 15%, and 20% (a,b,c,d), and with a magnification of 100 times. It appears that the increasing volume fraction of reinforced $Al_2O_3$, will increase the distribution of ceramic particles into the aluminum matrix. However, as it can be seen in the figure, stirring the melt is very useful to improve the incorporation of reinforcement particles in the matrix alloy. As a result, refinement of α-Al grains and improving the distribution of reinforcement particles within the melt are the most important effects of vortex method [2]. In Fig 3, this could be the initiation of the weak areas of a composite. Composite strength comes from its effectiveness in inhibiting the movement of dislocations, but by increasing numbers reinforced the function of it being effective Clumping and porosity of $Al_2O_3$ particles clearly visible especially on the volume fraction of 15% and 20% (Fig 3 (a,b)).

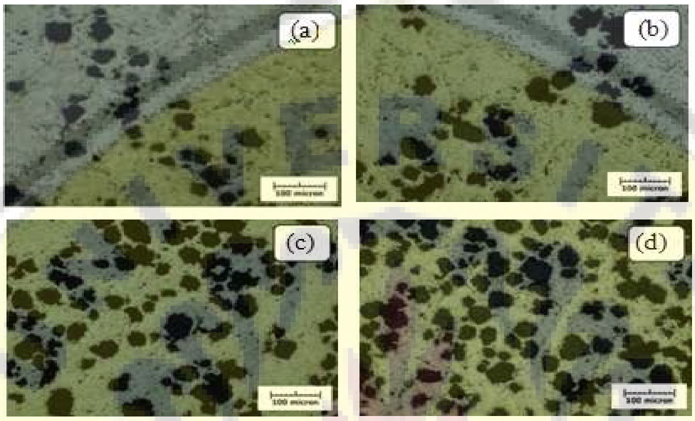



Fig. 2 Figure microstructure with magnification 100x : (a) 5% (b) 10% (c) 15% (d) 20%

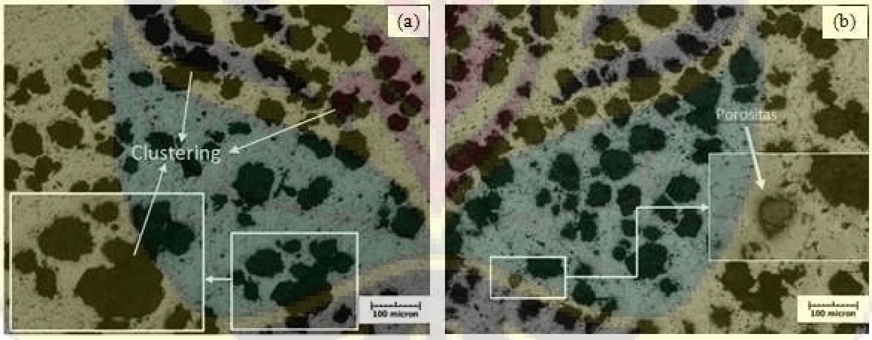



Fig. 3 $Al_2O_3$ particles in the composite matrix with 100x magnification (a) clustering (b) porosity

It is caused by poor wetting and vortex formation that occurs during stirer will cause gas into molten metal. And gas trapped into the matrix during cooling takes place, due to the viscosity of the liquid metal decreases. The existence of $Al_2O_3$ particle clumping in composites will affect the mechanical properties. Particles that can not agglomerate completely wetted by the molten metal so that when the uniaxial tensile load is going to be easy the release of the bond between the matrix reinforcement.

**SEM and EDS.** SEM and EDS Observations on Al.6061/$Al_2O_3$ composites with 10% volume fraction is shown in Fig.4, with a magnification of 500x. Observed by SEM to determine the topography of the composite. EDS analysis to determine the elements present in the composite, which is at point 1 is indicated as reinforcement $Al_2O_3$ particles. Since there are two dominant elements of Al and O. The point 2 is intended to look at the elemental composition of the matrix of aluminum alloy 6061. The element is dominant at 66.07% aluminum.

While is at point 3 indicates the formation of $MgAl_2O_4$ phase. Ratio of Al/Mg phase is 0.5. Located between MgO phase (Al/Mg = 0) and $MgAl_2O_4$ (Al/Mg = 2). Therefore, the phase is a phase transition closer to the MgO phase [6].

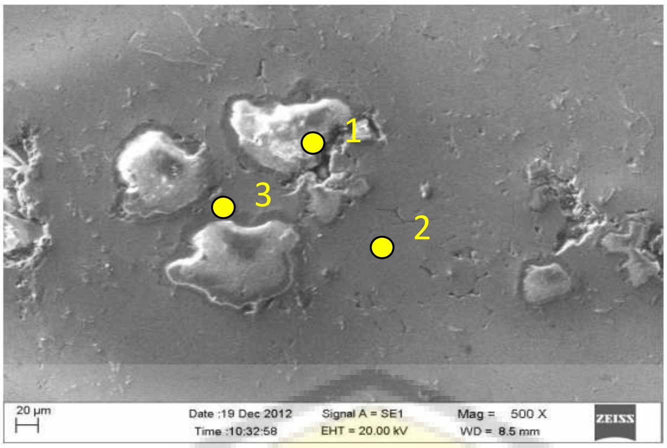



Fig. 4 Micrographs interface and EDS spectrum Al.6061/$Al_2O_3$ Composite volume fraction of 10%

## Conclusion

In this study, characterization of Al.6061/$Al_2O_3$ produce by vortex method obtained the following key findings :

1. Optimum tensile strength of the composite Al.6061/$Al_2O_3$ of 190 MPa at 10% volume fraction and compared with Al.6061 alloy without reinforcement will increase to 78%.
2. It can be seen from images of microstructures of composites, with increasing volume fraction of $Al_2O_3$ reinforcement will improve the distribution of $Al_2O_3$ particles in the matrix of the composite
3. Clustering and porosity of $Al_2O_3$ particles are still present in the matrix and composite interfaces. This will affect the properties of composites.

## Acknowledgments

Authors would like to thank to RISTEK-SINas LAPAN for financial support to carry out this research.

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**Advances in Materials, Processing and Manufacturing**
10.4028/www.scientific.net/AMR.0

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