MECHANICAL BEHAVIOR & ANALYSIS OF LM30 ALUMINIUM MMC REINFORCED WITH TIB2 FOR PISTON AT ELEVATED TEMPERATURE

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ABSTRACT

The growing steel prices have significantly affected the manufacturing expenditure in automobile and household industries, thus making a strong case for substituting steels with materials having lightweight and high-strength to weight ratio. The aluminum and its alloys have outstanding properties such as lightweight, wear, and corrosion resistance that make them suitable in numerous industrial applications. In today's scenario, customer perceived Quality is very important in view of increasing competition in global market. The engine sector is one of the example in which customer expectations in terms of Quality & Cost are boosted across world.

Pistons are required to meet two essential material requirements. One is resistance to deformation, or strength, under high combustion pressure and cyclic loads. This is required to perform at high compression range without fatigue ensuring safe working operations. The other requirement is toughness at high temperatures. This is required to perform at high temperature range without creep which is exposed to high flame areas.

Aluminium metal matrix composites with reinforcing particles shows great results at elevated temperature. In present work, base aluminium metal matrix LM-30 reinforced with 5, 10, 15 and 20% of TiB2 were made using stir casting process. The new metal matrix composite (MMC) formed was tested for different elevated temperatures. This paper mainly focused on the results of stress- strain, hardness-reinforcement and microstructure analysis of AMMC.

Keyword: - *Aluminium metal matrix composite, LM-30, TiB2, stir casting, High temperature, Hot tensile test.*

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1. INTRODUCTION

Among commercial aluminium casting alloys, aluminium TiB2 alloy are the most important ones. Mainly due to their excellent combination of properties such as good castability, good surface finish, light weight, fewer tendencies to oxidation, low coefficient of thermal expansion, high strength-to-weight ratio and strength to cost ratio, good corrosion resistance. These properties led to their excessive use in many automobile and engineering sectors where wear, tear and seizure are the major problems in addition to the weight saving. Some of these components are cylinder heads, pistons, connecting rods and drive shafts for automobile industries and impellers, agitators, turbine blade, valves, pump inlet, in many marine and mining sectors.

Generally the prediction of behavior of material at high temperature is very difficult and therefore hot tensile test is used to test the material subjected at high temperature. In this research work aluminium piston is taken as reference and by adding the composite material aluminium strength is increased at high temperature.

2. LITERATURE REVIEW

Jonathan A. Lee [2003] developed the new material for piston. NASA 398 is an aluminum-silicon alloy that may be used in a bulk alloy form with silicon content ranging from 6% to 18%. At high silicon levels the alloy exhibits excellent dimensional stability, low thermal expansion, high surface hardness and wear resistant properties. new material in hyper eutectoid aluminium piston & studied the cast aluminium alloy for tensile strength of many other applications (pistons, cylinder heads, cylinder liners, connecting rods, turbo chargers, impellers, actuators, brake calipers and rotors) at elevated temperatures from 232°C to about 400°C. Automotive legislation requiring low exhaust emission, the novel NASA alloys also offer dramatic increase in strength, enabling components to utilize less material, which can lead to reducing part weight and cost as well as improving gas mileage and performance for automobile engines.[1]

G.K. Sigworth ‘Grain Refinement of Aluminum Casting Alloys.’ In this paper an overview is given for grain refinement in aluminum casting alloys as well as benefits of refinements are described. The review shows the titanium characteristics, Titanium can be present in two forms. One which dissolves in aluminum, the other is insoluble to dissolve. Each must be controlled separately by refiners. Due to the presence of Al-Ti-B refiners today, there is no need to add soluble titanium separately in different alloys in large amount. From this paper we can say that grain refinements are always associated with boron and not titanium. For the formations of Al-5Ti-1B or Al-3Ti-1B rod it is recommended to add 10-20 ppm of boron. Titanium provides resistance to hot cracking in some alloys as well as it improves hardness of compound.[2]

3. PROBLEM DEFINATION AND OBJECTIVE FUNCTION

Most of the studies on IC Engine components had focused on fatigue behavior, yield behavior, creep behavior and wear behavior, deformation mechanisms in metallic materials, hardening mechanism of metals alloy at different temperature & structural analysis of piston. However, very less research is done on hot tensile testing. The main causes of piston damage are irregulrity in material or excessive load of thermal or mechanical nature. The results are to damage the pistons at operation.

Therefore the objective is”**to study the tensile property of aluminium alloy at elevated temperature and to suggest alternative piston material to overcome existing problem**”.

4. PREPARATION OF MATERIAL

Aluminium LM-30 cast al alloy which is hypereutectic Al-si alloy mixed with (reinforced) particles of titanium diboride (TiB_2) in proportion of 0%, 5%, 10%, 15% and 20% to form metal matrix composite. For preparing the composite aluminium stir casting is used.

Firstly aluminium was melted in electrical furnance at 760 °C and hold for 5 minutes for homogenization of the temperature while being stirred at 600 rpm using a zirconium coated ms stirrer. Reinforcement was preheated at a specified 800 °C temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating was done in muffle furnace. The preheating promotes the bonding between reinforcement and matrix.

To create vortex the molten slurry of LM-30 alloy is stirred by stirrer for 5 minutes at 600 rpm in clockwise & anticlockwise direction. By using nitrogen gas so as to avoid the formation of blow holes or inclusions in casting the molten slurry is degassed. During stirring of molten metal the preheated TiB_2 particles are added at same stirring rate. Due to vortex formation, negative pressure is created at center and TiB_2 particles get well disperse in Al matrix. The stirring is carried about 25 minutes holding time and casting is prepared in form of round bar after the molten melt is poured into sand mould. Round bar of dimensions Ø16x200 are prepared by sand mould which are then prepared according to standard ASTM E21:2009 as gauge diameter 10 by gauge length 50 (Ø10x50). The five sets containing 4 bars of PureLM-30 and 5 to 20% of reinforcements.

Fig -1: Samples prepared.

5. EXPERIMENTAL SETUP

Hot tensile test set-up fig. 2 shows that the hot tensile set-up made by SHIMADZU AUTOGRAPH, showing the furnace consisting test specimen. SHIMADZU AUTOGRAPH is real time live monitoring system. This machine consists temperature range between 0 to 900° C can be controlled by knob on the panel. Temperature inside the furnace is continuously monitored by thermo-couple placed inside the furnace. Hydraulic jack applies the load on test specimen. All tests were conducted under steady state condition. After the specimen was fixed as shown in fig. 2, the kiln or furnace temperature was raised to the required temperature and then held constant for half an hour to allow the test specimen to reach the same temperature. However, temperatures inside the furnace and on specimen surface were continuously measured by thermo-couples. In addition, a pilot reading was taken before the strength tests by monitoring the temperature inside the furnace. During the strength test, the target temperature was maintained at a specified degree and the test sample was loaded to failure. The furnace or closed chamber is used in order to ensure temperature setting consistency and to avoid temperature or thermal gradient along the test bar.

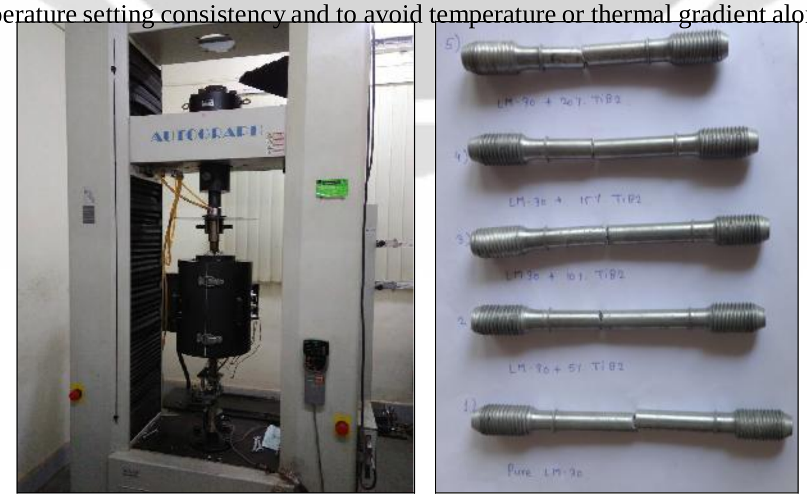

Fig -2: Hot Tensile Test Setup (SHIMADZU) & Actual Breaking of Sample

6. EXPERIMENTAL RESULT AND ANALYSIS

6.1 Stress vs Strain Analysis

The specimens of different reinforcements are tested in Hot tensile machine. Firstly pure LM-30 is tested at room temperature, 100°C, 150°C and 200°C and the same procedure is repeated for different reinforcement samples. The specimens are tested with strain rate of 0.05mm per minutes.

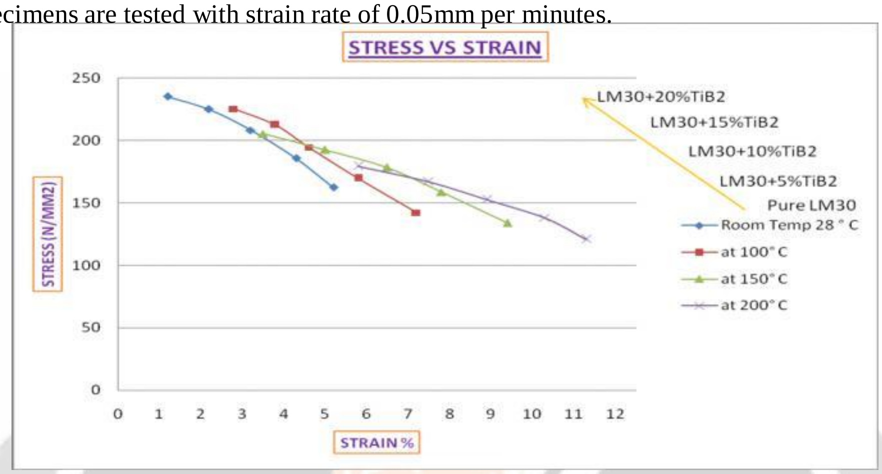

Chart -1: Stress vs % Strain

	Room Temp			100 °C			150 °C			200 °C		
	UTS in MPa	YTS in MPa	Elongation (%)	UTS in MPa	YTS in MPa	Elongation (%)	UTS in MPa	YTS in MPa	Elongation (%)	UTS in MPa	YTS in MPa	Elongation (%)
LM 30 Pure	162.4	108.8	5.2	142.2	95.27	7.2	133.8	89.64	9.4	120.7	80.86	11.3
LM 30 + 5% TiB2	185.6	126.13	4.3	169.6	116.17	5.8	158.5	108.57	7.8	138.0	94.53	10.3
LM 30 + 10% TiB2	208.2	145.75	3.2	194.5	136.15	4.6	178.3	124.81	6.5	152.6	106.82	8.9
LM 30 + 15% TiB2	224.8	161.85	2.2	212.2	152.78	3.8	192.5	138.6	5	166.8	120.09	7.5
LM 30 + 20% TiB2	235.1	176.32	1.2	225	168.75	2.8	205.1	153.82	3.5	179.4	134.55	5.8

Table -1: Experimental Results (HTT Readings)

6.2 Observations:

From the above graph we can conclude that,

1) At room temperature, alloy composition having 20% of reinforcement of TiB2 has high stress value while it has at the most less elongation 1.2%.
2) As the temperature increases, we can see the difference in stress values of alloys. Room temperature having highest strength carrying capacity while, the elongation is maximum for 200 °C for pure aluminium alloy.
3) The trends of graph for room temperature and for 100°C are likely to be same but as the temperature increases further the trend is changing.
4) For each graph of different temperatures, the UTS values became smaller as compared to room temperature.

5) For each graph of different temperatures, % elongation values become increasing compared to room temperature graph.
6) As the temperature increases, even though increasing the reinforcement percentage, uts decrease. But elongation decreases with increases in temperature.
7) Though the trends of graphs are different, but for each individual trend, the graph shows linearity.
So we can conclude that, the designing of any components for a particular temperature can be predicted easily as it will depend upon the linearity of aluminium.

6.3 Hardness vs Reinforcement

The Brinell test consists of measuring the indent depth to which a carbide ball or diamond ball is forced by a heavy load beyond the depth of a previously applied light load i.e. the reading is taken after releasing the load. The diameter of the hybrid compositeLM-30 TiB2 is 10mm. applied load = 100kgf =980.6N. At different areas in hybrid composite TiB2 we applied a load for 15 seconds by using load lever.

The indentation mark was seen under scale microscope. The results are tabulated below:

Composite	Load(Kgf)	Hardness (BHN)
LM-30	100	94
LM30+5% TiB2	100	106
LM30+10% TiB2	100	118
LM30+15% TiB2	100	128
LM30+20% TiB2	100	137

Table -2: Hardness Values

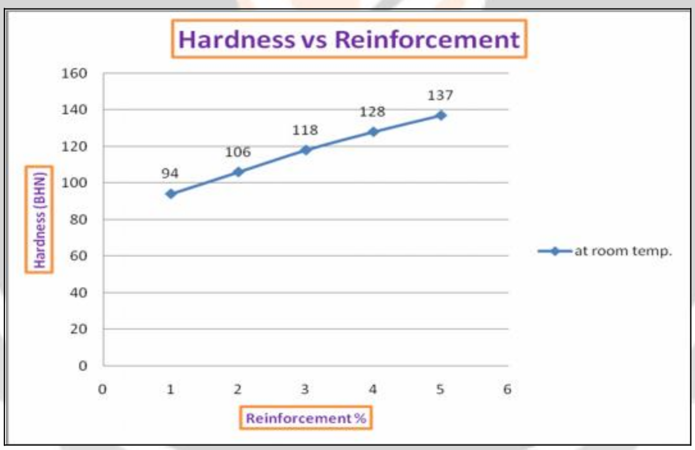

Chart -2: Hardness vs Reinforcement

7. CONCLUSIONS

From the above analysis following conclusions are drawn:

1) LM30 TiB2 metal matrix composites were synthesized successfully.TiB2 reinforcement phase was made to be distributed uniformly in the LM-30 matrix phase by the in-situ method. A uniform distribution of reinforcement particles has been obtained in the matrix phase.
2) Mechanical properties gets improved by using reinforcing material in LM-30
3) The ultimate tensile strength of material, stress values, hardness are increased by addition of reinforcing material TiB2.
4) The in-situ preparation of TiB2 in LM-30 refines its grain structure and ensures equal-axial matrix grains.
The matrix becomes finer by addition of TiB2 Particulates.
5) The increased volume fraction of the TiB2 particles contributed to increase the strength of composites.

6) Due to increase in temperature, uts decreases and elongation increases but Titanium holds the strength of material at elevated temperature as compared to pure aluminium alloy.

8. REFERENCES

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BIOGRAPHIES

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