IJARST
International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

Analysis of spur gear using tungsten carbide particulate reinforced lm 25 aluminum metal matrix composite

Dr.V.Vikram Reddy, Dr. S. Mohana murugan, Mr. S. Phaneendra Seshabattar
Balaji Institute of Technology & Science

Abstract: In the present investigation work, fabrication and mechanical study of LM25 Aluminum and Tungsten Carbide (WC) composites containing weight ratios of 5%, 10% and 15% of Tungsten Carbide were prepared by stir casting method. Mechanical tests such as tensile test, hardness test, compression test and micro structure tests had conducted with required testing machines. Modeling and analysis soft wares like CATIAV5 and ANSYS 17.1 work bench had been using to model the spur gears and to perform finite element analysis. The main aim of this paper is minimization of both contact stress as well as deformation using the composite materials. The obtained results of the FEM analysis from Ansys compared with the theoretical Hertz equation values. Both the results agreed well and it shows the FEM model was accurate. Generally Gears will be failed due to contact stress exceeds the maximum stress. That contact stress beyond the critical level causes pitting on the gear teeth. Gear undergo huge amount of compressive stresses in power transfer, so materials like LM25Al-WC composite has used as the compressive strength of this composite very higher than LM 25 Aluminum and alloy steel. Finally the spur gears with different module and pressure angle were modeling in CATIAV5 and analyzed in ANSYS work bench 17.1 and it has observed that increase in module and pressure angle decreases the contact stress among the mating gears [1].The contact stress was also decreased with increasing face width.

Keywords — Compressive strength, Contact Stress, Finite element analysis, LM25Al – WC composite, MMC's, Spur gear, Stir casting

I. INTRODUCTION

In the present generation, conventional materials are being substituted by metal matrix composites due to their Sound properties like high strength to weight ratio, low density etc... The LM 25 aluminum alloy is used in this point of application; it contains very good strength and mechanical properties such as hardness, toughness, weld ability, resistance to corrosion and machine ability. The LM 25 aluminum alloy used in many different applications such as casting of auto mobile machine parts, air craft frame and missile structure components. The aluminum – silicon alloy properties were impacted by the shape and transference of the eutatic silicon particles in the matrix, forther more by the iron inter metallic and copper stages that happen upon solidification remarked[3]. The part of Fe, Mn, Cu, and Mg substance was touchier to varieties in microstructure and malleable properties of Al- Si close-eutectic compound. Aluminum LM 25(Al- Si7 Mg) means the composition in % wt of 0.20 Cu, 7.50 SiMg, 0.6 Fe, 0.50 Mn, 0.30 Ni, 0.10 Zn, 0.10Pb, 0.05Sn, and 0.2TiAl. Here it can shows the LM 25 Aluminum alloy contains nearly 7.50% of SiMg and so it was using as matrix due to following details. Al- Si Alloy as matrix (saheb et. al. 2001)[2]: Al- Si alloy considered as a frame work material on account of its gigantic properties like high wear resistance, low warm extension coefficient, great consumption resistance, and enriched mechanical properties at an extensive change of temperature (saheb et. al. 2001). Aluminum – silicon composites were the bubbliest and usually employed throwing combinations to cast parts with complex shapes in light of simple cast ability and great bargain between mechanical properties and gentility. (Merlin et al, 2009)[3]: The use of aluminum compounds was likewise mostly consumed as a part of car division which quick financially supportable advancement. The aluminum – Silicon alloy properties were wedged by the shape and transportation of the eutectic silicon particles in the matrix, furthermore by the iron inter metallic and copper stages that happen upon solidification observed by Mohamed et al (2009).

(Anasyida et al., al 2010).[4] The part of Fe, Mn, Cu, and Mg substance was more sensitive to diversities in microstructure and mallable properties of Al- Si close – eutectic compound. Aluminum –Silicon (AL – Si) alloys, they used as engineering materials and established usually application in the field of aerospace, automobile, and military applications. Al – Si alloys was good castability, high wear resistance, low density and thermal expansion coefficient near – eutectic. These compounds were likewise impacted by their tribological properties, so they utilized as a part of transportation vehicle segment. It has established that wear resistance of Al- Si compound was impacted by different variables like burden and speed and additionally by microstructural parameters, for example, the morophology and volume division of the silicon stage. Al – Si alloy had improved the wear properties by fusing hard ceramic particles, for example, Al2O3, Sic and TiB2 to create composites (Daoud et al, 2004).[5], Due to outstanding castability, at some point Aluminum – Silicon eutectic or close eutectic compounds were thrown to deliver „Piston Alloy‟, which gives the best overall equalization of properties (Day et.al.,1970) far enhanced mechanical properties such as better strength to weight ratio, more hardness, and hence less probabilities of failure. Gears manufactured from composite provides almost 60% less weight compared to steel gear, while power rating of both gears remains almost same. FE Analysis also shows less chances of failure in Al- Sic gear. Almost 3-4% difference has observed between theoretical and FEA values of bending stress. Vivek Karaveer et al [6] studied the contact stress analysis of spur gears and presented that the results of Hertz equation and FEA were comparable. The materials used in their study were, cast iron and steel. Additionally the contact stress determined through the transmission of torque of 1500lb -in or 1694.7725 Nm using finite element analyses. Dhavale A.S et al [7] paper discovers when gear has exposed to load, high stress developed at the root of the teeth, Due to these high stress, probability of fatigue failure at the root of teeth of spur gear growths. The moment of torque is 15000 lb-in or 1694.7725 N-m using finite element analyses. Putti Srinivasa Rao et al [8] considered the contact stress analysis of different materials such as aluminum steel alloy and cast iron. The minimum contact stress has observed aluminum. The author authenticated the results both ansys and Hertz theory.

II. METHODOLOGY OF FABRICATION

A. Materials LM25Al was using as matrix material and Tungsten Carbide particles added as reinforcements to prepare composites in the study. The chemical composition of LM25Al was using as matrix material. The particle size of Tungsten carbide ranges from 30 to 40 microns.

B. Preparation of Composite LM 25 Aluminum metal matrix ingots were taking in a graphite crucible at room temperature by stir casting equipment according to required weight percentages. Simultaneously the required percentage of tungsten carbide reinforcement were also preheated at 400 degree centigrade in furnace to remove moisture content as shown in fig 1 .The ingots were heating at 800 degree centigrade temperature until a slurry manually. Then composite slurry was reheating again to obtain a fully liquid state and the stirrer rotated with the help of a motor at an average speed of 200 rpm for nearly 2 hours‟ time, for the purpose to even distribution of Tungsten Carbide particles in LM25 Al-alloy [9]. Then finally the liquid metal purred into a mould of cylindrical shaped with diameter of 15mm as shown in fig: 2. Finally the castings cooled at room temperature to relive the residual stress and then taken out from mould.

Fig: 1 Stir casting Furnace

Fig: 2) Poured Liquid metal into mould

Fig: 3) Composite specimens

III. EXPERIMENTAL TESTING

A. Hardness Test The hardness tests of all specimens have been conducted by using a Vickers hardness testing machine with applying 1 kg load and indentation time of hardness taken as 15 seconds. For the purpose of accuracy three readings were taking for each %of reinforcement composite material. Vickers hardness testing machine was shown in figure 3. From the obtained results the hardness values of composite were increasing with the increase in % of tungsten carbide.

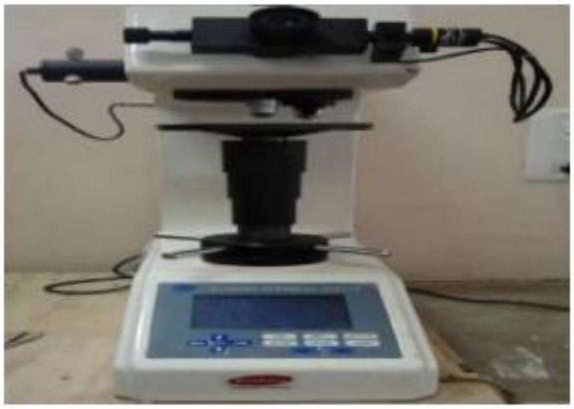


Fig: 4) Vickers hardness tester

Fig: 5) Hardness of the composite samples

S. NO	Specimens	Hardness(VHN)
1	Aluminum	65.92
2	LM 25 Al- 5% WC	80.19
3	LM 25 Al – 10% WC	90.52
4	LM 25 AL-15% WC	99

Table: 1) Hardness values of composite

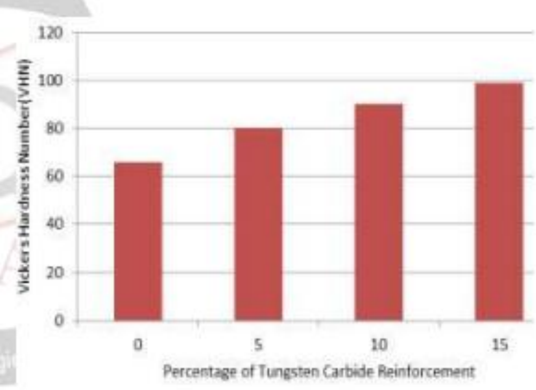


Fig: 6) Hardness variations of composite

S. NO	%of Reinforcement	Youngs Modulus (Gpa)
1	Aluminum	71
2	LM 25 Al- 5% WC	71.5
3	LM 25 Al – 10% WC	71.55
4	LM 25 AL-15% WC	71.6

Table: 2) Yong's Modulus value of Alloy and Composite material

%of Reinforcement	Ultimate Tensile strength (Gpa)	%of Elongation
Aluminum	71	27.8
LM 25 Al- 5% WC	71.5	17.4
LM 25 Al – 10% WC	71.55	12
LM 25 AL-15% WC	71.6	9.2

Table: 3) comparison of tensile behavior of the alloy and composite

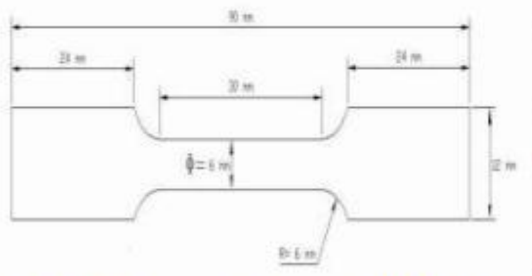


Fig: 7) Dimensions of tensile test specimen ASME 8 standard

Fig: 8) Machined specimens on Lath

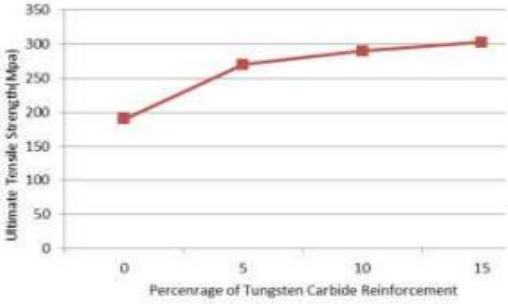


Fig: 9) Variation of Ultimate Tensile strength with the %of Reinforcement

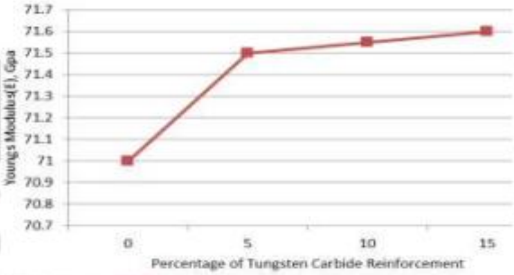


Fig: 10) Variation of Young's modulus of composite with the % of reinforcement

S. NO	Specimen	Density (gm/cc)	
		Theoretical	Measure
1	Aluminum	2.68	2.65
2	LM 25 Al- 5% WC	2.666	2.645
3	LM 25 Al – 10% WC	2.635	2.623
4	LM 25 Al – 15% WC	2.602	2.60

Table: 4) Theoretical and measured densities of LM 25 Al *and LM 25 –WC Composite*

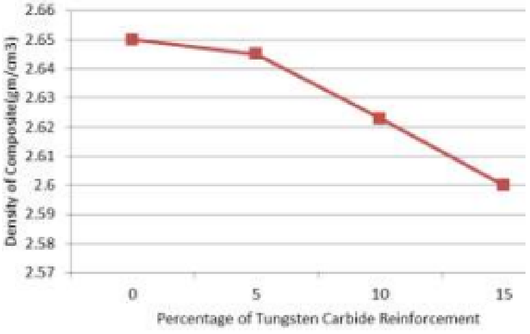


Fig: 11) Variation of Density with Reinforcement

S. No	Specimen	Poison's Ratio
1	Aluminum	0.3300
2	LM 25 Al-WC 5% Composite	0.314
3	LM 25 Al –WC 10% Composite	0.308
4	LM 25 Al –WC 15% Composite	0.302

Table: 5) Poisons ratio of the composite

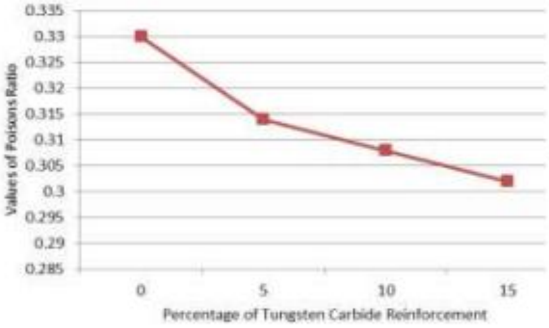


Fig: 12) Variation of poisons ratio with change in % of reinforcement

S. no	%of Tungsten carbide	Length of Specimens				%of compression
		Initial (mm)	Final after 40 KN	Final after 50KN	Final after 60 KN	
1	0	20	17	15	13.2	34
2	5	20	18	17	16	20
3	10	20	19	18	17	15
4	15	20	19.5	18.5	17.5	12.50

Table: 6) % of compression with respect to loads applied

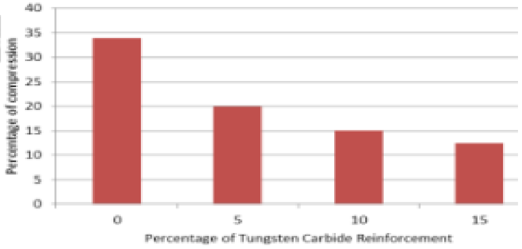


Fig: 13) Variation of % of compression with respect to change in % of reinforcement

Micrographs of LM 25 and LM 25 with 5, 10 & 15% of tungsten carbide composites observed by optical microscope, Etching finished using the Keller‟s reagent. The Micro graphs was showing from figure 14 to figure 17.The Micro graphs showed that uniform distribution of tungsten particulate reinforcement throughout the matrix alloy. This study concluded that good bonding among matrix and reinforcement particles which yields better load transfer from matrix to reinforcement material.

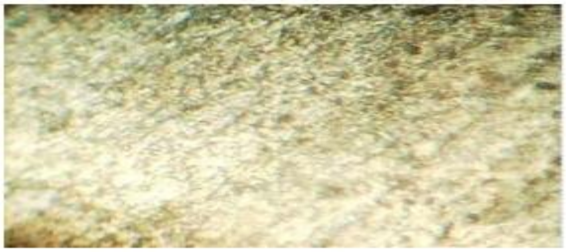


Fig: 14) Optical micro structure of LM 25 Aluminum

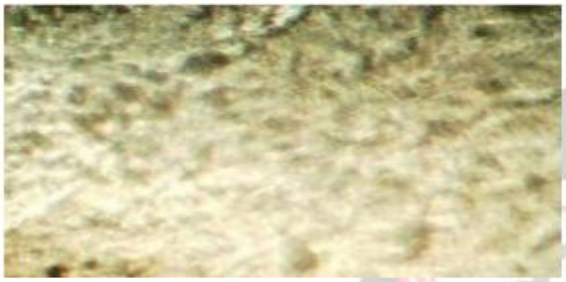


Fig: 15) Optical micro structure of LM 25 Al -5% WC

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

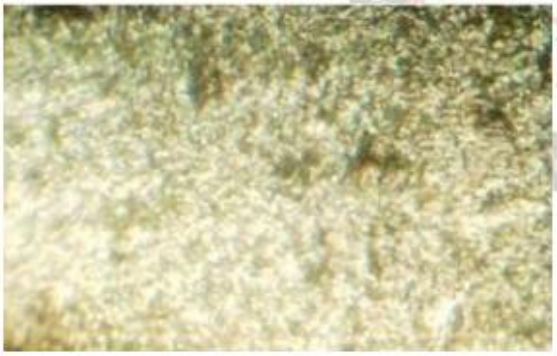


Fig: 16) Optical micro structure of LM 25 Al -10% WC

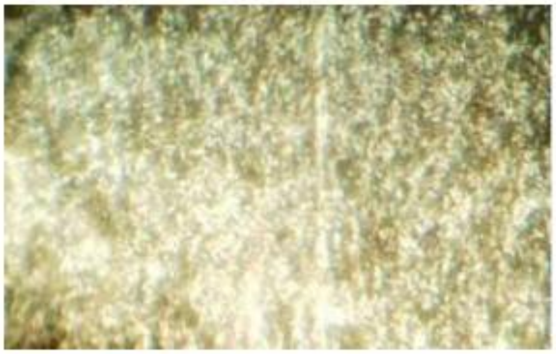
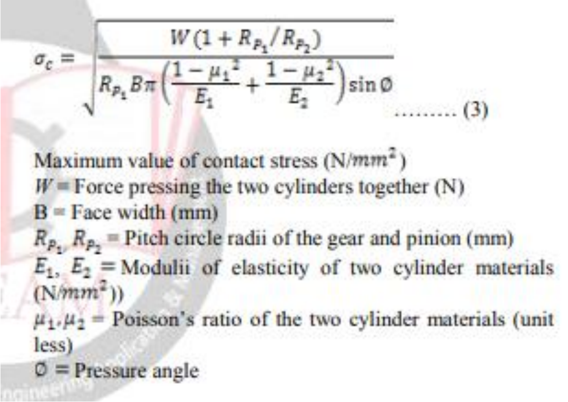


Fig: 17) Optical micro structure of LM 25 Al -15% WC

IV. THEORETICAL ANALYSIS OF CONTACT STRESS OF SPUR GEAR

Earle Buckingham (1926) used the Hertz theory to determine the contact stress between a pair of teeth while transmitting power by treating the pair of teeth in contact as cylinders of radii equal to the radii of curvature of the mating involves at the pitch point.



$$\sigma_c = \sqrt{\frac{W\left(1 + R_{P_1}/R_{P_2}\right)}{R_{P_1} B\pi\left(\frac{1-\mu_1{}^2}{E_1} + \frac{1-\mu_2{}^2}{E_2}\right)\sin\emptyset}} \quad \text{………} \ (3)$$

Maximum value of contact stress (N/mm^2)
W = Force pressing the two cylinders together (N)
B = Face width (mm)
R_{P_1}, R_{P_2} = Pitch circle radii of the gear and pinion (mm)
E_1, E_2 = Modulii of elasticity of two cylinder materials (N/mm^2))
μ_1.μ_2 = Poisson's ratio of the two cylinder materials (unit less)
$\emptyset$ = Pressure angle

V. MODELING OF SPUR GEAR IN CATIA

By using different specifications like change in module and pressure angle the spur gear pairs were modeling in CatiaV5. Those design models converted into IGES format and static analysis anlysized in Ansys work bench 17.1.In this case same moment of torque 1694.8N-m[6] given as input to all three spur gear pairs and it observed that with increase in module and pressure angle the contact stress decreased. From the theoretical hertz equation contact stress calculated from equation (3) and it was comparing with ansys values.

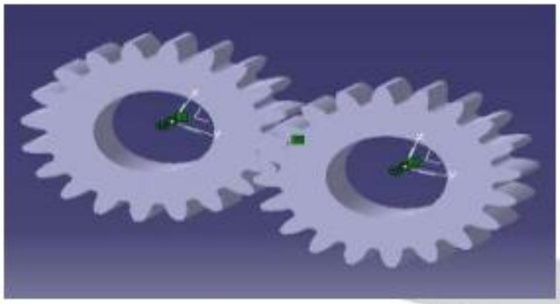
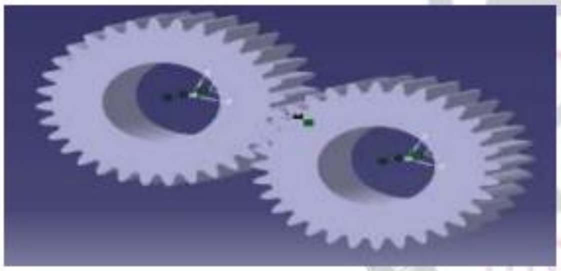


Fig: 18) Spur Gear Design –I



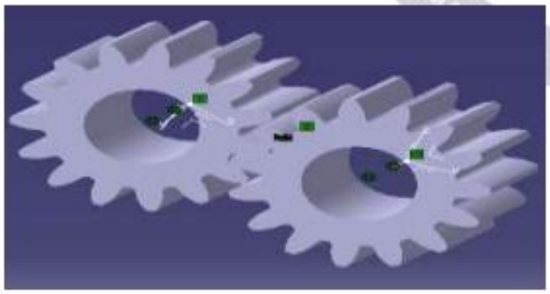


Fig: 20) Spur Gear Design –III

VII. RESULTS

The uses of composite materials in gear manufacturing provide a range of contact stresses. This range of contact stresses and deformation is useful in the selection of material in unusual applications. From design -1 analysis of spur gear using aluminum composite (LM 25-WC) noticed that the contact stress is less than structural steel and aluminum material. An LM 25 Al- WC composite of weight ratio 5%, 10% and 15%, least contact stress occurred at 15% of tungsten carbide. The lowest contact stress occurred at design -3 and design -1 compared with design-2 by using LM 25 -15% WC composite material. The values obtained by Hertz‟s equation and simulation concur with each other with a maximum error of 5% which is acceptable. It shows that the simulation done in ANSYS is compatible and scopes up with hertz equation for a range of materials used in the experiment. Aluminum composite on the other hand provides less contact stress when mated with any of the gears. The lowest contact stress is recorded when LM 25- 15%WC using spur gear face width 107.6mm.

VIII. CONCLUSION

LM 25 Al- WC composites of weight ratio 5%, 10% and 15% were invented through stir casting technique. A mechanical property like tensile strength, young‟s modulus, poison‟s ratio and hardness had valued. Spur gears with different specifications had modeled in catiaV5 and analyzed through Ansys work bench 17.1 which were comparing with Hertz equation contact stress values. The hardness of the composite increased from 65.92(VHN) for pure LM 25Al to 99(VHN) for LM 25 Al - 15% WC reinforcement. The tensile strength of the composite increased from 190 Mpa for pure alloy to 303 Mpa for LM 25 Al - 15% WC reinforcement. It has detected that modulus of elasticity of the composite also increased from 71 Gpa for pure alloy to 71.6 Gpa LM 25 Al - 15% WC reinforcement. The density of the composite declined from 2.65 gm/cc for pure LM25 Al alloy to 2.60 gm/cc for LM25 Al-15%WC composite, which displayed that the strength to weight ratio growths with increase in % of reinforcement for composite. The compression strength of the composite also increased with the increase in % of reinforcement and which was the most desired property for the gears to with stand high compressive stresses. The % of compression varies from 34% for pure LM 25 Al alloy to 12.50% for 15% reinforced LM 25Al –WC composite. The poisons ratio of the composite also declined from 0.33 for pure LM 25 Al alloy to 0.302 for 15% reinforced LM 25 Al –WC reinforced composite, which specified that the contact stress decreases with decline in the poisons ratio by Hertz equation. Thus the composite can be chosen for gears. It was concluded that the contact stress was decreasing with increases in module and pressure angle, which can be considered in designing the gear. From in this point of view LM 25 Al – 15% Tungsten carbide composite material of the contact stress and deformation was less when compared with alloy steel and pure LM 25 Al alloy. The contact stress values from both Hertz theory and Ansys results has approved. The contact stresses declined with varying of the face width in Design modification.

REFERENCES

[1] Krishna gupta", Effect of pressure angle of spur gear omn bending and contact stress: A comparative study using finite element software, "IJARSE, Vol. No. 4, Special issue (01), March2015.

[2] Dunia Abdul sahib, "Aluminum Silicon carbide and aluminum Graphite particulate composites". ARPN journal of engineering and applied scinces, 6(10).

[3] Karaveer, Vivek, Ashish Mogrekar, and T. Preman Reynold Joseph. "Modelling and Finite Element Analysis of spur gear." International

journal of current engineering and technology ISSN (2013): 2277-4106.

[4] A.S. Anasyida, A.R. Daud and M.J. Ghazali, Dry sliding wear behariour of al-4Si-4Mg alloys by addition of cerium, International journal of mechanical and materials engineering (IJMME)- Vol.4 No.2,2009,127- 130.

[5] N.Saheb, T.Laoui, A.R Daud, M.Harun, S. Radiman, R. Yahaya "Infulence of Ti addition on wear properties of Al- Si eutectic alloys" wear 249(2001)656-662.

[6] Karaveer, Vivek, Ashish Mogrekar, and T. Preman Reynold Joseph. "Modelling and Finite Element Analysis of spur gear." International journal of current engineering and technology ISSN (2013): 2277

[7] Dhavale A.S., Abhay Utpat "Study of stress Relief Features at Root of teeth of spur gear". International Journal of Engineering Research and applications (IJERA).Vol.3, Issue3, May-june 2013, pp.895-899.

[8] Putti Srinivasa Rao, NadipalliSriraj, Mohhammad Farookh, Contact Stress Analysis of Spur gear for different materials using ANSYS and Hertz equation" (2014)

[9] K Punit Gowda, J.N Prakash, Shiva sankar Gowda, B. Satish Babu, "Effect of particulate reinforcement on the mechanical properties of Al2024-WC MMCs" Journal of Minarals and materials characterization and engineering, 2015,3,459-476

[10] K. Ravi Kumar, K. Kiran, V.S Sreebalaji, "Characterization of Mechanical properties of aluminum/Tungsten carbide composite". Elsevier

[11] J.N Venkata Kishore, K. Venkata Rao," Mechanical properties in MMC of Aluminum Alloy (A356/LM 25) Matrix and Born Carbide (B4C) Reinforcement". International journal of Engineering and Technology (IJERT) ISSN: 22708-0181, Vol.5 Issue 02, February -2016