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MODELING AND STATIC THERMAL ANALYSIS OF CONNECTING ROD WITH METAL MATRIX COMPOSITE MATERIALS USING FEM

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ABSTRACT

The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. Existing connecting rod is manufactured by using Carbon steel. Composite materials are now a day widely used in the engineering field. The general characteristics possessed by the composite materials are found to be the reason for using it in the automotive applications. The objective of the project is to design and Static Thermal analysis of connecting rod using metal matrix composite (MMC) with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) The connecting rods are commonly used in the internal combustion engines and are subjected to millions of varying stress impacted. While the Composite connecting rods are lighter and may offer better compressive strength, stiffness and fatigue resistance than conventional connecting rod their design still represents a major technical challenge. In this project both the standard material and composite connecting rods are modeled and analyzed using catia v5 and ANSYS WORKBENCH 16.2. software respectively. A comparative study was undertaken to predict the structural and thermal behavior of connecting rods using three dimensional finite element analysis model, and to determine the most cost effective modeling and analysis approach. The finite element results verify that the performance is same as that of standard steel connecting rod. The stress and static Thermal analysis of the composite connecting rods is found to be better than that of the standard connecting rod. Finally concluded the suitable material of connecting rod based on the stresses, strains, deformations, shear stress, temperature distribution, heat flux values.

1 INTRODUCTION

Internal Combustion engine has many parts like cylinder, piston, connecting rod, crank and crank shaft. The connecting rod is very important part of an engine. Working of the connecting rod is to transmit power of piston to crank pin. Connecting rod has two ends one is pin end and other is crank end. Pin end is attached with piston. The big end (crank end) is attached to the crank pin by a crankshaft. The function of crank shaft is to transmit the reciprocating motion of piston into rotary motion. The connecting rod should be such that it can sustain the maximum load without any failure during high cycle fatigue. The connecting rod has generally three parts; pin end, crank end, and long shank. Design of shank can be different type like rectangular, tubular, circular, I-section and H-section. Circular section is generally used for low speed engines. I-section is used for high speed engines.

Connecting rod is among large volume production component in the internal combustion engine, which connects the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it in to transmission. Hence, these rods must have lowest weight to achieve the highest possible rigidity. There are different materials and manufacturing process used in the production of connecting rods. During operation the combination of axial and bending stresses are induced in the connecting rod. The cylinder gas pressure produces the axial stresses which is compressive in nature and the inertia force arising in account of reciprocating action which includes both tensile and compressive force, whereas the centrifugal effects cause the bending stresses. The con rod consists of a long shank, a small end and a big end. The cross-section of the shank may be I-section, rectangular, circular, tubular or H-section. Generally I-section is preferred for high speed engines which provide the maximum rigidity with minimum weight and circular section is used for low speed engines. The manufacturing processes used are casting, forging, and powdered metallurgy. Now a days the particulate reinforced Aluminum matrix composite are going importance because of low processing cost, having isotropic properties and chances of secondary processing Generally there are few common materials like Aluminum, Steel alloy and Titanium which are used in manufacturing of connecting rods. Aluminum and Titanium are used in high performance engines. To reach various specifications required the manufacturing and heat treatment is done. The combination of materials like Al and Ti is done with reinforcing with hard materials like B4C, SiC, Al2O3, Graphite particulates, etc. In obtaining the performance engine, great attention should be paid on connecting rods, which is obtained by suitable cross section design, manufacturing process, material and its reinforcements

1.1COMPOSITE MATERIAL:

A material composed of two or more constituents is called composite material. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites, whereas in alloys, constituent materials are soluble in each other and forms a new material which has different properties from their constituents.

MMC materials have a combination of different superior properties to an unreinforced matrix which are; increased strength, higher elastic modulus, higher service temperature, improved wear resistance, high electrical and thermal conductivity, low coefficient of thermal expansion and high vacuum environmental resistance. These properties can be attained with the proper choice of matrix and reinforcement. The matrix can be selected on the basis of oxidation and corrosion resistance or other properties. Generally Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag, Zn, Sn and Si are used as the matrix material, but Al, Ti, Mg are used widely. Now a day's researchers all over the world are focusing mainly on aluminum because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. The unique thermal properties of aluminum composites such as metallic conductivity with coefficient of expansion that can be tailored down to zero.

1.2 ABOUT ALUMINUM :

Aluminum is the most abundant metal in the Earth's crust, and the third most abundant element, after oxygen and silicon. It makes up about 8% by weight of the Earth's solid surface. Due to easy availability, high strength to weight ratio, easy machinability, durable, ductile and malleability aluminum has been amongst the most useful metals. It have various type of properties such as light weight, strong and long-lasting, highly corrosion resistance, excellent heat electricity and electricity conductor, god reflective properties, very ductile, completely impermeable and odorless and it is totally recyclable. It has atomic number 13, atomic weight 26, and melting point 730oC. the density of aluminum at 293k is 2700gm per cubic cm with hexagonal close packing crystal structure

1.3 CLASSIFICATION OF COMPOSITES

1. Polymer matrix composites
2. Metal matrix composites
3. Ceramic Matrix composites

Metal matrix composites (MMC) are a family of new materials which currently experiencing active development in various fields. The potential of MMC materials for significant improvements in performance over conventional alloys has been widely recognized. Besides performance, the other major factor in determining the applications for a material is cost. Raw materials cost is not the only factor determining the overall cost effectiveness of the material in a particular component application.also depends on the processes through which the material advances.

Composite materials are important engineering materials due to their outstanding mechanical properties. Composites are materials in which the desirable properties of separate materials are combined by mechanically binding them together. Each of the components retains its structure and characteristic, but the composite generally possesses better properties. Composite materials offer superior properties to conventional alloys for various applications as they have high stiffness, strength and wear resistance. The development of these materials started with the production of continuous-fiber-reinforced composites. The high cost and difficulty of processing these composites restricted their application and led to the development of

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discontinuously reinforced composites. A composite material is produced from two or more constituent materials with significantly different physical or chemical properties. The constituent materials, then work together to give the composite unique characteristics that are different from the individual components. The individual components remain separate and distinct within the finished structure as they do not blend or dissolve into each other. Wood is an example for natural composite, made from long cellulose fibers (a polymer) held together by a much weaker substance called lignin. The bone in the human and animals' body is also a natural composite. It is made from a hard but brittle material called hydroxyapatite (which is mainly calcium phosphate) and a soft and flexible material called collagen (which is a protein). The terms of matrix and reinforcement are very often used when talking about composites. Matrix is a relatively ‘soft’ phase with specific physical and mechanical properties, whose sole purpose is to bind the reinforcements together by virtue of its cohesive and adhesive characteristics, to transfer load to and between reinforcements. The reinforcement phase (or phases) is usually stronger and stiffer than the matrix and mainly carries the applied load to the composite . Composite materials can be subdivided into three main groups: Polymer, Ceramics and Metals. Reinforcements added to these materials produce Polymer Matrix Composites (PMC), Ceramic Matrix Composites (CMC) and Metal Matrix Composites (MMC). Among different composites, Metal–matrix composites are the most widely used in the industrial scale due to its advantages compared to Polymer Matrix Composites and Ceramic Matrix Composites.

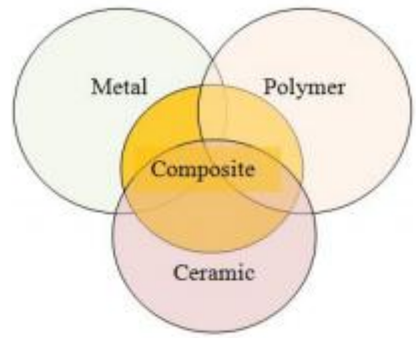

FIGURE 1FAMILY OF COMPOSITE MATERIAL

Metal matrix composite materials are produced by combining tough metallic matrix with hard ceramic or soft reinforcement materials. The reinforcement materials systems can be generally divided into five major categories, i.e. particulates, wires, continuous fibers, discontinuous fibers, and whiskers . Table 1 displays typical reinforcements used in MMCs. MMC can be defined as the materials whose microstructures comprise a continuous metallic phase into which a second phase, or phases, have been artificially introduced This is in contrast to conventional alloys in which the microstructures are produced during processing by phase transformations

When the matrix material has high ductility, the cracks formed by the breakage of weak fibers can be arrested and if the matrix is not ductile enough, the cracks can propagate, and the strength of composite is determined then by the crack propagation [13]. MMC’s potential for achieving major jumps in property enhancement compared with the conventional alloy made it to widely use in various field

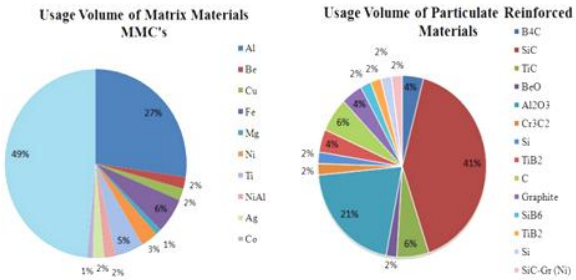

FIGURE 2USAGE VOLUME OF DIFFERENT MATRIX AND REINFORCEMENT MATERIALS

1.4 ADVANTAGES OF METAL MATRIX COMPOSITES (MMCS) OVER METALS AND PMC:

Metals	PMC
Major weight savings due to higher strength-to-weight ratio	Higher strength and stiffness
Significantly improved cyclic fatigue characteristics	Better transverse properties and radiation survivability (laser, UV, nuclear, etc.)
Exceptional dimensional stability (for example, SiC/Al to Al)	Higher thermal conductivity and service temperatures
Better wear resistance	Improved joining characteristics
Higher elevated temperature stability, i.e., creep resistance	Higher electrical conductivity (grounding, space charging)

2 LITERATURE REVIEW

K.Sudershan kumar, [1] described modeling and analysis of Connecting rod. In his project carbon steel connecting rod is replaced by aluminum boron carbide connecting rod. Aluminium boron carbide is found to have working factory of safety is nearer to theoretical factory of safety, to increase the stiffness by 48.55%andtoreducestress by 10.35%.

Vivek. C. Pathade, [2] he dealt with the stress analysis of connecting rod by finite element method using pro-e wild fire 4.0 and ansys work bench 11.0 software. And concluded that the stress induced in the small end of the connecting rod are greater than the stresses induced at the bigger end, therefore the chances of failure of the connecting rod may be at the fillet section of both end.

Pushpendra Kumar Sharma, [3] performed the static FEA of the connecting rod using the software and said optimization was performed to reduce weight. Weight can be reduced by changing the material of the current forged steel connecting rod to crack able forged steel (C70). And the software gives a view of stress distribution in the whole connecting rod which gives the information that which parts are to be hardened or given attention during manufacturing stage.

Ram Bansal, [4] in his paper a dynamic simulation was conducted on a connecting rod made of aluminum alloy using FEA. In this analysis of connecting rod were performed under dynamic load for stress analysis and optimization. Dynamic load analysis was performed to determine the in service loading of the connecting rod and FEA was conducted to find the stress at critical locations.

Folgar [5] (1987) developed a Metal matrix composite Connecting Rod with the aid of FEA, and loads obtained from kinematic analysis. Fatigue was not addressed at the design stage.

S.Venkatesh [6] "Design and Analysis of Connecting Rod with Modified Materials and FEA Analysis‖ The main objective is to reduce the weight of connecting rod by replacing steel with aluminium fly ash composite material without losing any of its strength and hardness. Experimental results are obtained from the compressive and tensile tests of connecting rods. Spectrometer test is also performed and the results are found out. It is found that by using aluminium fly ash composite material weight is greatly reduced up to 50% without losing any of its strength and hardness. Finally aluminium and steel connecting rods are analyzed with the help of Ansys and the FEA results are compared with the experimental results both the results are give equal value.

K. Sudershan Kumar, Dr. K. Tirupathi Reddy, Syed Altaf Hussain et al, [7]conducted Finite element analysis of connecting rod by considering two materials ,viz.. Aluminum Reinforced with Boron Carbide and Aluminum 360. The best combination of parameters like Von misses stress and strain, Deformation, Factor of safety and weight reduction for two wheeler piston were done in ANSYS software. Compared to carbon steel, aluminum boron carbide and aluminum 360, Aluminum boron carbide is found to have working factor of safety is nearer to theoretical factor of safety, 33.17% to reduce the weight, to increase the stiffness by 48.55% and to reduce the stress by10.35% and most stiffer.

Mr. Dharun Lingam, Mr..Arun Lingam et al. [8]has performed analysis on both the standard steel and composite connecting rods. Both are modeled and analyzed using Pro-E Wildfire 4.0 and ansys workbench 11.0 software respectively. A comparative study was undertaken to predict the structural behavior of connecting rods using three dimensional finite element stress and fatigue analysis model, and to determine the most cost effective modeling and analysis approach. The finite element results verify that the performance is same as that of standard steel connecting rod. The stress and fatigue analysis of the composite connecting rods is found to be better than that of the standard connecting rod Design and Fatigue Analysis on Metal Matrix Composite Connecting Rod Using FEA.

VenuGopal Vegi and Leela Krishna Vegi: [9]In their paper describe designing and analysis of a connecting rod. Currently existing connecting rods are made of carbon steel. Finite element analysis is carried out on a connecting rod made of forged steel. The parameters like Von mises stress, strain, deformation, factor of safety etc were calculated and found that forged steel have more factor of safety, reduced weight, greater stiffness than carbon steel. Pravardhan S.Shenoy and Ali Fatemi: They carried out the dynamic load analysis and optimization of connecting rod.

3 PROJECT OVER VIEW

3.1 PROBLEM STATEMENT

Improper material leads to the failure Connecting rod undergoes repetitive loads during it service life, fatigue performance and durability of this component has to be considered in the Design Process. generally using material (structural steel) of connecting rod replaced with developed Aluminum Metal matrix materials. with different material (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) and its behavior study by FEM analysis. . The model of connecting rod was created in CATIA V5 and imported in ansys 14.5 workbench for static and thermal analysis. After analysis a comparison is made between an existing steel connecting rod finally concluded the which material is the suitable for the connecting rod

3.2 OBJECTIVES OF THE PROJECT:

The following are the main objectives of the present work:

1. To design connecting rod by using catia work bench with gemotery given below data
2. To determine von-misses stresses, shear stresses, strain, Total deformation, Temperature distribution and heat flux
3. To identify suitable Metal matrix material for the fabrication of connecting rod based on results obtained from finite element analysis

3.3 METHODOLOGY

Step 1: Collecting information and data related connecting rod.

Step 2: A fully parametric model of the connecting rod is created in catia software.

Step 3: Perform the static and steady state thermal analysis.

Step 3: Model obtained in igs format analyzed using ANSYS 14.5(workbench), to obtain von-misses stresses, shear stresses, strain, Total deformation, Temperature distribution and heat flux.

Step 4: Manual calculations are done.

Step 5: Finally, we compare the results obtained from ANSYS Results.

3.4 DESIGN FOR PRESSURE CALCULATION

Consider 150cc Engine Specifications

Engine type = air cooled 4-stroke

Bore x Stroke (mm) = 57 × 58.6

Displacement = 149.5 CC

Maximum Power = 13.8 bhp @ 8500 rpm

Maximum Torque = 13.4 Nm @ 6000 rpm

Compression Ratio = 9.35:1

Density of Petrol (C8H18) = 737.22 kg/m^3

=737.22× 10^{-9}kg/mm^3

Auto ignition temp. =60^0F =288.85^0 K

Mass = Density x volume

$= 737.22 \times 10^{-9} \times 149.5 \times 10^3$

= 0.110214 kg

Molecular weight of petrol = 114.228 g/mole

= 0.11423 kg/mole

From gas equation

$PV = m \times R_{specific} \times T$

Where,

P = Gas Pressure, Mpa

V = Volume

m = Mass, kg

T = Temperature, °k

$R_{specific}$ = Specific gas constant $= \frac{R}{M}$

$R_{specific} = 8.3144/0.114228$

$R_{specific} = 72.788 \frac{Nm}{kg} K$

$PV = m \times R_{specific} \times T$

P = 0.110214 x 72.788 x (288.85 / 149.5)

= 15.49 Mpa ≅ 16 Mpa

Calculation is done for maximum Pressure of 16 Mpa.

3.5 PROPERTIES OF MATERIAL

MATERIALS	DENSITY (g/cm^3)	POSSION'S RATIO (µ)	YOUNG'S MODULUS (Mpa)	TENSILE STRENGTH (Mpa)	THERMAL CONDUCTIVITY (w/mk)
Al 6061-1.5%B4c-1.5%Sic MMC Material	2.7	0.33	293600	522	42
6092 Sic/25 P-T6 Al MMC Material	2.84	0.31	123000	545	38
AL360 Material	2.6	0.33	60000	303	45
Steel c45	7.85	0.29	205000	780	40

Aluminum alloys (or aluminum alloys; see spelling differences) are alloys in which aluminum (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminum is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminum alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminum alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.[1]

Alloys composed mostly of aluminum have been very important in aerospace manufacturing since the introduction of metal-skinned aircraft. Aluminum-magnesium alloys are both lighter than other aluminum alloys and much less flammable than alloys that contain a very high percentage of magnesium

Aluminum alloy surfaces will develop a white, protective layer of aluminum oxide if left unprotected by anodizing and/or correct painting procedures. In a wet environment, galvanic corrosion can occur when an aluminum alloy is placed in electrical contact with other metals with more positive corrosion potentials than aluminum, and an electrolyte is present that allows ion exchange. Referred to as dissimilar-metal corrosion, this process can occur as exfoliation or as intergranular corrosion. Aluminum alloys can be improperly heat treated. This causes internal element separation, and the metal then corrodes from the inside out.

4 DESIGN PROCEDURE IN CATIA

Go to the sketcher workbench create the two circles big end inner &outer circles by using the profile tool bar again go to the part design workbench create the pad by using the sketch based tools again go the sketcher create circles inner outer radius now go to the part design apply pad as per the dimensions .Now go to the center of the plane create the alongated hole and project the two circles after go to the trim option.Now go the part design workbench apply pad option.

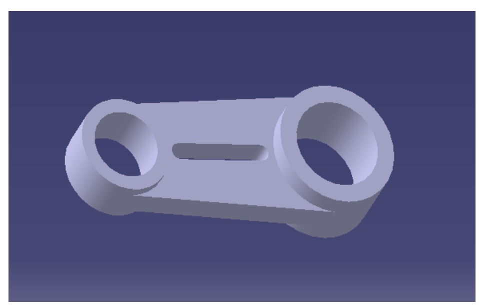

FIGURE 3 3D MODEL IN CATIA

5 STATIC ANALYSIS:

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis include:

5.1 THERMAL ANALYSIS:

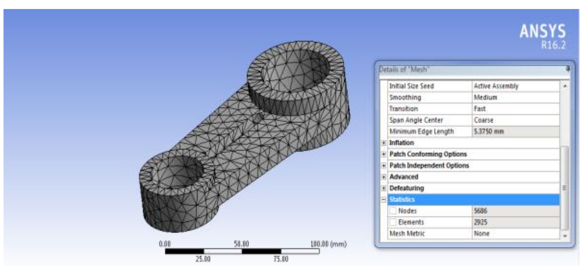

FIGURE 4MESH

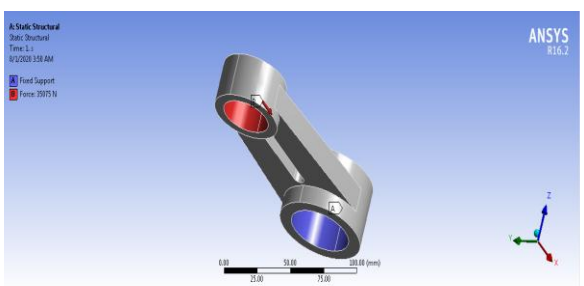

FIGURE 5 BOUNDARY CONDITIONS

5.1 BOUNDARY CONDITIONS:

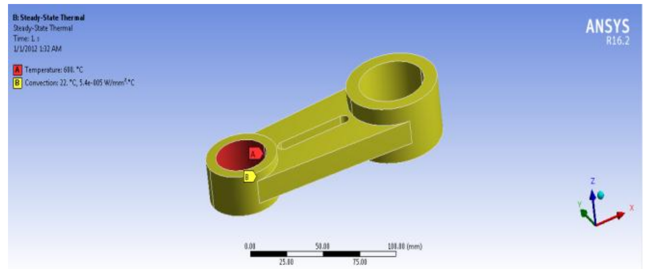

FIGURE 6 THERMAL BOUNDARY CONDITIONS

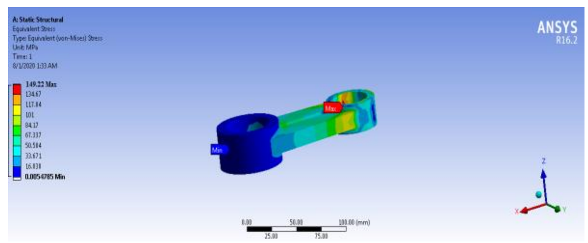

FIGURE 7VON-MISSES STRESS

6 RESULTS AND DISCUSSTION

6.1 VONMISSES STRESS:

The static analysis of connecting rod is done with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) results are obtained Equivalent (Von-Misses) stress Al 6061-1.5%B4c-1.5%Sic material have less stress as shown below graph .

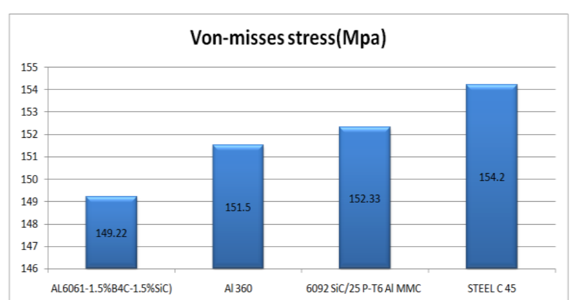

FIGURE 8VONMISSES STRESS GRAPH

6.2 SHEAR STRESS:

The static analysis of connecting rod is done with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) results are obtained Shear stress Al 6061-1.5%B4c-1.5%Sic material have less shear stress as shown below graph .

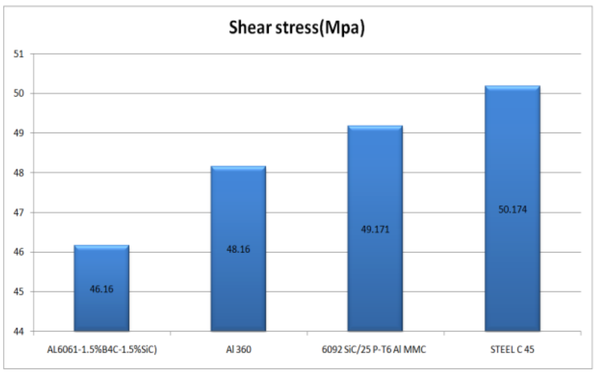

FIGURE 9 SHEAR STRESS GRAPH

6.3 TOTAL DEFORMATION:

The static analysis of connecting rod is done with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) results are obtained Shear stress Al 6061-1.5%B4c-1.5%Sic material have less total deformation as shown below graph .

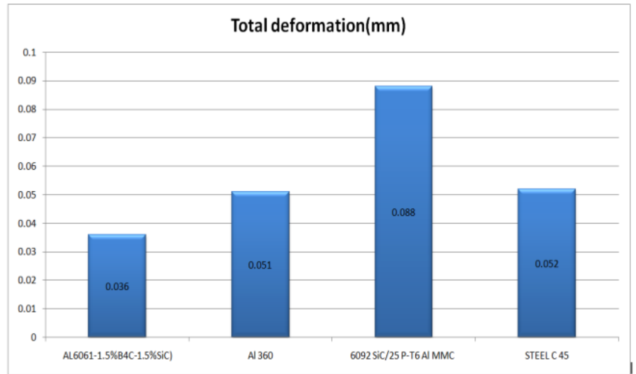

FIGURE 10TOTAL DEFORMATION GRAPH

6.4 STRAIN:

The static analysis of connecting rod is done with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) results are obtained Strain Al 6061-1.5%B4c-1.5%Sic material have less Strain as shown below graph .

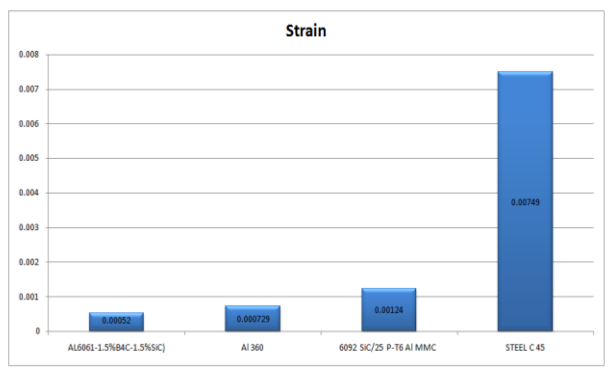

FIGURE 11 STRAIN

6.5 TEMPERATURE DISTRIBUTION ^{O}C:

The steady state thermal analysis of connecting rod is done with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) results are obtained Temperature distribution Al 6061-1.5%B4c-1.5%Sic material is best as shown below graph .

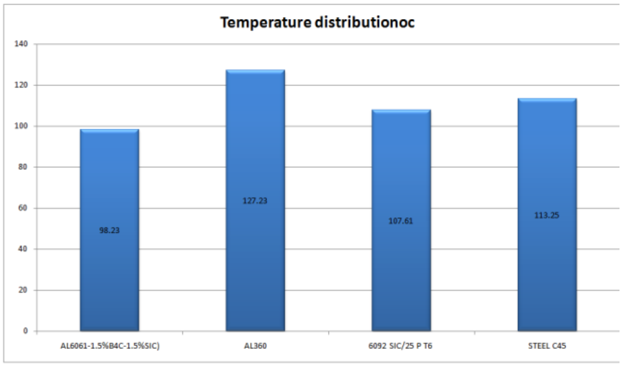

FIGURE 12 TEMPERATURE DISTRIBUTION

6.6 TOTAL HEAT FLUX:

The steady state thermal analysis of connecting rod is done with different materials (Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45) results are obtained Total heat flux is high Al 360 and Al 6061-1.5%B4c-1.5%Sic the rate of heat transfer rate is high material is best as shown below graph .

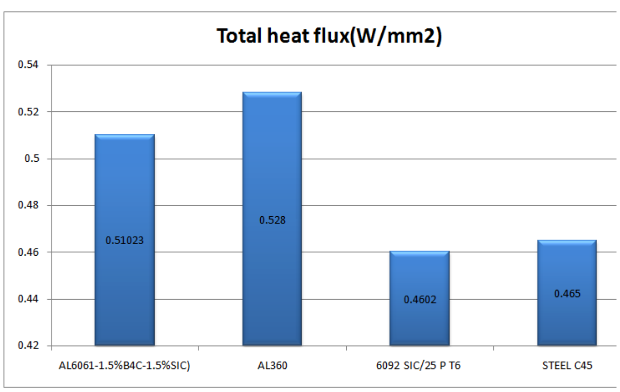

FIGURE 13TOTAL HEAT FLUX

7 CONCLUSION

In a reciprocating engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminum (for lightness and the ability to absorb high impact at the expense of durability) or B4C (for a combination of strength and lightness at the expense of affordability) for high performance engines. The aluminum composite connecting rod has light weight about 1/3 of steel .Connecting rod plays an important role in ic engine ,Design and static thermal analysis done with different materials(Al 6061-1.5%B4c-1.5%Sic MMC Material, Al 360 Material, 6092 Sic/25 P-T6 Al MMC Material, Steel C45). In this present work, connecting rod created in software CATIA we are taking specifications pulsar 150cc dimensions apply theoretical value loads different materials, finally find out the stress, strains, deformation, shear stress, Temperature distribution, Heat flux in all cases Al 6061-1.5%B4c-1.5%Sic MMC Material is the best material because of Light weight, high strength, non corrosion material, better heat transfer, fuel consumption will be reduced.

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