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ANALYSIS OF MECHANICAL BEHAVIOR OF LM28 ALUMINIUM MATRIX COMPOSITE REINFORCED WITH TIC FOR CYLINDER HEAD OF COMMERCIAL VEHICLE

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Abstract: Now a days new challenges for the Al alloys are used for the production of casting for automotive engine components. In particular, Cylinder heads are operated at high operating temperature and stress levels. For cylinder head Al-Si-Cu alloy material used, but the resistance of base Al-Si-Cu alloy shows good result up to 150°C, while some of the interesting improvements have been achieved by modifying the composition of the base alloy LM28 with the addition of wt.% of TiC. The present project work was aimed to evaluate /analyze the mechanical behavior of LM28 AMC reinforced with wt.%TiC at room temperature and elevated temperature. Mechanical properties like, UTS,YTS and % of elongation were evaluated at as per ASTM standards at different temperature range and hardness at room temperature. The expected result shown that, (1) The strength of material LM28 increases with increment of wt.% of TiC in LM28. (2) The strength of material LM28 decreases with increase of operating temperature. (3) The % elongation of specimen increase with increase in temperature but decrease with increase of wt.% of TiC. (4) The hardness of LM28 is increases with wt% of TiC reinforcement.

Keywords: Aluminium alloy, Cylinder head, Elongation, HTT, LM28, Mechanical behavior, TiC, UTS,YTS.

I. INTRODUCTION

The importance of the analysis of mechanical behavior used to determine response of a metal or alloy to elastic and plastic deformation under the applied load. Some of the important tests are used to determine mechanical behavior are tensile test, hardness test, compression test, impact test, creep test etc. [18]

A cylinder head, is the main part of IC engine and it is placed in its upper region, used to lock the engine and must sustain the explosion, since, in this region; air and fuel are mixed, thus generate the ignition flame. [1]

During operation of cylinder head it subjected stresses are mainly related to the forces shown as:

1. Fatigue loading of the structure occurs because of load due to pressure peaks in the combustion chamber.
2. Dynamic loads from the valve train system, acting mainly on the upper side of the structure.
3. By the screws of connecting head to the cylinder block, the cylinder head bolts loads.
4. Thermal loads due to the uneven temperature distribution in the component.[1]

So the material requirement for the cylinder head' are as follows:

It must be rigid to distribute the gas forces acting during running condition on it as uniformly as possible through the engine block. It must give good mechanical, fatigue, creep resistance at operating temperatures, ductility. Material should have good thermal, electrical conductivity. Also have good hardness, high corrosion resistance and wear resistance and toughness at high temp.

In some countries, grey cast iron have been almost completely eliminated by cast Al alloys cylinder heads from last 23 years.[8]

II. LITERATURE REVIEW

R. Molina et al.[1] had worked on the mechanical behavior of Aluminium alloys, measured by using tensile testing and brinell hardness. The test result had shown that strongly influenced by test temperature and by the exposure time at high temperature. The resistance of base alloy Al-Si-Cu is good up to 150°C, but drops at 250°C. Some interesting improvements have been achieved by modifying the composition of the base alloy by adding of Mn and Ni. Resulting in an increment of UTS, YTS and ductility at both temperature and high temperature. J.Jebben Moses Et al.[2] have been done their work on investigation on the tensile strength and hardness of Aluminium alloy AA6061/TiC matrix composite. The specimens of Aluminium alloy AA6061with 15% wt. TiC was fabricated by using Stir casting technique. It is observed that stirrer blade angle, speed and stirring time is main stir casting parameters, which influences the mechanical properties of AMCs. By taking some testing the results obtained was like the levels of process parameters result in low UTS and also hardness, clusters, porosity and agglomeration of TiC particles are formed. At stirring blade angle of 30°, stirring time 15 minutes and speed of 300 RPM make homogeneous mixture of TiC with minimum porosity. Jayasheel Harti et al. [3] are focused on work entitled hardness and tensile behavior of Al alloy Al2219-TiC MMCs. Al2219- TiC particles composites were successfully produced by liquid stir casting technique with wt.% 2,4,and 6 of TiC reinforcement. The density of Aluminium alloy increased with addition of wt.% of TiC. Improvements in UTS and YTS of the Al alloy Al2219 matrix were obtained by addition of wt.% TiC particulates. The extent of improvement in UTS obtained in Al2219 after adding TiC by wt.% of 2,4,6 were 6.4, 21.10 and 48 % respectively and YTS were 20.42, 41.60 and 68.5% respectively.Atul Kumar et al.[4] shows the literature survey of work has been done to improve properties of Al MMCs reinforced with SiC. Also shows advantage of enhanced properties of these composites. Madeva Nagaral et al. [5] showed that work on production and mechanical behavior of Al alloy Al2618 –TiC MMCs had led to following conclusion: MMCs were prepared by liquid stir casting technique with 3 and 6 wt.% of TiC particles. Hardness of composites changes with increment of TiC in Al alloy. Improvement in ultimate tensile strength and yield strength of the Al alloy were obtained with addition of TiC wt.%. Michael Oluwatosin Bodunrin [6] had work on the different combinations of reinforcement matrix in the synthesis of AMCs and how it influences its performance. Y.C Lin et al.[7] have done their work on high temp. material flow behavior of Al-Cu-Mg alloy was studies by HTT. Result shows the effect of the forming temp. and strain rate on the flow behavior of Al-Cu-Mg alloy for all tested conditions. Flow stress increases with decreasing temp. and increases of strain rate. The previous studies on cylinder head have concentrated on utilization of Al alloy with different reinforcement. The current work concentrated on mechanical behavior Al alloy LM28 with wt.% of TiC at elevated temperature which were not investigated in earlier research works. The parameters that influences the strength of Al alloy are evaluated at elevated temperature and wt.% of TiC.

III. PROJECT WORK OBJECTIVES

1. To study the effect on hardness before and after addition of wt.%of TiC with aluminim alloy LM28 at room temperature.
2. To study the effect of room temperature and elevated temperature on strength of aluminium alloy LM28.
3. To study of effect of variation in wt.% of TiC with LM28 on strength of AMCs at room temperature and elevated temperature.

IV. SPECIMEN PREPARATION

A. Material used

A main problem when we used Aluminium alloys as a material for high temperature application are the reduction of strength if we exposed it to high temperature. A cylinder head locally experiences high temperature in the range of 20 to300°C. We know that aluminium alloy has good properties like light weight and other, but because of these with low strength and Melting point of Al always create a problem. A cheap method is very beneficial to solve this occurred problem is to use a reinforcement of ceramic particle with Al alloy. For this project work Al matrix composite material was used. It contains base alloy LM28 of density 2.68 g/cc. and titanium carbide as a reinforcement particles of density 4.93 g/cc.

Table no.1 shows the chemical composition of LM28 material.

Table 1 Chemical composition of Al alloy LM28

Parameter	Actual value (%)
Si	17.02
Fe	0.697
Cu	0.897
Mn	0.134
Ni	0.710
Pb	0.101
Ti	0.199
Cr	0.601
Al	Remainder

TiC: Titanium carbide particles are used as reinforcement material with the AMCs. As compare to other, TiC is particularly attractive due to its high hardness, stiffness, wear resistance, high elastic modulus and temperature resistance properties. It is in the form of black color powder.

B. Fabrication procedure

The simple and most economical used procedure for the preparation of specimens was liquid stir casting or vortex technique. Al alloy LM28 was in the form of ingots. Thses ingots was cut into small pieces and heated to the 800°C in furnace. TiC particulates were preheated for an hour at a temperature, were added to the molten metal of LM28 and stirred continuously. Because of increase in wt.% of TiC into molten metal porosity defect may occur but it was controlled by increasing stirring time. Digital temperature controller was used to control the furnace temperature. Mechanical stirring was continuously carried out before and after addition of TiC into molten LM28. The stirrer rotated at a speed of 50 RPM and increase alowly in between 300 to 500 RPM for 6 to10 minutes. Mould die was heated for 5 minutes, before molten LM28 metal pouring into it. Dimensions of specimen was dia. 18 mm*200 mm.

Table 2 Volume % of TiC reinforcement with LM28

Composition	LM28 wt.%	TiC wt.%
A	Pure	0
B	95	5
C	90	10
D	85	15
E	80	20

V. EXPERIMENTATION

In this project work mechanical behavior of the Al alloy LM28 reinforced with wt.% TiC were studied. Testing was carried out on the:

A. Tensile Test:

One of the simple, relatively inexpensive and fully standardized test. We should easily determine how the material will react to load being applied in tension by pulling. The stress –strain curve obtained from tensile test. Where strength was on y-axis and strain was plotted on x-axis. The % elongation was obtained by multiplying the strain with 100. The testing result data used to calculate elastic limit, elongation, modulus of elasticity, proportional limit, reduction in area, UTS and YTS. Fig.1 shows the specimen geometry in CATIA software.

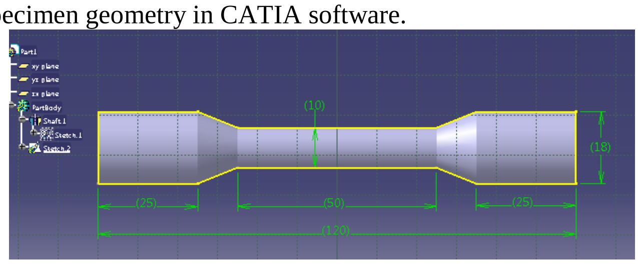


Fig.1 Specimen geometry in CATIA software.

For this project tensile testing was taken under room and high temperature (100,150 and 200°C) condition, namely

a. At room temperature

b. At elevated temperature

B. Room temperature Tensile Testing:

Tensile test was taken on universal testing machine (UTM) at room temperature condition. The specimens was fixed on jaw of UTM for testing and loaded by weight.

C. Hot Tensile Testing (HTT).

To measured mechanical behavior of LM28 and LM28- TiC material at high temperature, HTT machine was used. In automobile and power plant some parts are subjected high temperature, e.g in IC engine the cylinder head work under operating temperature in between 20 to 300°C. So in that case it is important while to study and analyze the effect of high temperature on material with the help of HTT machine. HTT machine is a UTM with connection of furnace and extensometer. The objective of this current work is to analyze the mechanical behavior of Al alloy LM28 reinforced with 5,10,15 and 20 wt.% of TiC at room temperature, 100,150 and 200°C. Fig.2 shows HTT setup made by SHIMADZU AUTOGRAPH, showing furnace consist of specimen. Temperature of furnace was controlled by using temperature control knob on panel of machine. Fig. 3 shows actual photograph of specimens of Al alloy LM28 with 0,5,10,15,20 wt.% of TiC respectively. Applied load on specimen in terms of tensile force through the hydraulic jack. The furnace temperature was raised up to the required temperature for testing and then held for 30 minutes to allow the test specimen to reach the same temperature.

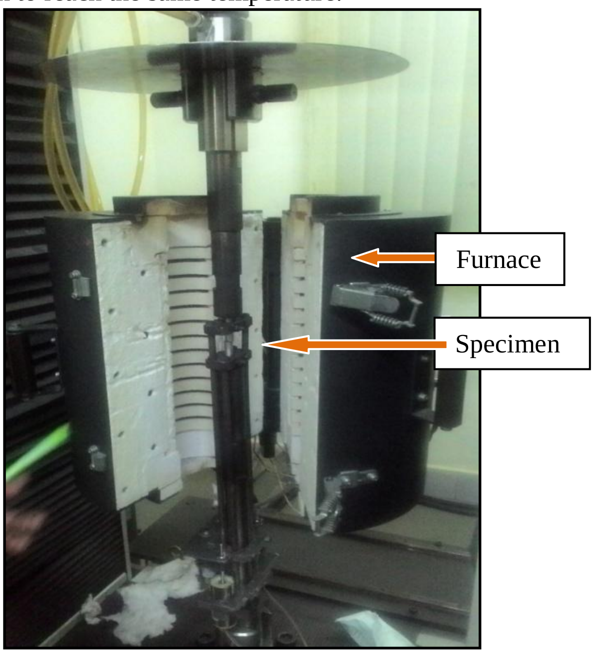


Fig. 2 Hot Tensile Testing AUTOGRAPH
[at ELCA LAB Bhosari Pune]

Fig.3 Photograph of tensile test specimens for various wt % of TiC particles of LM28/TiC composites.

D. Hardness test :

It is complex property and depends upon grain size, yield strength, ductility, work hardening coefficient resistance to abrasion, etc. There are various methods of measurement of hardness testing. For this project, hardness tested at room temperature on Rockwell hardness tester.

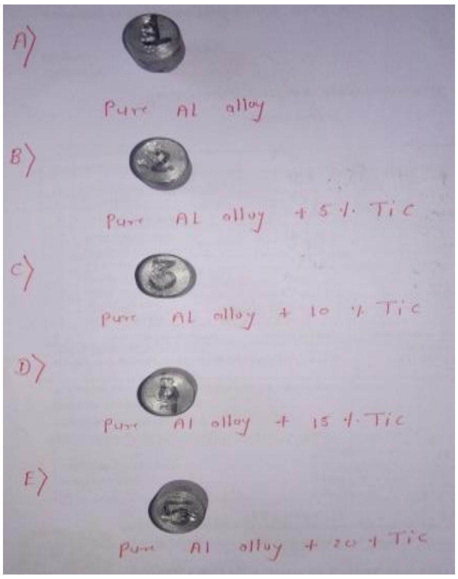


Fig.4 Photograph of hardness test specimens

VI. RESULT AND DISCUSSION

A. Hardness testing

After taking hardness testing, it shows that increment in hardness of specimen as increases wt.% of TiC with Al alloy LM28 as compare to plain LM28. Also shows that plain LM28 was soft material and its hardness was increased after reinforcement of hard particles such as TiC.

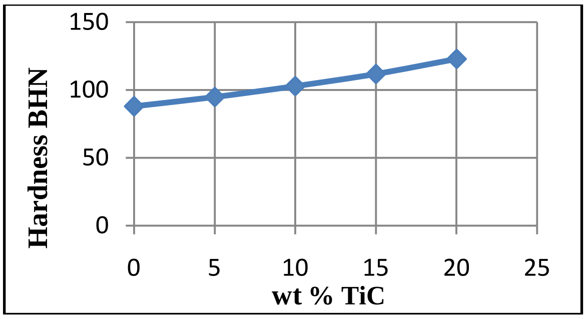


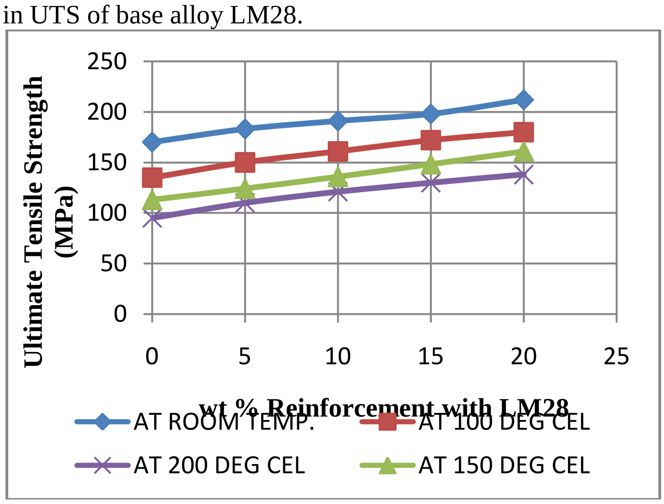
Fig. 5 Variations in hardness of Al alloy LM28 reinforced with wt. % of TiC

From fig.5, it is observed that effect of wt.% of TiC on LM28.

There is increment in hardness after mixing of TiC with Al alloy.

B. Tensile testing:

Fig.6 shows the variation of ultimate tensile strength (UTS) of base Al alloy LM28 and after reinforcement of 5,10,15, and 20 wt.% of TiC with LM28. The ultimate tensile strength of Al alloy LM28 – TiC is maximum as compare to base alloy LM28. The physical properties and microstructure of Titanium Carbide (TiC) particles control the deformation of the alloy LM28. Due to strong bonding between LM28 –TiC , load from the matrix transfer to the reinforcement resulting in increment in tensile strength. From taking test we got the results are, as we increase the reinforcement of 5,10.15 and 20 wt.% of TiC into Al alloy LM28, then there is increment in UTS of base alloy LM28.



Fig, 6 Variations in the ultimate tensile strength of Al alloy LM28 reinforeced with wt.% of TiC

At room temperature UTS of base alloy is less as compare to addition of 5 to 20 wt.% of TiC with step of 5%. By doing some improvement in material result was achieved. From fig. 6 it also indicates that as operating temperature during testing was increased, resulting the reduction of UTS of material.

At 100°C, all the AMCs material shows reduction of tensile properties as compare to RT condition. Same as at 150 and 200°c, we can see a further significant reduction of UTS for alloys. This high temperature effect on material was eliminated by doing modifications in base alloy LM28 material.

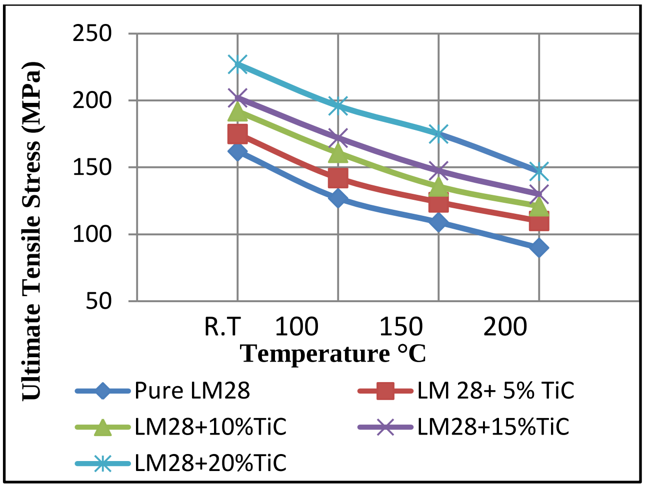


Fig. 7effect of temperature on variations of UTS of LM28 reinforced with wt.% of TiC

Fig.7 shows that, the value of UTS with material namely, base alloy LM28, LM28- 5%TiC, LM28-10%TiC, LM28-15%TiC,LM28-20%TiC at RT, 100,150 and 200°C.

The strength of Al alloy LM28 was maximum at room temperature but the strength of LM28 decreases as operating temperature was elevated during testing from 100 to 200°C by step of 50°C. From fig.7 also observed that strength of Al alloy with 20% Tic shows fairly good result at all temperature even LM28 -15% of TiC.

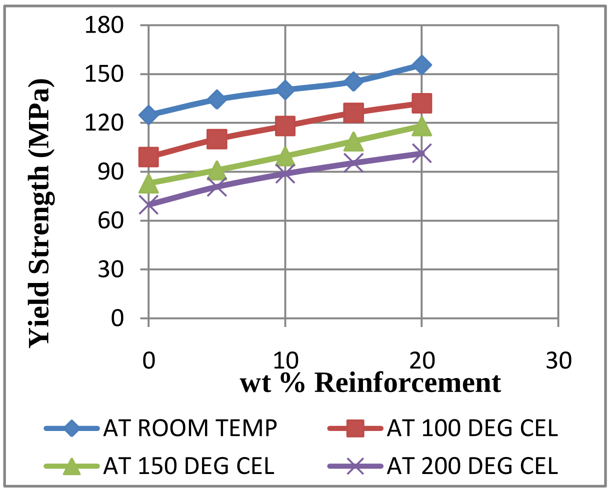


Fig 8. Effect of wt % of reinforcemet of TiC on Al alloy LM28 at room and elevted temp.

From fig. 8 it is observed that there is good effect of wt% of TiC reinforced with Al alloy LM28 on Yield strength even at room temperature and elevated temperature. Yield strength at room temperature was maximum and it more increases deu to good distribution of5,10,15 and20% of TiC with LM28. But by taking testing on HTT yiled strength of all alloys was decreases as temperature increaes. The increas in YTS of the AMCs was due to presence of hard material TiC particle which impart strength to the soft base alloy resulting in greater opposition of the composite against the tensile stress.

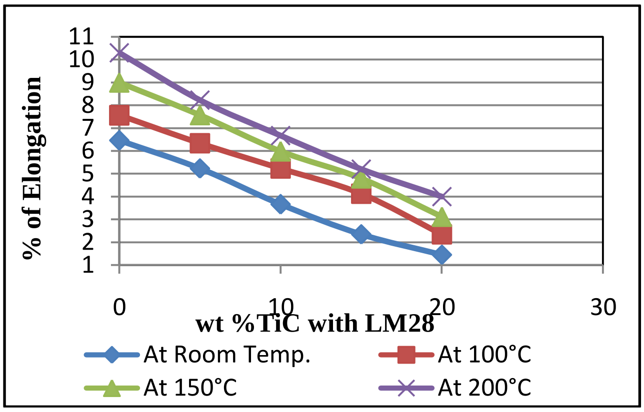


Fig. 9 variation in % elongation of Al alloy LM28 reinforced with wt.%TiC at Room Temp. and elevated temp.

Elongation is calculated by the ratio of change in gauge length with original (initial) gauge length, and multiplied by 100. Fig. 9 shows the variations of % elongation by effect of reinforcement on LM28. From fig.9, % elongation of Al alloy LM28decreased with 5, 10, 15 and 20 wt.% of TiC into AMCS. The effective slip distance of dislocation reduced by addition of maximum wt% of TiC, and due to it elongation % reduces fairly. For lower temperature range, deformation/ elongation of specimen was minimum but at high temperature % elongation was more.

VII. COMPARISON OF CURRENT MATERIAL WITH NEW MATERIAL FOR CYLINDER HEAD

Aluminium –Silicon (Al-Si) alloys are the most versatile materials used in the engineering material science, as compare to total Aluminium for casting of parts production in automobile industry. The Al alloy have excellent dimensional stability, low thermal expansion rate, high hardness, resistance to wear properties and improve fluidity at high silicon level. So for this project work LM28 used as base alloy which contain maximum wt.% of Si. Al- Si –Cu (A354 family) alloys are used for cylinder head, but the resistance base Al-Si-Cu alloys have good strength result up to 150° and drops strength above it. From the above result and discussion we can observed that proposed material had increment in strength at high temperature and room temperature. We can replace Al-Si-Cu alloys by taking the material as Al alloy with wt% of TiC. The material AlSi9Cu1(A354 family) studied by R. Molina et al. At room temp. strength of AlSi9C1 was 270 MPa, at 150°C 210MPa and at 200°C 70MPa. It is studied that, for high temperature range tensile property of LM28 –TiC have higher than current material. Hence, new material for cylinder head casting such as Al alloy LM28 –TiC is best replacement for A354 family.

VIII. VALIDATION

For Design engineer, FEA has become one of the best tool to solve the complex problem. For performing FEA the material was considered to be isotropic and boundary conditions and load applied as per experimental data.

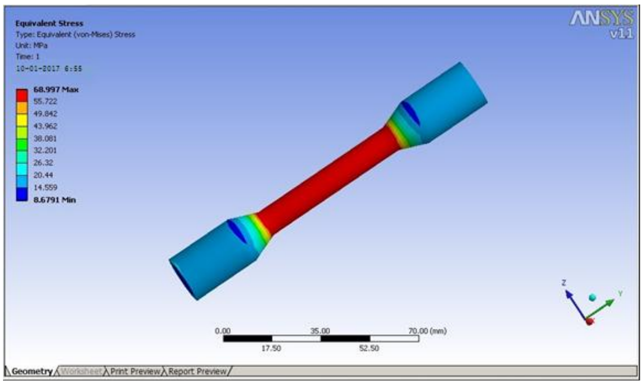


Fig. 10 Von misses stress on LM28 at 200°C.

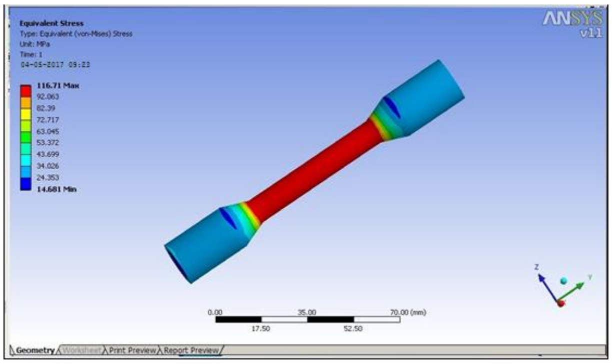


Fig. 11 Von misses stress on LM28-10%TiC at 200°C.

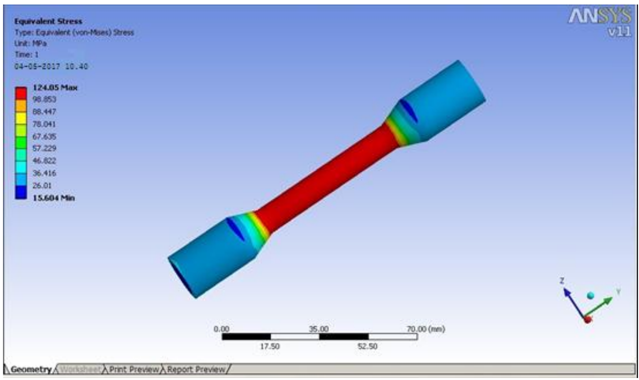


Fig. 12 Von misses stress on LM28 -15% TiC at 200°C

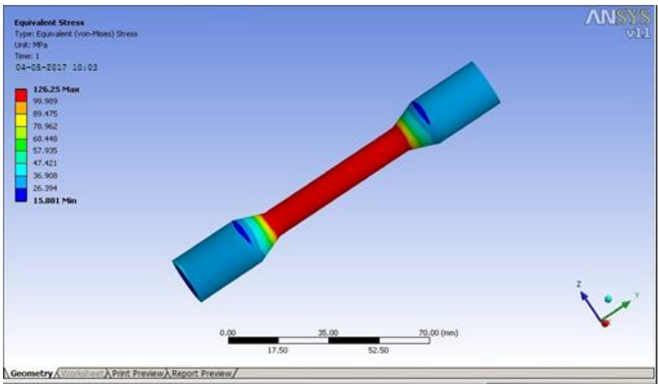


Fig. 13 Von misses stress on LM28-20%TiC at 200°C

Results from software work revealed that tensile strength results for numerical analysis are nearly closed to experimental results. This validates results of HTT.

Table 3 Comparison between experimental and numerical results at 200°C

Material	Experimental Stress (MPa)	Numerical stress(MPa)
LM28	90	70
LM28 -5% TiC	105	85
LM28-10%TiC	113	116
LM28 -15%TiC	119	123
LM28-20%TiC	130	127

IX. CONCLUSION

This current work presents the different combination of wt. % of reinforcements was used in the fabrication of AMCs and how it influences its performance. The mechanical behavior of Al alloy, measured by using tensile test and hardness test are strongly influenced by the room temperature and by the high temperature (100, 150 and 200°C).

The present work has led to following conclusions:

- LM28 –TiC particulate composites were successfully prepared by liquid stir casting method with 0, 5, 10, 15, and 20 wt.% of reinforcement in Al alloy.
- Improvements in both ultimate and yield strength of Al alloy matrix have been obtained with addition of TiC particulates. The extent of improvement in both strengths were obtained in Al alloy LM28 after addition of 5, 10, 15 and 20wt.% of TiC.
- The Al alloy LM28 showed better performance at room temperature, but decrement in performance at high temperature. This problem was solved by reinforcement of TiC with base alloy.
- The hardness of Al alloy LM28 with 5, 10, 15 and 20 wt.% TiC composite increased with the addition of TiC particulates in Al LM28 base alloy.

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