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Study of Tensile Properties for Aluminum 6061 Reinforced With AISI 1060 Steel Machining Chips

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Abstract: The present study focuses on the tensile properties of Aluminum 6061 reinforced with AISI1060 Steel machining chips. Three different types of samples of aluminium 6061 reinforced with AISI 1060 steel machining chips were prepared using stir casting. The tensile test was conducted using universal test machine (UTM) for fabricated composites to study the tensile properties of aluminium 6061 reinforced with steel machining chips AISI 1060.The samples were prepared with different composition of AISI 1060 steel machining chip of 5%, 10% and 15% according to the weight fraction of parameter variable. Two casting processes were applied in this project namely stir casting and sand casting process. The stir casting was used to mix the two different metals to become a composite at temperature between 750℃ to 800℃ in a furnace while sand casting was used to fabricate the samples into ASTM-E8M standard for tensile testing. The results showed that the samples with higher reinforcement percentages of steel machining (15%) showed higher tensile stress and higher modulus value characteristic compared to other samples. The experiment proved that the reinforcement material has good mechanical properties compared to the pure material.

Keywords: Tensile properties, Aluminum 6061, AISI 1060 steel

1. Introduction

Aluminium is a material that is typically utilized for industrial and general purposes. Al 6000 series is known to be one of the cheaper and readily accessible types of aluminium. AL 6000 is generally used to produce household equipment. In addition, Al 6000 is also applicable for the usage of heavy-duty structure which requires good corrosion resistance such as pipeline, truck, marine and aviation structure, stockpiling tanks, automotive body panels, doors, windows and furniture [1]. However, the strength characteristic of Al 6000 series which is lower than the other types such as Al 7000 and Al 2000 become a major drawback. The strain hardening and heat treatment processes are two typical techniques used to improve the mechanical properties of Al 6000 series [2]. Those methods were effective, but on the other hand, it relatively increases the material cost. Stir casting method is one of the potential methods to reinforce the strength of aluminium with other material matrices [3]. It is an attractive method as it uses a typical metal processing technique which is an economic route for production of metal matrix composite. The composite material

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preparation cost by stir casting method is approximately in the range of between 0.3 and 0.5 lower as compared to the other method [4].

Stir casting of metal matrix composites (MMC) is a process of introducing alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders. In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirrer. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mould casting, or sand casting. Study on aluminium casting method has been previously investigated by many researchers. A study has been conducted to alternatively use biomass ash instead of silica sand for preparation of molds in foundries as to mitigate the economic and environmental impact of sand mining and transportation [3]. The characteristic of prepared molds are thoroughly investigated to ensure their suitability to be poured with molten metal (LM 24 aluminium alloy). The molds strength of compression exhibited an increase from 360 gm/cm2 to 510 gm/cm2. The filling defects which were integrated with thin wall section is previously investigated. It thus affects the properties of 1060 aluminium casting via sand casting process. The result showed that the thin wall section (1mm-2.5mm) demonstrated a quick solidification before the metal was entirely occupied the mould cavity [4]. The production of Aluminum based MMC or co-cast components with high conductive characteristic produced using casting method has also been thoroughly investigated. A few arrangements of matrix-reinforcement and matrix-insert couples were assessed. The characteristic performance of those arrangement was also calculated using numerical simulation. The components of Aluminum-Diamond, Aluminum-Reduced Graphene Oxide and Aluminum-Thermal Pyrolytic Graphite were produced. The characteristic quality of those components were investigated via experimental testing. Results showed that specimen which contaminated with particulate of diamond exhibited a slightly higher performance as compared to straight aluminum [5].

The steel industry generally produces huge tons of wastes every year. Most of the steel waste is in the form of machining chips. Those chips are the waste resulted from the various machining activities such as milling, turning, drilling and grinding [6]. Any attempt to dispose and recycle those chips becomes a critical environmental issues and also an economic challenge. The waste steel chips can be used to reinforce the aluminium 6061 to form composite material by using stir casting. This significantly improves the strength of aluminium 6061 in the form of composite compared to original Al 6061. Thus, the present study aims to investigate the effect of using the waste carbon steel 1060 machining chips as a reinforcement matrix for aluminium through sand casting method.

2. Methodology

The present chapter explained briefly on the selection of the materials and processing methods. The properties of the Al6061 alloy and the preparation of Al6061 reinforced with the ASI1060 carbon steel were thoroughly discussed. The prepared composites used stir casting method. The properties of the reinforced material such as yield strength, elastic modulus and ultimate stress were carried out in the processed sheets through tensile test.

2.1 Specimens Preparation

The composite of 3 specimens were fabricated using sand casting method which contained 5%, 10% and 15% steel machining chips as listed in Table 1. The test of material mechanical properties was conducted twice for each specimen, and thus a total 6 samples were fabricated to ensure repetitiveness of the obtained results. The test matrix of all 6 specimens are showed in Table 2. Figure 1 (a)-(d) shows the process of fabricating the specimens of composite.

2.2 Stir Casting

The composites were prepared by stir casting process as depicted in Figure 2(a) and (b). The material matrix was primarily melted in the furnace using a temperature range of 3000oC. The furnace was equipped with temperature controller in which k type thermocouple was used to control and measure the temperature. An electric motor was installed at the top of the furnace to produce stirring effect via the stirrer. The speed controller was also provided to vary the control speed of the stirrer.

Table 1 - Composition of Al 6061 and Steel Machining Chips

Specimen composition	Mass of aluminium 6061 alloy used (gram)	Mass of machining chips used (gram)
5%machining chips +95% aluminium	256.5	13.5
10% machining chips + 90% aluminium	243	27
15% machining chips + 85% aluminium	229.5	40.5

Table 2 - Test matrix of 6 specimens

No of specimens	Details
1	5%machining chips +95% aluminium [Test 1]
2	5%machining chips +95% aluminium [Test 2]
3	10% machining chips + 90% aluminium [Test 1]
4	10% machining chips + 90% aluminium [Test 2]
5	15% machining chips + 85% aluminium. [Test 1]
6	15% machining chips + 85% aluminium. [Test 2]

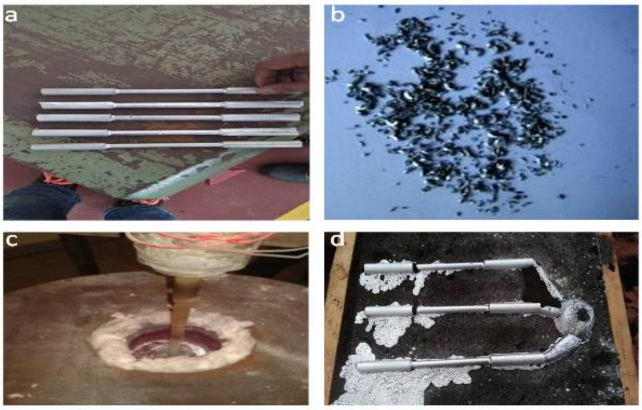


Fig. 1 - (a) specimens of Aluminium 6061 Reinforced with ASI 1060 Steel machining chips; (b) machining chips of carbon steel 1060; (c) mixing of machining chips in molten aluminium 6061 in stir casting; (d) product of specimens by sand casting

2.3 Sand Casting

Sand casting is a technique that involves a mould which produces either via metal, wood, or wax as to produce a reverse appearance in a specific sand which then is used as the mould for the molten metal. The sand mould was occupied with a molten metal which then being naturally cool and solidify. The solidified metal was removed by hitting the mould with any hard object like hammer and pipe to crack the sand mold and expose the metal object. The present study used the ASTM E8M as selected object shape as shown in Figure 3(a) due to simplicity and easy to cast with the sand mould without the aid of 3D printed method.

2.4 Tensile Testing

Tensile testing is the fundamental material science test, consisting of applying the tension force on the specimen until failure occurs. The data measured from this test was loaded and elongated. By knowing the dimension of the specimen, the mechanical properties of the material can be determined. The properties obtained from the measurements were Young's modulus, poison ratio and yield strength. The uniaxial tensile testing was employed to characterize the properties of composite material using the Universal Machine GT-7001-LS10, with load specification of 50kN as shown in Figure 3 (b).

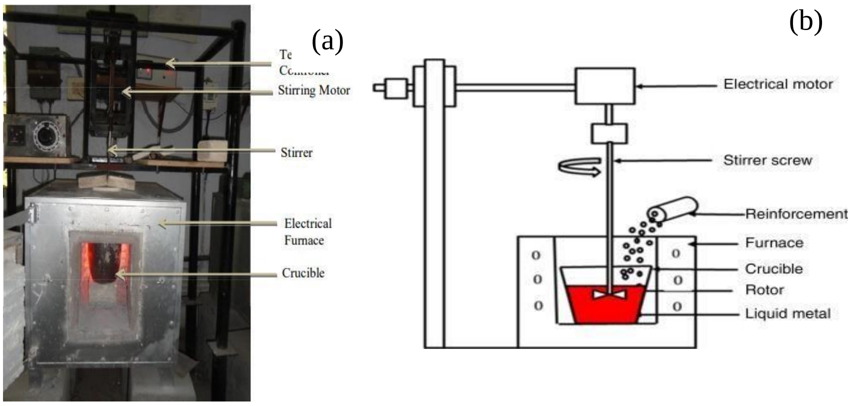
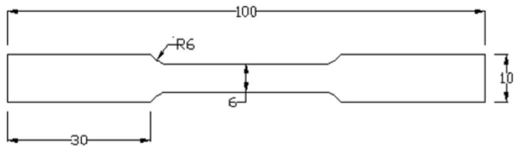


Fig. 2 - (a) Stir Casting Setup (b) Schematic Diagram of Stir Casting



(a) (b)

Figure 3 - (a) ASTM E8M Standard Dimension; (b) Universal Testing Machine

3. Results and Discussion

Figure 4(a) to (c) showed the results of stress-strain curved generated from universal testing machine for each specimen. The graph was tensile stress against tensile strain. The calculation of the strength was using the Bluehill software. The strain of the material was calculated by using extensor-meter attached to the tested material. The properties for tensile test of aluminium 6061 reinforced with steel machining chips were tabulated in Table 3. The present testing involved the specimens with diameter and dimension differences of ±0.02. The yield strength and elastic modulus of the composite aluminium with 15% of steel machining chips was higher compared to the specimens with 10% and 5% steel machining chips as depicted in Figure 5(a) and (b). The results showed that the high percentages of reinforcement element like steel machining chip 1060 seemed capable to increase the strength of the composite. The high yield and ultimate strength in steel machining cheap which were 485Mpa and 620Mpa, respectively, as one of the factors that increased the strength of pure AL6061. Thus, strength of the composite materials increased as the percentage of steel machining chips increased.

Table 3 shows that the yield strength for 5%, 10% and 15% of steel machining chips is 76.733MPa, 114.73MPa and 258.27MPa, respectively. The reinforcement of 15% of steel machining chips composition was exhibited 70% and 55.5% higher yield strength compared to 5% and 10% of composition, respectively. The specimen with the 15% steel machining chips also showed higher yield strength, elastic modulus and ultimate tensile stress compared to the other specimen's type. This was due to the presence of Mn (manganese) in the machining steel off 1060 that drove the substitution of solid solution, and created the atomic lattice strain, hence inhibiting the dislocation movement of atoms. In addition, the β' phase of Mn (manganese) also acted as pinning agent and inhibited the dislocation movement [9].

Table 3 - Tensile Test result for 5%, 10% and 15% of Reinforced Steel Machining Chips

Reinforcement composition (%)	Max. Load [kN]	Elongation @max [mm]	Elongation @break [mm]	Elastic modulus [MPa]	Yield strength [MPa]	Max Stress [MPa]	Max strain %	Stress @break [MPa]
5	5.49	4.00	2.012	7318.31	76.733	109.2	1.085	50.246
10	8.45	4.53	4.496	5023.14	114.73	167.8	1.76	82.488
15	15.5	9.952	13.0665	8441.9	258.27	307.8	1.18	152.68

The percentage of 10% reinforcement exhibited higher elastic modulus than 5% reinforcement. However, the reinforcement of 10% steel machining chips showed 31.3% lower elastic modulus compared to 5% reinforcement as illustrated in Figure 5 (b). One of the factors was probably due to the error that occurred during casting process. The defect may occur on the specimen fabricated using sand casting method. Some bubbles existed in the specimen that reduced the modulus of elasticity of the material. The bubbles were formed due to extra wet sand, thus producing gases when the hot metal pouring came into contact with the sprue of the sand casting.

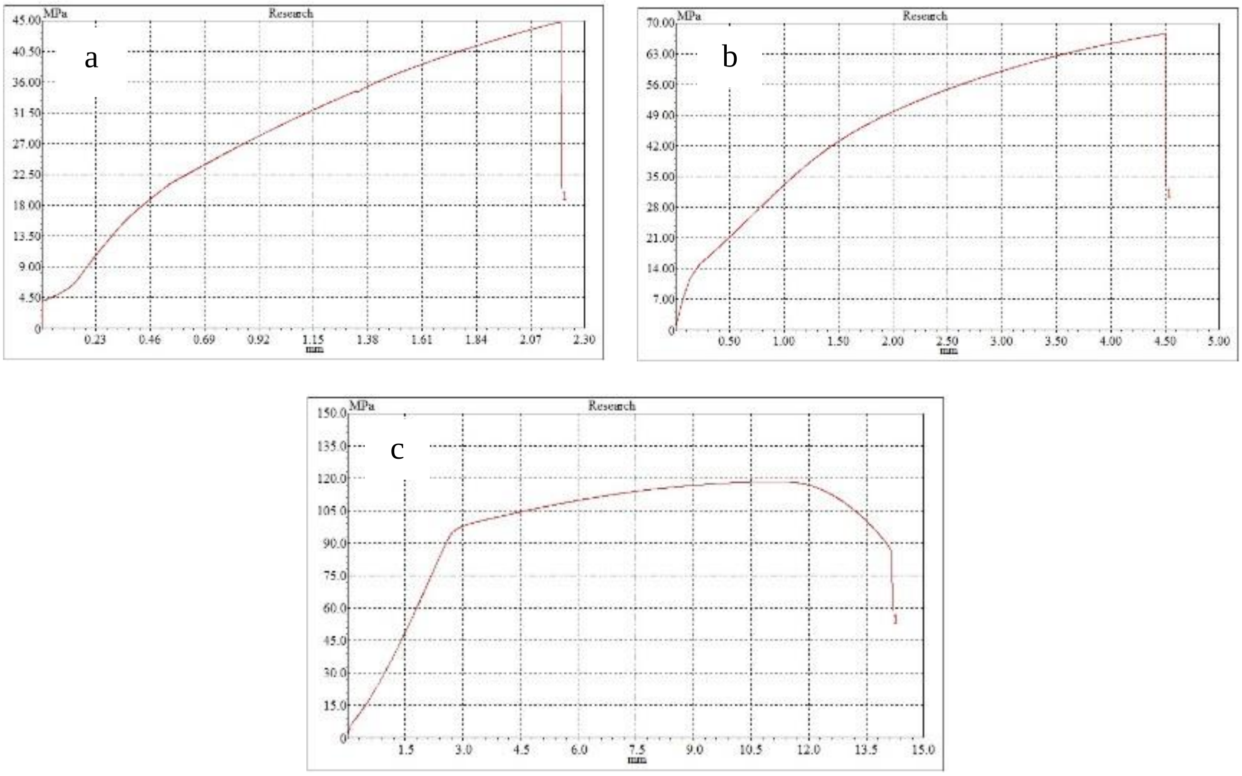


Fig. 4 - Stress-strain curve for Specimen with (a) 5%; (b) 10%; (c) 15% Reinforcement of Steel Machining Chips

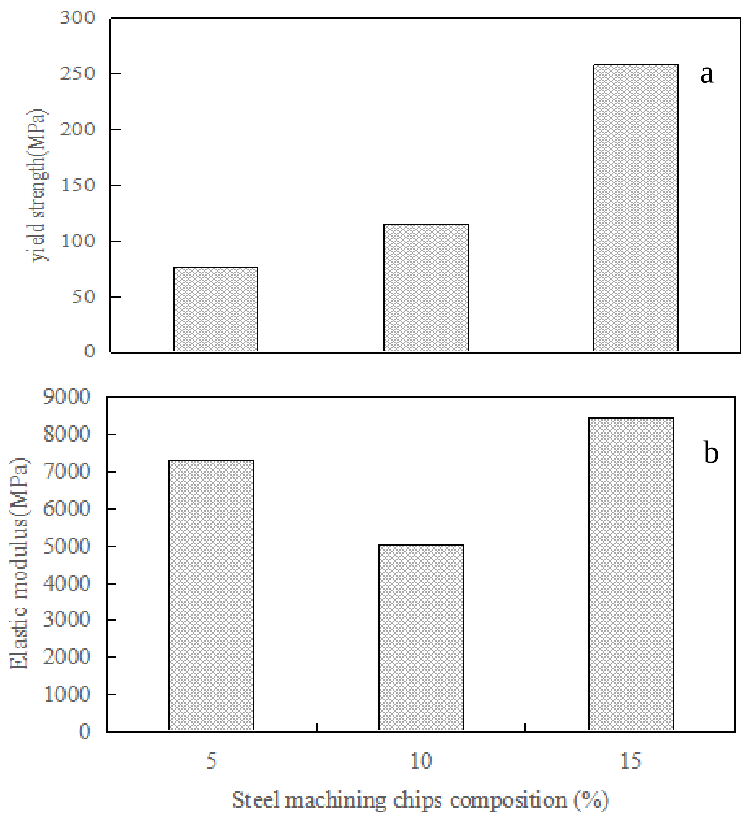


Figure 5 - (a) Ultimate Tensile Stress of different Composition; (b) Elastic Modulus of different Steel Machining Chips Composition

4. Conclusion

By The result shows that the higher percentage composition of the steel machining chips AISI 1060 reinforced with aluminium 6061 can give significant strength to the mechanical properties of the composite. The parameters of study are Yield strength, Ultimate tensile stress and Elastic modulus, which proportionally increase with the increasing of the percentage of steel machining chips by weight. The highest value obtained is the specimen with 15% composition of 1060 ASI steel machining chips which is also the highest percentage of composition among all three types of specimen tested, showing 258.27 MPa, 152.68 MPa and 8441.9MPa for the respective parameters. From this project, it can be concluded that the aluminium 6061 can increase their mechanical properties by reinforcing the ASI 1060 steel machining chips via stir casting method.

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