CU ADDITION EFFECT ANALYSIS ON MATRIX OF REMELTING PISTON ALUMINIUM COMPOSITE WITH SILICA SAND REINSFORCEMENT TO THE IMPACT STRENGTH AND MICRO STRUCTURE ON ALUMINUIM MATRIX COMPOSITE USING STIR-CASTING METHOD

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Keywords :
Aluminium Matrix Composite, Stir casting, impact test, miscrocopy test,

Abstract :

AMC (Aluminium Matrix Composite) is material which has a great potential for being developed. This research was done to find effect added of Cu variation for impact strength and microstructure on Al-Si composite. Mass fractions of sand silika is 3% and Cu variation adding is 0, 1, 2, 3 & 4%. Composite manufacture is using stir casting method with stirring 600 rpm during of 5 minutes on semi solid temperature. Speciments were tested using optical microscope and impact charpy testing machine. The value impact of composite without adding Cu is 0,333 J/mm^2 after added Cu value down. Until adding Cu 4% the value impact is 0,104 J/mm^2. Micro photograph showed the result of porosity and SiO_2 unform distribution with the adding of Cu to the composite. From the test results it is known that the strength of the impact decreases with mass fraction addition Cu. This is because the addition of Cu can increase the porosity and formed $CuAl_2$ phase which are brittle.

PENDAHULUAN

In recent years, aluminium has been occupying an important role in the automotive, aircraft and construction industry. In the automotive field, the aluminum applications is in second place after steel. Due to its corrosion resistant properties, good thermal conductivity, and high trenght-to-weight ratio, several automotive components are made of aluminum alloy, for instance, pistons, engine blocks, cylinder heads, valves, and so on. However, pure aluminum is not applied yet because it still has a poor casting and mechanical properties. Therefore, it is necessary to add other alloy elements to improve the mechanical properties on casting process. Alloy elements are often assembled, such as, copper (Cu), silicon (Si), magnesium (Mg), manganese (Mn), nickel (Ni), etc. [8].

In material development, a numerous research has been done to obtain an exact characteristic. Metal matrix composites (MMCs) are generally made by combining two or more ingredients, first ingredient is a base material (matrix) of light metals such as aluminum, while other material is a reinforcing material in particles form. It properties depends on several factors that influences them, such as, composite material type, reinforcement volume fraction, dimension, shape, and some other process variables.

Stir casting is a MMCs casting method in which materials are the combining of reinforcing material to a molten metal by stirring that makes the metal composites of uniform ceramic particles distribution and reduces bubbles which is trapped in the molten metal.

An old piston is recycled into new pistons that have quality which equaly expected to an original piston. The addition of Cu element into it which silica sand reinforced that contains of SiO2 by stir casting methods is necessary to increase its strength. It is expected to have an equal strength than the new piston.

From the description above, it is necessary to do research about additional Cu variations on aluminum matrix composite of a used piston remelting with silica sand casting by stir casting method to its impact strength and micro structure. The purpose of this study was to determine the variations effect in copper (Cu) addition on impact strength, porosity, photos macro, and microstructure of silica sand reinforced aluminum matrix composites by stir casting method.

RESEARCH METHODOLOGY

The stir casting was used in this process which metal alluminium heated to melt at 700 ^oC in the induction furnace.Then, it was added a copper powder and stir until blended, silica sand mixing temperature was lowered to 650 ^oC (semi-solid) and ran for 5 minutes at 600 rpm of speed swivel, after that the temperature was raised to the pouring temperature at 725 ^oC and poured on a mold which impact test specimens shaped.

The impact, porosity, macro, and microstructure photograph test was done in this research. The impact test was intended to measure how much energy that can be absorbed by a material until it fractures. This test used charpy impact test apparatus using the ASTM E23. The impact test specimen formula:

$$\mathbf{E = W \cdot R\ (\cos \beta - \cos \beta')}$$

From the formula above then obtained the formula to calculate the impact value:

$$\mathbf{I_S = HI = \frac{E}{A_O}}$$

Where:

I_s = Impact [J/mm^2]
E = Energy [Joule]
W = Pendulum weight [9,5 Kg]
R = Pendulum height [810 mm]
α = Initial deviation angle
β = Final deviation angle
A_o = Area [mm^2]
(Standar ASTM E 23)

After that, it was examined macro test to discover type of fault that occurred on the test specimen. Testing was conducted to determine the distribution of micro particles that occurred in the test specimen and the effect on impact strength.

Porosity testing was done by using the equation

$$\mathbf{P = (1 - \frac{\rho s}{\rho th})x\ 100\%}$$

with:

P = Porosity percentage (%)
Ps =Density sample or actual density (gr/cm^3)
ρth = Theoretical density(gr/cm^3)

The microstructure testing was conducted by optical microscope test equipment. This test was aimed to find the variation pengaruh addition of Cu in the aluminum metal matrix composite.

RESULT AND DISCUSSION

1. Impact Strength

Figure 1 shows that the impact strength is decreased with the addition of Cu mass fraction. Al-Si composite without the addition of Cu has the 0.333 J/mm^2 of impact strength, after the addition of Cu at 1% decline becomes 0.227 J/mm^2, and continued to decreased until the addition of Cu at 4% it resulted 0.104 J/mm^2 of impact. According to research [6] which more and more Cu density in the composite, it produced impact strength value declining due to the porosity increasing.

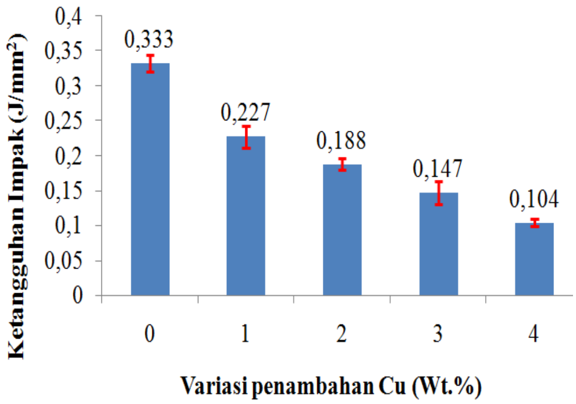

Figure 1 Impact testing result graph

2. Porosity Testing

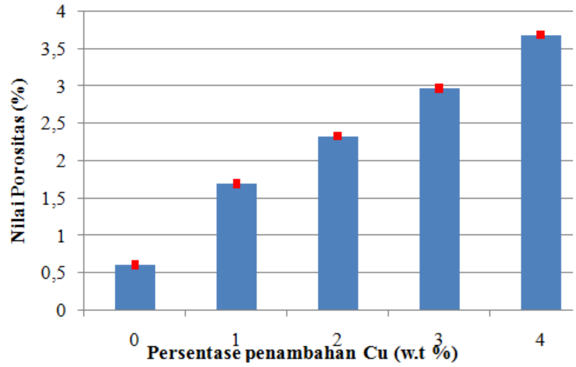

Figure 2 Porosity testing result graph

Figure 2 displays the porosity calculation results to 0%, 1%, 2%, 3%, and 4% of addition, where the porosity value is increased to the Cu addition. Cu has a negative effect on the porosity which more and more Cu is added to the composite Al-Si the more the porosity occurred. Copper was significantly increased the pressure of hydrogen gas causes the gas dissolved. On the Al-Si composite with copper addition was resulted in porosity which caused by gas increased, it is in line with the nature declining of the molten metal with increasing the percentage of Cu as stated by [3] and [11].

3. Macroscopic Photograph

The results on the cross-section of faulting macro image impact testing shows composite Al-Si mass fraction variation with the addition of copper has properties of ductile fracture, mix, and brittle.

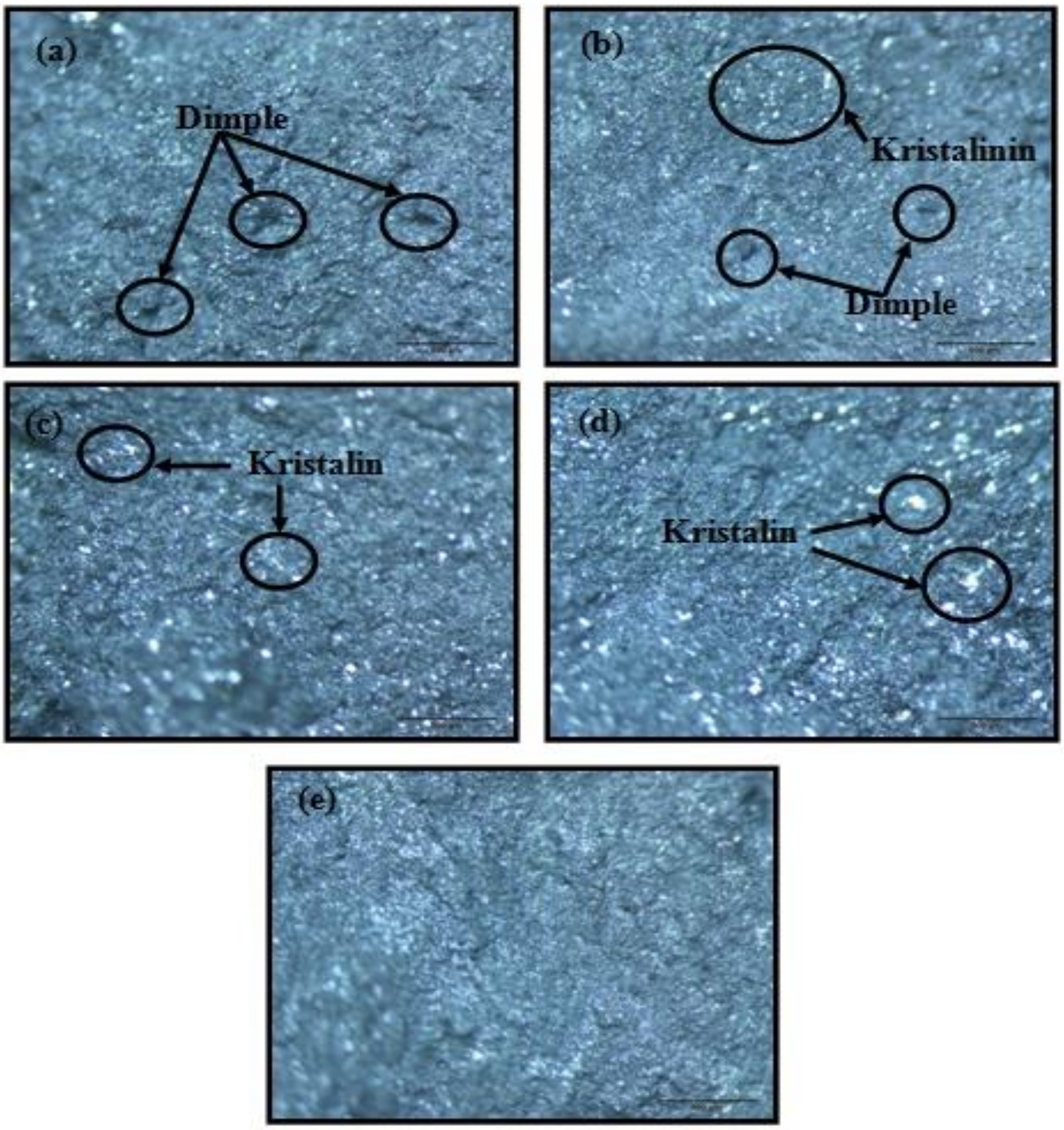

Figure 3 Macroscopic testing result (a) 0%, (b) 1%, (c) 2%, (d) 3%, and (e) 4% of Cu

Figure 3a portrays a composite Al-Si without Cu addition. Fracture surface is showed some dimpels (the part that absorbs the light) that are large and slightly crystalline (the part that reflects light). It indicates the occurrence of plastic flow is large enough before fracture so it can be classified into ductile fracture. According to research which conducted by [7] of the fault analysis of impact on Al-Si composite which enforced by SiO2 limits the plastic deformation that is absorbed by the matrix.

Figure 3b, 3c, 3d and 3e show a cross section of fracture composite with 1%, 2%, 3% and 4% of Cu mass fraction variations. Figure 3b, 3c and 3d display the mixed fracture (towards brittle), which is characterized by dimpel that began to decrease, crystals began to appear and growing. While Figure 3e is a composite Al-Si with the addition 4% of Cu mass fraction showed very brittle fracture, where it characterized by more flat fracture surface and more flat crystalline distributions. According to research conducted by [5] on the faults analysis on impact charpy testing, where the fracture of brittle is produced from the grains cleavage mechanism of brittle metal, so when it exposed to external forces (impact), it exhibit a fracturing brittle which characterized by a flat fracture surface.

4. Micro Structure

Figure 4 shows the phase that formed on the Al-Si composites, such as aluminum (α) with the visible light colors, β form SiO_2 particles are grayish or dark, AlSi on the edge of SiO_2 and $CuAl_2$ elongated yellowish. According to research [4] and [12] on the aluminum microstructure analysis with the Cu addition, Figure 4 portrays the Cu adding effect on the SiO_2 distribution, where the composite without the Cu addition occurs the clumping of SiO_2 and after the addition the SiO_2 Cu is getting spread. It shows that the Cu addition on Al-Si composite serves as a wetting agent [9] where Cu can help the spread of particles reinforcement evenly. Copper aluminide ($CuAl_2$) is a phase that aluminum and copper are cooled slowly from a single phase solid solution at room temperature [1] and [2]. $CuAl_2$ has very brittle properties and yellowish bright colored according to the study [13] on the analysis of micro structure AlSiCu with the Cu addition. $CuAl_2$ phase in the composite AlSi was found on 2%-4% of Cu addition variation. Figure 4 also shows a porosity increasing where porosity is marked by the black dark and absorb light.

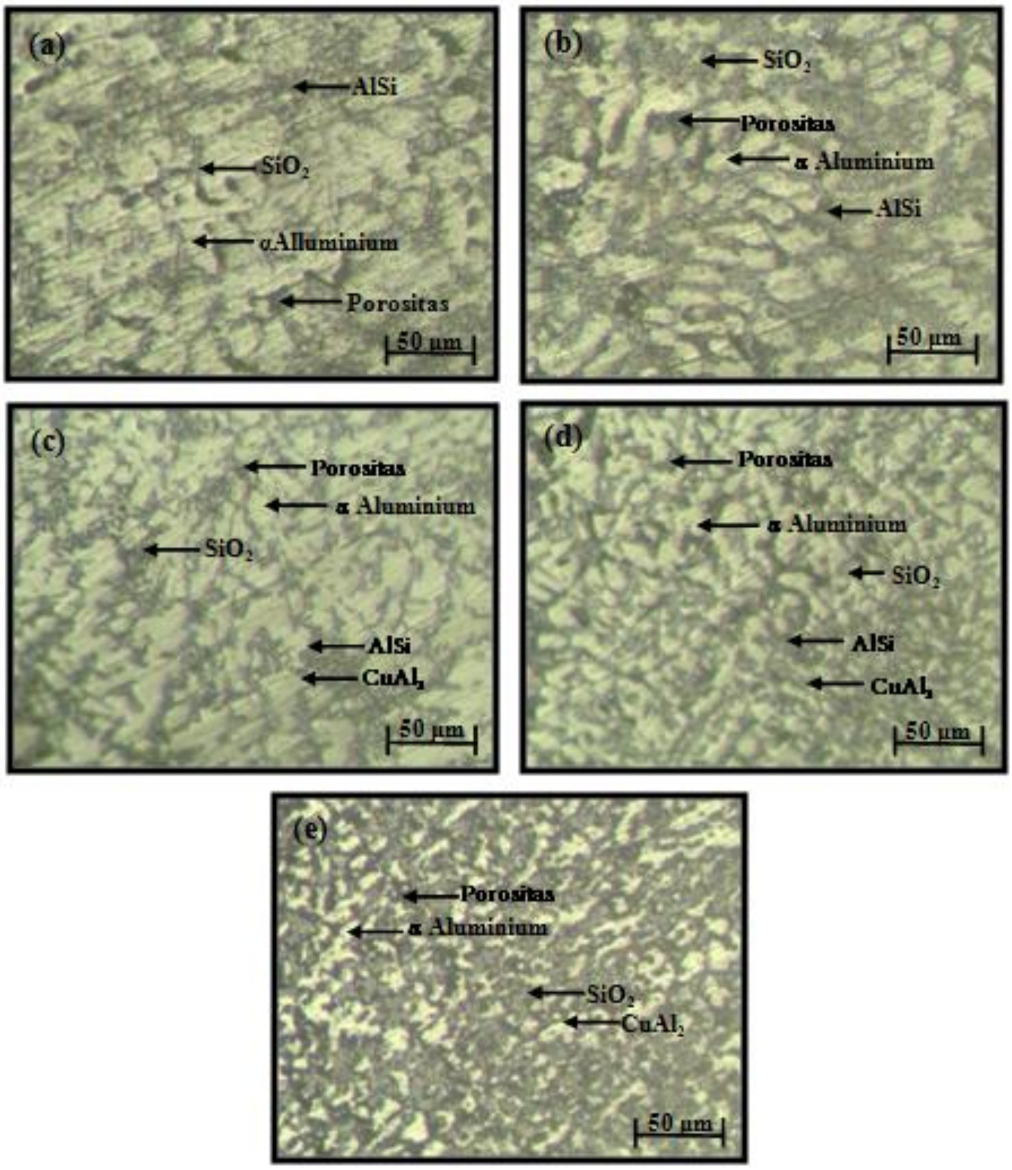

Figure 4 Composite Micro Structure (a)0%, (b)1%, (c)2%, (d)3%, and (e)4% of Cu

5. SEM Observation

Figure 5 displays the Al-Si composite without Cu addition. It shows the SiO_2 clots in certain areas, AlSi alloys found on the banks of SiO_2. Figures 6 and 7 show the composite Al-Si with 2% and 4% of Cu mass fraction addition variations. Figures 6 and 7 show that SiO_2 is spreading and elongated shape with the addition of a mass fraction of Cu, this form resulted in strength impaknya decreased, due to the form of SiO_2 tapered and elongated when exposed to external forces (impact) force will be centered at the ends so will be susceptible to fracture. This is according to research conducted by [10] on the characteristics of aluminum AC_8H/ SiC with stir casting process, in which the impact strength decreased due to the spread of the elongated SiO_2.

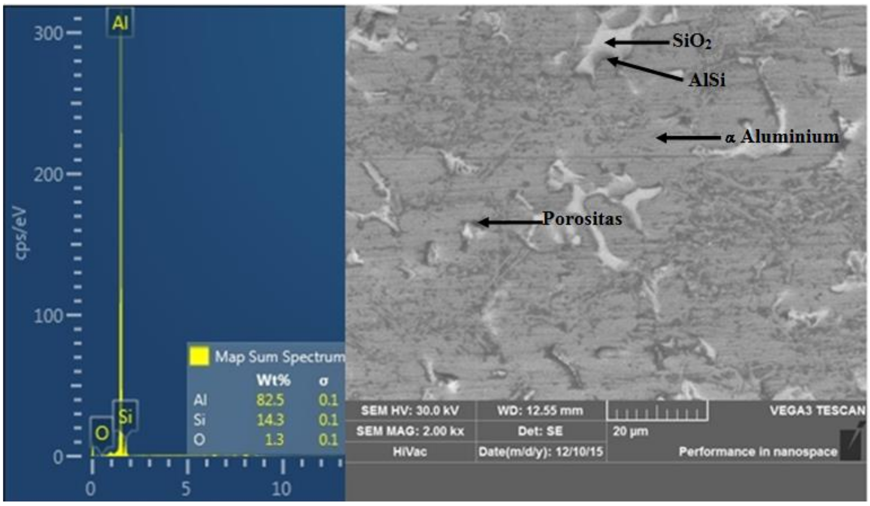

Figure 5 SEM testing result of composite without Cu addition

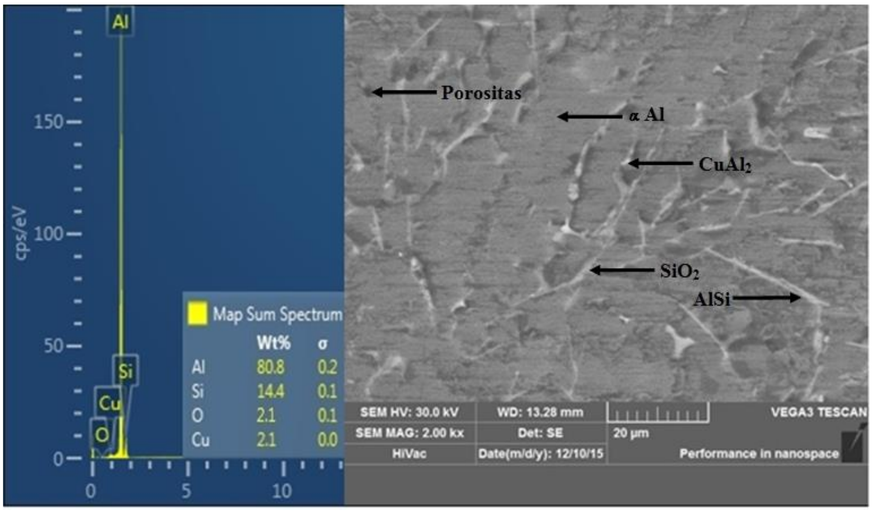

Figure 6 SEM testing result of composite with 2% of Cu

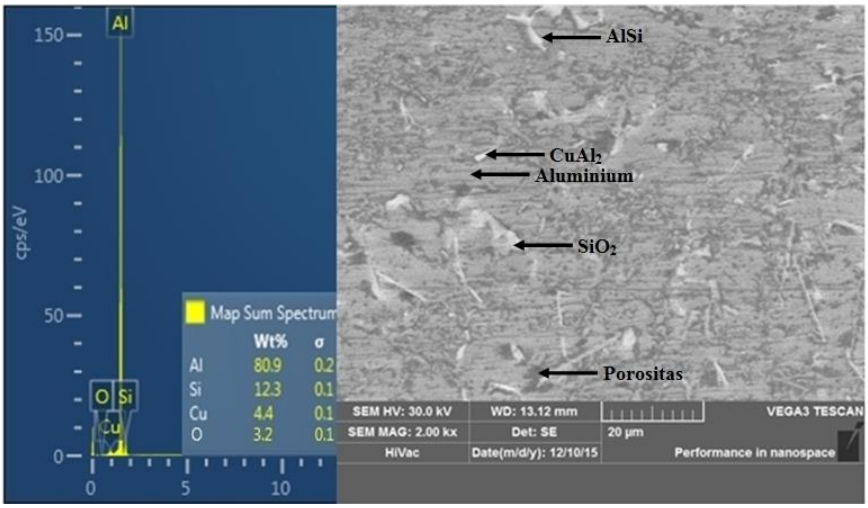

Figure 7 SEM testing result of composite with 4% of Cu

CONCLUSSION

1. The composite impact strength was declined with Cu mass fraction. It can be seen from the porosity increasing calculation with Cu addition and macro image test results show a cross section fracture impact test results experienced ductile fracture, mixture, and brittle.
2. The test results display that the microstructure and SEM SiO_2 which lengthen increasingly, tapered, and spreads along with Cu addition, due to its the mechanical properties tend to be weak

because if the material has a force from the outside, it will be centered on the ends of silicon, in addition to it also formed CuAl2 phase which is brittle.

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