EXPERIMENTAL EVALUATION OF MECHANICAL PROPERTIES OF TIN COMPOSITE (TIN, RICE HUSK AND SILICON CARBIDE) FOR SUSTAINABLE PRODUCTION TOOLING

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ABSTRACT: Experimental specimens were fabricated using Tin (Sn) as core material while silicon carbide and rice husk acted as reinforced materials to increase the specimen's hardness. Silicon carbide and rice husk were reinforced in the Tin using metal casting process (mold plate casting). The specimen mold plate was cut using laser cutting machine and the material plate used was Aluminum. After metal casting process has been completed, the specimen in the mould were pressed using the hot press molding machine. Two types of testing were used in this study namely tensile test and hardness test. Three specimens have been used for each test. The result for the testings have been observed and analyzed based on their tensile strength and material hardness. It has been found that the tensile strength for the composite material is higher than the initial Tin (Sn), as well as its hardness. However, the mixing technique could have been improved to obtain better SiC and rice husk distribution.

KEYWORDS: *Metal Casting, Rice Husk, Tin, Silicon Carbide, Composite*

1.0 INTRODUCTION

A work holding device is used to pinpoint and grip the workpiece on the working table [1]. Clamp is one of the work holding devices that is used to securely hold the position of the part against the locators throughout the machining cycle. The clamp must be strong enough to hold the part and to resist movement [2] and to reduce vibration, as vibration plays a big role in affecting the quality of machining process and the workpiece's machined surface [3]. In addition, the clamp must not damage or deform the part. The clamp also should be fast-acting and allow rapid loading and unloading of parts. To use the proper clamp for each job, the basic principles of clamping must be known and understood. Clamps should always contact the work at its most rigid point. This prevents the clamping force from bending or damaging the part. Hence, the material used to produce clamps must exhibit high toughness and high hardness.

Apart from the material requirements for the production tooling, the design process itself is facing challenges to contribute to the transition towards a sustainable society at the present day. The most important advantage of production tooling is to ensure the workpiece is held securely during machining process. In recent years, researchers have viewed metal matrix composite (MMC) for its potential in increasing the overall performance of materials [4-5]. One of them is aluminum silicon carbide, which has been receiving attention because of its advantages such as elevated temperature, weight reduction and fatigue life improvement [6]. However, the actual cast specimens or products need to be fabricated in order to analyze the mechanical properties of cast metal matrix such as impact strength and yield strength. The purpose is to ensure the cast aluminum silicon carbide meet the expected strength and fatigue life. This leads to higher cost and lead-time in the design stage of production tooling. There is a gap for further research in order to increase the casting quality such as fiber-reinforced technique. Therefore, the composition between matrix material and composite reinforced and fiber reinforced must be further studied in designing of production tooling. There are so many recycled materials in manufacturing, and the one that is easy to find is Tin (Sn). Therefore, the study of production tooling using SiC/Sn as matrix composite material and rice husk as a fiber reinforced is very important to fulfill the sustainable design requirements.

In this research project, SiC/Sn was selected as molten metal in designing of production tooling at the design stage. The specimens were fabricated according to ASTM standards for tensile and hardness test. In addition, rice husk fiber reinforced was coated to the specimens to increase the quality.

2.0 MATERIALS AND METHODS

In general, the methodology consists of 2 main stages; (1) preparing the specimens and (2) physical experiments (tensile and hardness).

2.1 Fabrication of Specimens

The specimens were prepared according to ASTM E8 for tensile test and ASTM E18 for hardness test (20 mm x 150 mm x 3 mm). Tensile test specimens' dimensions are shown in Figure 1 and Table 1 below.

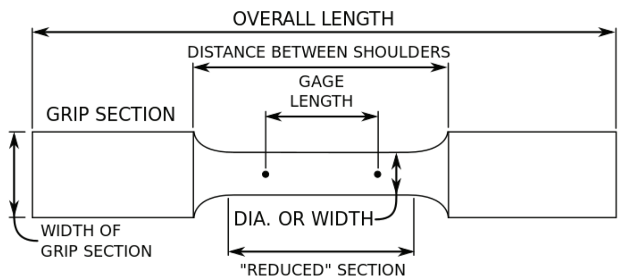

Figure 1: Dimensions of tensile test specimens

Table 1: Dimensions values of tensile test specimens

Dimensions, mm		
G	Gage length	50.0
W	Width	12.5
T	Thickness	3.0
R	Radius of fillet	12.5
L	Overall length	200.0
A	Length of reduce section	57.0
B	Length of grip section	50.0
C	Width of grip section	20.0

An aluminum plate has been used to create an open mould, where the specimens' profiles were cut out using a laser-cutting machine. 3D model of the mould plate is illustrated in Figure 2.

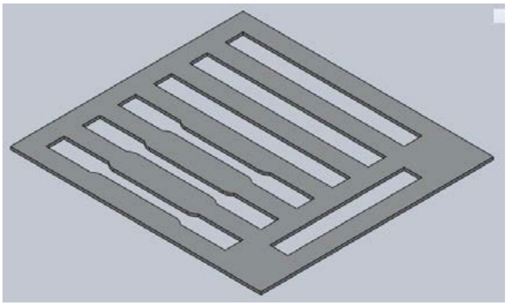

Figure 2: 3D model of the mould

Next, the materials used for the specimens fabrication were weighted; 1000g of Sn, 10g of SiC and 5g of rice husk, before the Sn was melted and stirred together with the SiC and the rice husk in a melting pan. Then the molten mixture was poured into the open mould cavities (which was clamped onto a metal plate acting as a base) and left to solidify (Figure 3).

Figure 3: Solidified molten mixture inside the open mould

In order to create compact and solid specimens according to the required profiles, the hot press moulding process was used. Hot press moulding process is generally used for polymers, where it has a limit of 300°C. However, since the melting temperature of Sn is only 232°C, it is possible to use this process to compact the specimens. Figure 4 shows the hot press moulding machine while Figure 5 depicts the compressed specimens in the mould plate.

Figure 4: Hot press moulding machine

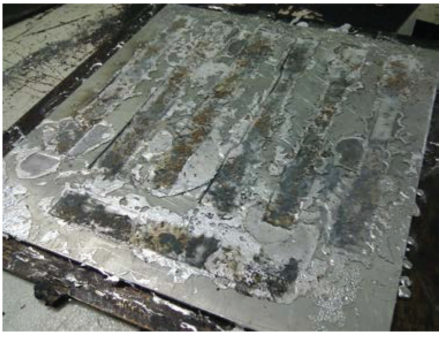

Figure 5: Compressed specimens

2.2 Tensile Test

Three specimens were used for tensile test. The test has been done at the strain rate of 0.00025/s (1.5%/min) on an Autograph AG-1 Universal Testing Machine (UTS), until the specimens failed (Figure 6).

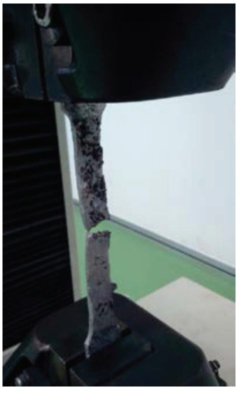

Figure 6: Tensile specimen being tested

2.3 Hardness Test

Hardness test was conducted using a Wizhard Rockwell Hardness testing machine. As other tests, three specimens have been used. The hardness value is recorded in HRB unit. Vickers method could not been use for the specimens as their surface flatness is rough and not suitable for such test.

Figure 7: Rockwell hardness test on a specimen

3.0 RESULTS

3.1 Tensile Test

The results obtained from the tensile test are presented in Table 2 below:

Table 2: Tensile test results

TENSILE STRENGTH				
Specimen	Tensile Strength (Mpa)	Mean (MPa)	Standard Deviation	Standard Error
Specimen 1	37.00	36.00	1.32	0.76
Specimen 2	34.50			
Specimen 3	36.50			

Based on the results, the new composite material clearly has a higher Tensile Strength average value compared to the original Tin (Sn); 13.79 MPa [7]. The combination of SiC and rice husk has elevated the strength for about 161 percent. Further observation on the specimens showed uneven distributions of the rice husk and the SiC, where some areas has higher density of the reinforced materials (Figure 9).

Figure 8: Uneven distribution of rice husk and SiC

3.2 Hardness Test

Three specimens have been used for the test and ten readings have been taken from each specimen. The HRB value was later converted into Vickers HV values using the ASTM E140-97 hardness conversion. The results obtained from the hardness test are presented in Table 3 below.

Table 3: Hardness test results

n=10	Mean, HV	Std. Dev.	Std. Error
Specimen 1	195.00	55.59	17.58
Specimen 2	190.00	28.43	8.99
Specimen 3	166.90	17.40	5.50

The average HV value across all three specimens is 183.96 HV. This value is far greater than the hardness value of pure Sn, which is about Mohs 1.5 – 2.0 (approximately 56 - 61 HV) [8]. It is also noticed that the standard error on the first specimen is higher than the rest, mainly caused by the uneven distribution of SiC and rice husk in the specimen (Figure 9).

Figure 9: Hardness test specimen with uneven distribution of rice husk and silicon carbide

4.0 CONCLUSION

In conclusion, the introduction of SiC and rice husk as reinforced materials into a Sn metal matrix has been successful in increasing the strength and the hardness of the material. An improvement of 161 percent in strength and over 200 percent in hardness has been achieved. However, inconsistent distributions of Sic and rice husk have been observed throughout the test specimens, which led to higher values in measurement error and also affecting the material's overall performance. To overcome this problem, powdered Sn could be used, together with a mixer. The mixer would be able to produce more uniform mixture and it would also be much easier to melt. Exploring other pouring techniques might also help to reduce the significance of the problem. The next step of the research is to find the optimal mass fraction Sic and rice husk to obtain the best material properties out of the Sn Metal Matrix Composite. Flexural test is also required to determine its flexural strength.

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