Effect of Hardness and Tensile properties of Al6061 based composites for Piston alloy using Stir casting method

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ABSTRACT

The proposed work is to analyse the hardness and tensile properties of aluminium alloy Al6061 reinforced with the silicon carbide, aluminium oxide and zirconium oxide to improve the strength of piston material. There will be several failures occurring in the piston due to continuous working. To eradicate the failure, the composition of aluminium alloy material is made through the stir casting technique in various composition and tested as per ASTM standard size. The analysis is attempted with the proportion of AA6061+SiC+Al_2O_3+ZrO_2 (88%+5%+5%+2%), AA6061+SiC+Al_2O_3+ZrO_2 (84%+7%+6%+3%), AA6061+SiC+Al_2O_3+ZrO_2 (80%+9%+7%+4%) using Stir casting process and the hardness and tensile test is done. It shows the weight to strength ratio will be increased in the third sample and it is used to manufacture the piston material to avoid the failures.

KEY WORDS: Aluminium alloy, Aluminium Oxide, Silicon Carbide, Zirconium Oxide.

1. INTRODUCTION

Aluminium alloy and their metal matrix composites have found application in the manufacturing of various automotive engine components such as cylinder blocks and pistons. However, most Al based alloys are not suitable for high temperature applications. But the AA6061 metal matrix composites should be carrying temperature is minimally increased up to 650 to 700 of melting point.

The pistons for high-speed engine are primarily made for aluminium alloys which containing the reinforcement of materials to improving the hardness and temperature properties. The widely used particles for reinforcing Al alloys are alumina (Al_2O_3) and silicon carbide (SiC). Besides their high hardness, they show low density and low cost compared with other reinforcements. Piston is the key part of the engine as it works under high temperature, high pressure, corrosive and wearing conditions while running with high speed. However, reinforcement non-homogeneous distribution or particle agglomeration in the molten matrix and during solidification, and pore formation are considered the critical problems facing the fabrication of MMCs by liquid-state processes the pistons lie at the heart of the internal combustion engine and their reciprocating motion will generate severe stress on the piston crown, sidewall, and the piston's top rings.

Firstly, the presence of hard particles and chemicals in cooling and lubrication fluid results in abrasive and corrosive wear. Secondly, erosive wear is also significant from the impact of hot air and gases. Third, friction between the block wall and piston ring can produce adhesion even in oil lubrication. Finally, fatigue also contributes to the wear of engine block. Various types of aluminium alloys are continually being developed to improve their wear resistance. Among these alloys, aluminium-silicon (Al-Si) alloys have been found to be beneficial in many industrial applications and considered to be appropriate substitutes for cast iron components. The addition of silicon in aluminium alloys improves their wear, casting, machining and corrosion characteristics.

Al–Si piston alloy base composites reinforced with different mixtures of Ni and nano-Al_2O_3 particles have been fabricated by squeeze casting and their metallurgical and mechanical characterization has been investigated. (Abdelaziz, 2014). The effect of alloying elements on mechanical behaviour of Al12 mass % Si casting alloys for piston has been done. The influence of compounds features on the high temperature mechanical performance became more pronounced to minimize the defects (Chang- Yeol Jeong, 2012). The casting material of the present work will be Aluminium Silicon scraps of piston. Metallic mould technique is used for casting of piston. The molten material prepared for piston in required composition is poured to the cavity to get desired shape of the piston (Francis Uchenna Ozioko, 2012). This research study exhibits the powder forging of aluminium alloy for piston material by the composition of materials, preform design by FEM simulation, cold compaction of aluminium alloy powder and perform sintering. The properties like strength, hardness were compared between newly developed piston and existing casted piston (Hyos Lee, 2001). This article represents the reinforced composite and reinforced alloy of static structural characteristics of a piston under gas pressure force and inertia force (Prakash Gadade, 2013). The research investigation shows the heat treatment effect of microstructure and mechanical properties of non-aluminium alloys used for piston manufacturing. The chemical compositions are investigated experimentally in various timings and temperatures to calculate the heat treatment. By influencing the temperature and aging time the hardness of the material is investigated. The investigation of wear behaviour of Al6061MMCs and its relation with Processing & microstructure. Al 6061 MMC composite containing different weight percentages of Al_2O_3 & keeping 2 weight % graphite constant have been fabricated using a stir casting method. The mechanical characterization and fabrication of aluminium silicon based hybrid metal matrix composite with cenosphere particulates and silicon carbide were investigated for engine applications. Strength, lightweight, thermal expansion, thermal conductivity, good resistance are the important parameters required material properties.

The effect of failures are identified in the piston are; Piston weight, Loss of power, Piston melting point, Lack of lubrication, Temperature distribution, Frictional power losses of the engine, Wear during the piston movement.

Figure.1. Damaged Piston view-1

Figure.2. Damaged Piston view-2

2. METHODOLOGY

The methodology of the proposed work is carried out using the stir casting technique under suitable considerations due to the cost effective method when compared to all other methods.

Step 1: **Mould Preparation**: Moulding sand or plaster of pairs as it is popularly known is used with binding material to form the cope and the drag or the cores of the mould.

Step 2: **Preparation of Materials in Various Compositions**: Base materials of AA6061 with reinforcement of Sic, Al_2O_3, ZrO_2 to be mixed with different mixture.

Step 3: **Casting of materials**: Bottom pouring type stir casting machine used melting the materials at 900°C to casting the piston.

Step 4: **Machining of Work Pieces**: The work piece should be machined at required dimension depends on the testing process.

Step 5: **Testing of Hardness and Tensile Properties**: Tensile test work piece machined at the ASTM International standard size and testing the tensile properties and hardness of the specimen.

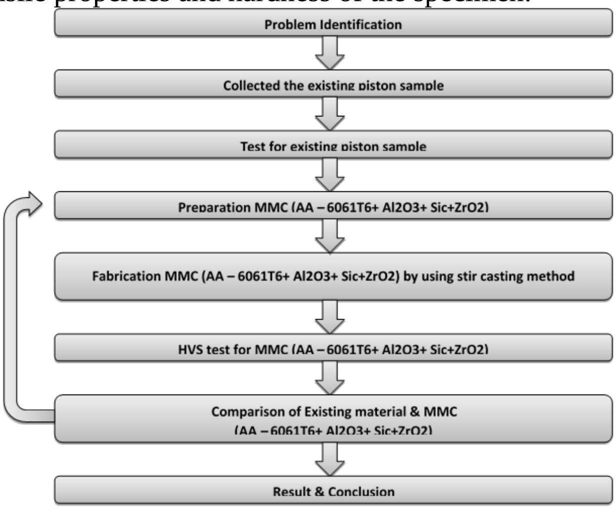

Figure.3. Problem solving flowchart

Experimental procedure:

Fabrication of materials: The fabrication of material by using the stir casting method. Manufacturing method is made from the raw material instead of already existing material. The metal fabrication is done with the considerable specifications of the furnace temperature. The stirrer speed is maintained constantly and the preheating of material to be done before the process. The metal melting temperature has to be maintained constantly for all the samples. The stirrer timing is maintained constantly for all the samples. The manufactured specimen from the process using die will be prepared as per ASTM standard size. Machining process has to be done after the preferred size specimen for making the test.

Table.1. stir casting furnace specification

Specification	
Furnace temperature	900°C
Stirrer speed	600 rpm
Metal Melting Temp.	810°C
Reinforcement Pre heating Temp in °C	600°C
Stirrer Timing	5 min

Table.2. Material heating temperature and stirrer speed

Work pieces	Furnace Temp. in ⁰C	Metal melting Temp. in ⁰C	Reinforcement pre heating Temp. in ⁰C	Stirrer speed in RPM	Stirrer timing in min.
Sample 1	800-830	780-790	560-570	750	5
Sample 2	800-830	775-790	610-630	750	5
Sample 3	800-830	778-794	620-640	750	5

Ratio of Reinforcement Materials: The base material of AA6061-T6 is used for better application and 6061 is a precipitation hardening aluminium alloy. Reinforcement of Sic, Al_2O_3, ZrO_2 is added to improving the hardness and its physical properties. The Proportion of base material and reinforcement material of three sample specimen is shown in the below mentioned table.

Table.3. Proportion of Reinforcements

Materials		Sample 1 (Composition wt %)	Sample 2 (Composition wt %)	Sample 3 (Composition wt %)
Base material	AA6061-T6	88	84	80
Reinforcement	SiC	5	7	9
	Al_2O_3	5	6	7
	ZrO_2	2	3	4
Total		100	100	100

3. RESULTS AND DISCUSSION

Vickers Micro Hardness Tester: The Vickers hardness test is mainly to find the plastic deformation. Microscope indentation integrated with the measuring indentation dimensions. As per ASTM standards the minimum distance between indentations and the distance from the indentation to the edge of the specimen to considered in account.

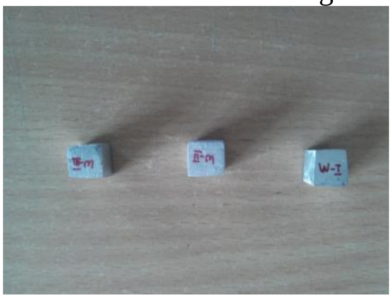

Figure.4. Tested work piece

Table.4. Values of Hardness Test

Piston Sample material		Load in (KN)	Trial – I	Trial – II	Average in (Hv)
Imported piston sample		50	96	106	101
Cast piston	Sample 1	50	109	117	113
	Sample 2	50	142	138	140

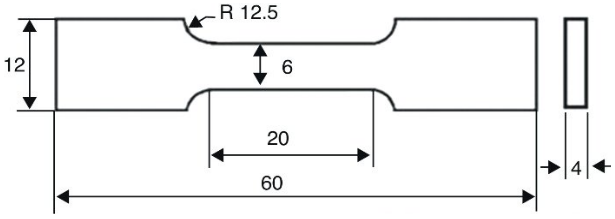

Figure.5. ASTM Standard Size

Figure.6. Tensile test sample piece

Table.5. Values of Tensile Test

Sample work piece	Gauge Length	Maximum Force (KN)	Nodal Diameter (mm)	Tensile Strength (KN/mm^2)	Percentage of Elongation
Sample 1	90	22.606	8	0.398	9.756
Sample 2	90	18.60	8	0.328	4.878
Sample 3	90	16.60	8	0.306	1.68

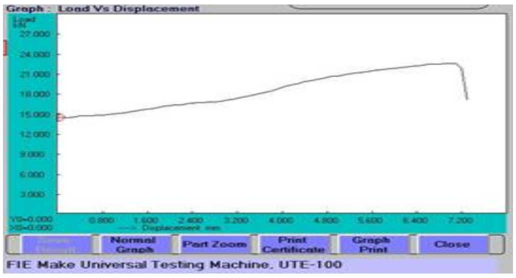

Figure.7. Graph for tensile test in base material of AA6061 (88%) with reinforcement of SiC (5%), Al_2O_3 (5%), ZrO_2 (2%)

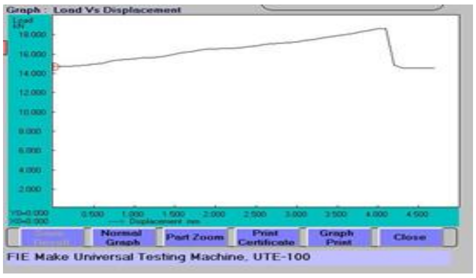

Figure.8. Graph for tensile test in base material of AA6061 (84%) with reinforcement of SiC (7%), Al_2O_3 (6%), ZrO_2 (3%)

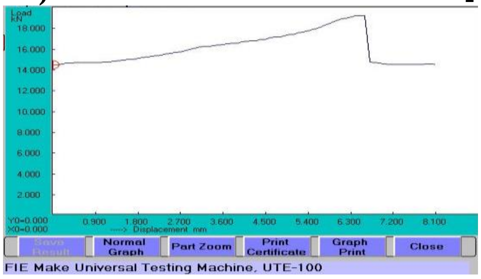

Figure.9. Graph for tensile test in base material of AA6061 (80%) with reinforcement of SiC (9%), Al_2O_3 (7%), ZrO_2 (4%).

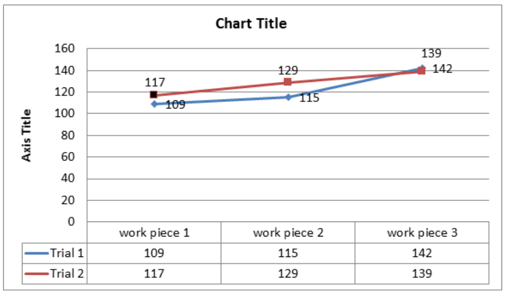

Figure.10. Hardness Test Graph Comparison

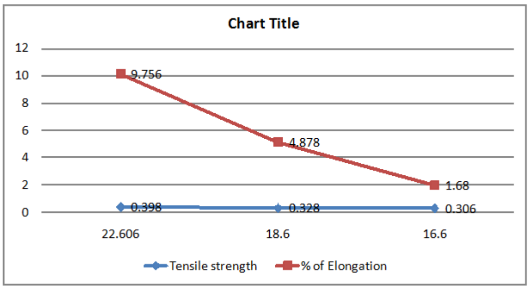

Figure.11. Tensile Test Graph Comparison

In this work, AA piston was dispersed with different contents of reinforcement of SiC (5%, 7%, 9%), Al_2O_3 (5%, 6%, 7%) & ZrO_2 (2%, 3%, 4%) is fabricated by using the stir casting method. The result of hardness and the thermal, mechanical properties should be increased for adding the reinforcement of materials. The above discussion deals with testing their properties and submitted the reading and proof of their testing.

The external surface of the casted piston has a higher softness but the internal surface of the piston shows lower softness than the external surface. The size and shape of the aluminium alloy powders are depends on the cooling rate, flow rate of the cooling medium and the surface tension of aluminium alloy melt.

In this work the effect of surface tension of aluminium alloy melt can be neglected because of the similar composition of aluminium alloy and same melting temperature of 800°c. The aluminium alloy metal matrix composite shows the improved weight to strength ratio. By using the stir casting process the aluminium alloy composite have been manufactured for low cost. The dispersion of reinforcement material with the base material to be made uniformly throughout the composition. The process parameter is taken to the consideration for uniformity distribution of materials.

4. CONCLUSION

Aluminium alloy composite materials exhibit good strength towards the automobile applications. In this work the result of Al 6061 with SiC, Al_2O_3, ZrO_2 proportion shows the Aluminium alloy will have the good weight to strength ratio. It implies that the Aluminium silicon carbide material exhibits less weight and more strength.

This paper deals with investigation of metal matrix composites and its mechanical properties. The result of AA MMC'S should be used for the engine application and testing their properties. It is to be used the base materials of AA6061 with reinforcement of SiC, nano-Al_2O_3 & ZrO_2 for increasing the hardness and their tribological properties.

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