International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 3 Mar. 2021, pp: 01-11 www.ijaem.net ISSN: 2395-5252

Analysis and Evaluation of connecting rod using composite materials (Al+SiC)

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Submitted: 25-02-2021 Revised: 05-03-2021 Accepted: 10-03-2021

ABSTRACT: Connecting rod is one of the most important parts of the engine assembly as it acts as a arbitrator between piston set and crankshaft. Its transforming the reciprocating action of the piston to rotary action of the crank set. Also it faces a lot of tensile and compressive loads during its life time. In general these connecting rods are manufactured from carbon steel and in recent days aluminum alloys are also utilized or the services and its applications. In this project work the material of the connecting rod is replaced by aluminum based composite material reinforced with Silicon Carbide. Here developed the model and analysis of the connecting rod. Solid works modeling software is used to generate the 3-D solid model of connecting rod. ANSYS software is used to analyze the connecting rod. The main aim of the project is to analysis the stress, strain, deformation of connecting rod by varying material with same geometry.

Keywords: Connecting rod, ANSYS, composite, silicon carbide, Al6061

I. INTRODUCTION

A connecting rod is the link between the reciprocating piston and rotating crank shaft. Small end of the connecting rod is connected to the piston by means of gudgeon pin. The big end of the connecting rod is connected to the crankshaft. A combination of axial and bending stresses act on the rod in operation. The axial stresses are product due to cylinder gas pressure and the inertia force arising on account of reciprocating motion. Whereas bending stresses are caused due to the centrifugal effects. To provide the maximum rigidity with minimum weight, the cross section of the connecting rod is made as I – section and end of the rod is a solid eye or a split eye, this end holding the piston pin. The big end works on the crank pin and is always split. In some connecting rods, a hole is drilled between two ends for carrying lubricating oil from the big end to the small end for lubrication of piston and the piston pin axial stresses. Therefore in order to study the strain intensity, stress concentration and deformation in the crank end of the connection rod, firstly based on the working parameter and the vehicle chosen the design parameter or dimensions of the connecting rod is calculated and results thus achieved will provide us the required outcome of the work done here .Also further study can also be carried out later on for the dynamic loading working conditions of the connecting rod and also improvement in design can also be made for operation condition and longer life cycle against failure

1.1 CONNECTING ROD

In a reciprocating piston 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 titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters. They are not rigidly fixed at either end, so that the angle between the connecting rod and the piston can change as the rod moves up and down and rotates around the crankshaft. Connecting rods, especially in racing engines, may be called "billet" rods, if they are machined out of a solid billet of metal, rather than being cast. The con rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed. Failure of a connecting rod, usually called "throwing a rod" is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance, or from failure of the rod bo

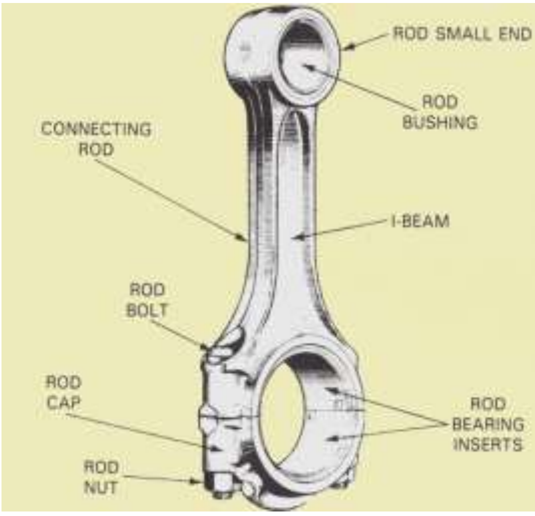


Fig 1:connecting rod

lts from a defect, improper tightening, or re-use of already used (stressed) bolts where not recommended. This is because production auto parts have a much larger factor of safety, and often more systematic quality control. Generally connecting rods are being made up of stainless steel and Aluminium alloy through the forging process, as this method provides high productivity and that too with a lower production cost.

Forces generated on the connected rod are generally by weight and combustion of fuel inside cylinder acts upon piston and then on the connecting rod, which results in both the bending and axial stresses.

In a reciprocating piston engine, the connecting rod or corned connects the piston to the crank or crankshaft. Together with the crank, they form a simple mechanism that converts reciprocating motion into rotating motion.Connecting rods may also convert rotating motion into reciprocating motion. Historically, before the development of engines, they were first used in this way a connecting rod is rigid, it may transmit either a push or a pull and so the rod may rotate the crank through both halves of a revolution, i.e. piston pushing and piston pulling. Earlier mechanisms, such as chains, could only pull. In a few two-stroke engines the connecting rod is only required to push.Today, connecting rods are best known through their use in internal combustion piston engines, such as automotive engines. These are of a distinctly different design from earlier forms of connecting rods, used in steam engines and steam locomotives.

II. LITERATURE SURVEY

Prof. N.P.Doshi "Analysis of Connecting Rod Using Analytical and Finite Element Method". The connecting rod is a major link inside of a combustion engine. It connects the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission. The most common types of materials used for connecting rods are steel and aluminum. Connecting rods are widely used in variety of engines such as, in-line engines, V-engine, opposed cylinder engines, radial engines and oppose-piston engines. For the project work we have selected connecting rod used in light commercial vehicle of tata motors had recently been launched in the market. We found out the stresses developed in connecting rod under static loading with different loading conditions of compression and tension at crank end and pin end of connecting rod. Design of connecting rod which is designed by machine design approach is compared with actual production drawing of connecting rod. We found that there is possibility of further reduction in mass of connecting rod.

S. Venkatesh "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.

Kuldeep B "Analysis and optimization of connecting rod using Alfasic composites".This research is motivated by the responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally connecting rods are manufactured using carbon steel and in recent days aluminum alloys are finding its application in connecting rod. In this work connecting rod is replaced by aluminum based composite material reinforced with boron carbide and fly ash. And it also describes the modeling and analysis of connecting rod. FEA analysis was carried out by considering two materials. The parameters like von misses stress, von misses strain and displacement were obtained from ANSYS software. Compared to the former material the new material found to have less weight and better stiffness. It resulted in reduction of 43.48% of weight, with 75% reduction in displacement.

III. OBJECTIVES

Designing of the analysis rod based on the input parameters and then modeling of the connecting rod in the SOLID WORKS software. FEM tool software ANSYS is given model and material input based on the parameters obtained.To determine the Von Misses stresses, Strain Intensity, Total Deformation and to optimize in the existing Connecting rod design.To calculate stresses in critical areas and to identify the spots in the connecting rod where there are more chances of failure.To reduce weight of the existing connecting rod based on the magnitude of the output of analysis.The main aim of the project is to determine the Von-Misses Stresses, Strain Intensity output and optimize the new material used for connecting rod. Based on which the new material can be compared with the existing materials used for connecting rod

IV. SMALL END AND BIG END

The small end attaches to the piston pin, gudgeon pin or wrist pin, which is currently most often press fit into the connecting rod but can swivel in the piston, a "floating wrist pin" design. The big end connects to the bearing journal on the crank throw, in most engines running on replaceable bearing shells accessible via the connecting rod bolts which hold the bearing "cap" onto the big end. Typically there is a pinhole bored through the bearing and the big end of the connecting rod so that pressurized lubricating 201motor oil squirts out onto the thrust side of the cylinder wall to lubricate the travel of the pistons and piston rings. Most small two-stroke engines and some single cylinder four-stroke engines avoid the need for a pumped lubrication system by using a rolling-element bearing instead, however this requires the crankshaft to be pressed apart and then back together in order to replace a connecting rod.

V. ENGINE WEAR AND ROD LENGTH

A major source of engine wear is the sideways force exerted on the piston through the connecting rod by the crankshaft, which typically wears the cylinder into an oval cross-section rather than circular, making it impossible for piston rings to correctly sealagainst the cylinder walls. Geometrically, it can be seen that longer connecting rods will reduce the amount of this sideways force, and therefore lead to longer engine life. However, for a given engine block, the sum of the length of

Fig 2: Failure of connecting rod

the connecting rod plus the piston stroke is a fixed number, determined by the fixed distance between the crankshaft axis and the top of the cylinder block where the cylinder head fastens; thus, for a given cylinder block longer stroke, giving greater engine displacement and power, requires a shorter connecting rod (or a piston with smaller compression height), resulting in accelerated cylinder wear.

VI. STRESS AND FAILURE

The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases as the square of the engine speed increase. Failure of a connecting rod, usually called throwing a rod, is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance, or from failure of the rod bolts from a defect, improper tightening or over-revving of the engine. FIn an unmaintained, dirty environment, a water or chemical emulsifies with the oil that lubricates the bearing and causes the bearing to fail. Re-use of rod bolts is a common practice as long as the bolts meet manufacturer specifications. Despite their frequent occurrence on televised competitive automobile events, such failures are quite rare on production cars during normal daily driving. This is because production auto parts have a much larger factor of safety, and often more systematic quality control.

VII. FABRICATION OF METAL MATRIX COMPOSITE

7.1 Powder Metallurgy Technique

The powder metallurgy procedure is the utmost widely used strategy for the production of discontinuous reinforced Metal matrix composites. Reinforcements are usually in the form of whiskers and particulates in the form of powder. Normally the matrix and reinforcement materials are blended in form of powder by subjecting them to various mechanical operations such as atomization and ball milling process. The powders are mixed according to the desired volume fractions and the powder is fed in to the mould of preferred shape. Pressure is applied to compact the mixed powder (i.e., Cold pressing) then the compacted specimen is subjected to sintering which involve heating of the compacted specimen in a controlled atmosphere well below the melting point of material, which ensures significant amount solid state diffusion of reinforcement in to the matrix material. Thus compacted metal matrix composite specimen is then subjected to further machining operations to get desired shape .The fabrication of components by powder metallurgy technique involves the following steps in sequence

(1) Production of metallic powders
(2) Mixing and Blending of powders
(3) Compaction of powders
(4) Sintering
(5) Secondary machining operations
(6) Finishing and inspection.

7.2 STIR CASTING PROCESS

In a stir casting process, usually the particulate reinforcement is distributed into aluminum melt by mechanical stirring. Mechanical stirring is the key element of this process.Composites with up to 30% volume fractions can be suitably manufactured using this method. A problem associated with the stir casting process is the segregation of reinforcing particles due to settling of particles during solidification. The distribution of the particles in the final solid depends on strength of mixing, rate of solidification, wetting condition of the particles with the melt and relative density. Geometry of the mechanical stirrer, position of the stirrer in the melt, melt temperature and the properties of the particles added determines the distribution of the particles in the molten matrix. In a recent development in stir casting is a twostep mixing process. The matrix material is heated to above its liquidus temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquidus and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. The effectiveness of this two-step processing method is mainly attributed to its ability to break the gas layer around the particles surface.

VIII. MECHANICAL PROPERTIES

The mechanical properties of composite materials depend on several factors such as size, shape, quality and type of reinforcement particles. It was studied the influence of SiC on the tribological and mechanical properties of Al_{7075}-SiC composites. The authors has revealed that the hardness of composite increased when compared with base alloy because of addition of SiC particular's and wear rate of composite decreased when compared with base alloy.Later was investigated the Effect of silicon carbide reinforcement on aluminium matrix composites. The authors produced Al- B_4C by stir casting route with different particle size (Viz 37µ,44µ,63µ,105µ,250µ) of reinforcement and observed that the micro Vickers hardness of AMC's was to be maximum for the particle size of 250µ and for 12 wt.% in case of varying wt.% of the reinforcement of 105µ size. And the tensile strength of AMC's was found to be maximum for the particle size of 105µ and found maximum for 8 wt.% in case of varying wt.% of the reinforcement of 105µ size. A.Mazahery studied on hardness and tensile strength of Al356- SiC composites (stir casting) and Authors revealed that porosity level of composite increased slightly with increasing particulate content and the hardness of the MMCs increases with the volume fraction of particulates in the alloy matrix because of the increasing ceramic phase of the matrix alloy. The higher hardness of the composites could be because SiC particles act as obstacles to the motion of dislocation. F. Topton studied the effect of Ti addition on the properties of Al- SiC interface and a micro structural study and author reported that an effective bonding could not be formed on the material/reinforcement interface in Al- SiC composite produced at temperature of 858ºc. Because of poor wetting of SiC particles by liquid aluminum and the wetting problem was effectively solved by the formation of very thin TiC and TiB_2 reaction layers with addition of

K_2TiF_6 flux .Mosheostad shabani investigated A_{356} composites reinforced with SiC particles by FEM and ANN and author revealed that the great enhancement of mechanical properties of A_{356} composite reinforced with SiC particulates in values of hardness, elastic constant and UTS relative to monolithic aluminum experimentally. K. Kalai investigated production and characterization of Al_{6061}- SiC stir casting composite authors concluded that the addition of 4 to 12 wt.% of SiC particles the micro and macro hardness of the composite were changed from 51.3HV to 80.8HV and 34.4BHN to 58.6BHN respectively. Later studied the influence of graphite reinforcement on mechanical properties of Al- silicon carbide composites and revealed that with increasing graphite particles the hardness of the composite is decreased.

By studying the micro structure and metallurgical properties of Al $_{7075}$-T651 Alloy/ SiC 4% volume surface composite by friction stir processing and the authors revealed that average hardness of friction stir processed surface composite was 1.5 higher than that of the base metal aluminum matrix .By studying the process development in stir casting and investigation on microstructures and wear behavior of TiB_2 on Al_{6061} MMC and concluded that strength, micro and macro hardness of Aluminum composites increased with inclusion of reinforcement(TiB_2) in it .Topcu et al. (2009) produced pure Al- SiC composite by powder metallurgy route and investigated its mechanical properties. They observed that the hardness of the composite were increased with increasing weight percent of SiC and sintering temperature. But, the effect of sintering temperature over, 625 ºC is lost after 15 wt% of SiC. andimpact resistance of the composite reduced with increase in SiC content in the matrix and sintering temperature. And, the effect of sintering temperature is lost after 15 wt% of SiC.

IX. MATERIAL AND ITS PROPERTIES

Generally there are a few materials that are commonly used in the creation of connecting rods.like steel alloys ,aluminium and titanium. The connecting rods are usually made of steel alloys like **42CrMo4, 43CrMo4**, **44csr4,C-70,EN-8D,SAE1141,**etc. Connecting rods are usually drops forged out of a steel alloy.aluminium and titanium are both materials that are also used in the manufacturing of connecting rods for performance vehicles.Most after market performance rods are made using 4340 billet or forged steel.This is achrome molly alloy with high tensile and compressive strength.That all 4340 steel alloys are not neccessarily the same.Heat treatments can vary,and this will affect the properties of steel .Sometimes mixtures of materials are used to prepare connecting rod such as aluminium and titanium.It is directly taken out from casting by bending twisting and titanium. Connecting rods are made with balancing bosses so that their weight can be adjusted to specification

9.1 MATERIAL PROPERTIES

9.1.1 ALUMINUM ALLOY

Density	$2.77e^{-009}$ tonne mm^{-3}
Coefficient of thermal expansion	$2.3e^{-005}$ C^{-1}
Specific heat	$8.75e^{+008}$ mJ $tone^{-1}$
Young’s modulus(Mpa)	71000
Poisson’s ratio	0.33
Bulk modulus (Mpa)	69608
shear modulus(Mpa)	26692

9.1.2 CARBON STEEL

Ultimate tensile strength (Mpa)	620
Yield strength (Mpa)	415
Endurance strength(Mpa)	310
Young's modulus (GPa)	200
Poisson ratio	0.33
Density	$7.85e^{-009}$ tonne mm^{-3}

9.1.3 SILICON CARBIDE

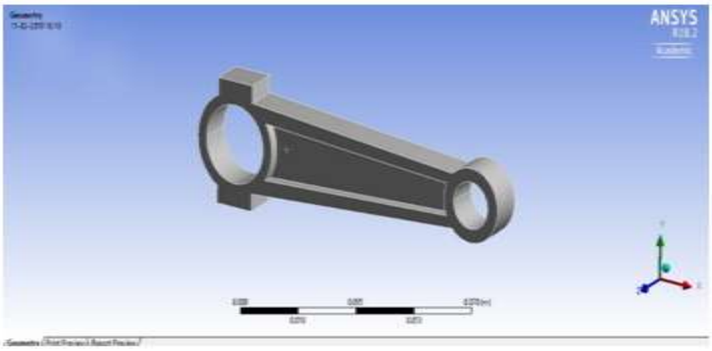
Density	4.36 Mg/m^3
Bulk modulus(Gpa)	100
Poisson's ratio	0.35
Sherar modulus(Gpa)	32
Tensile strength(Mpa)	240
Young's modulus(Gpa)	90
Melting point(K)	1750K
Specific heat	510 J/Kg.K
Thermal conductivity	3.8W/m.K
Thermal expansion	$7.9 * 10^{-6}$/K

9.1.4 ALUMINIUM SILICON CARBIDE(Al6061-85%SiC-15% (Al + SiC)

Ultimate tensile strength (Mpa	422
Yield strength (MPa)	363
Young's modulus (GPa)	70
Poisson's ratio	0.33
Density	$2.61161\ e^{-009}$ tonne mm^3

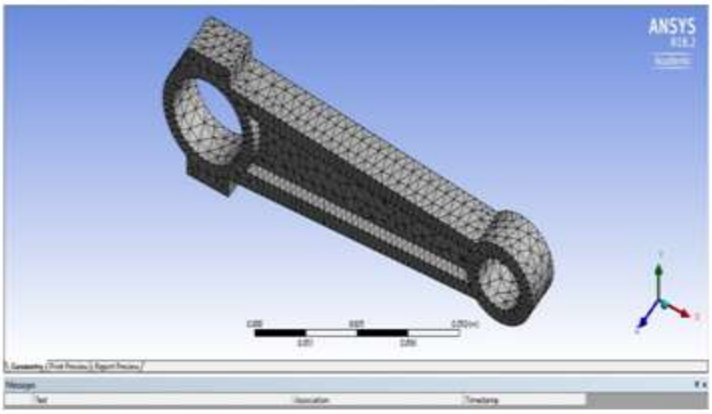
X. ANSYS ANALYSIS ON CONNECTING ROD:

10.1 MODEL OF CONNECTING ROD

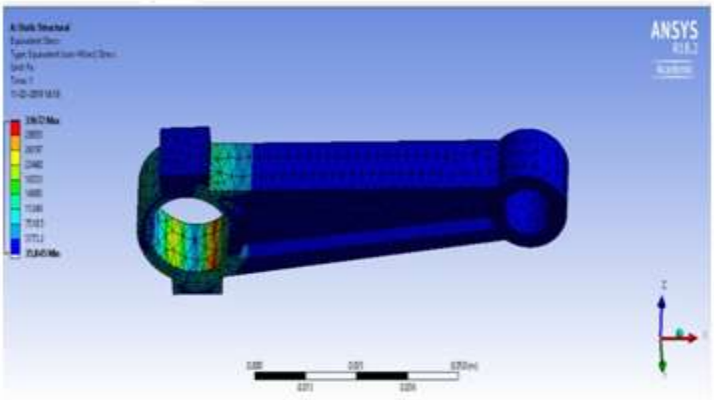


International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 3 Mar. 2021, pp: 01-11 www.ijaem.net ISSN: 2395-5252

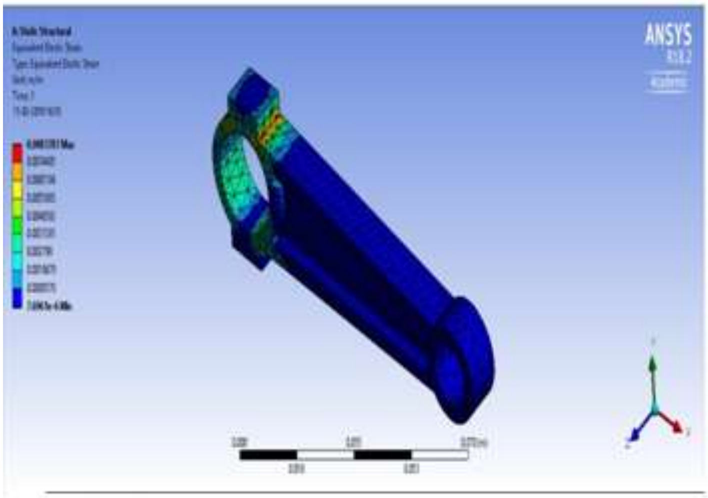
10.2 MESH MODEL



10.3 MATERIAL: ALUMINIUM (Al 6061)
10.3.1 Von mises stress



10.3.2 Von mises strain



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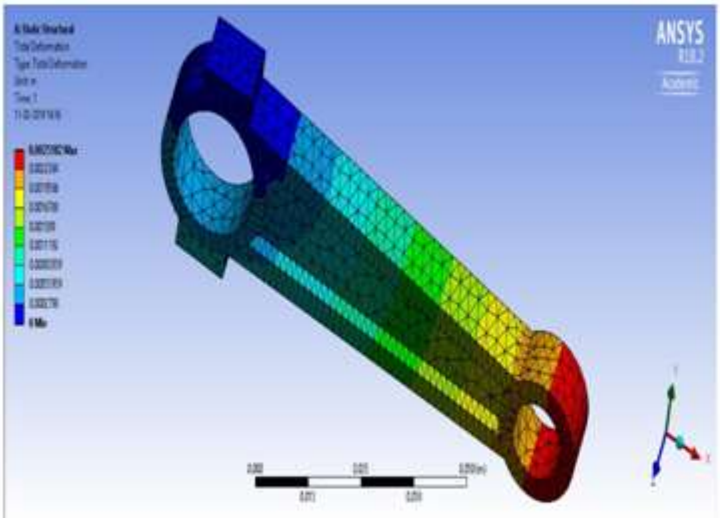
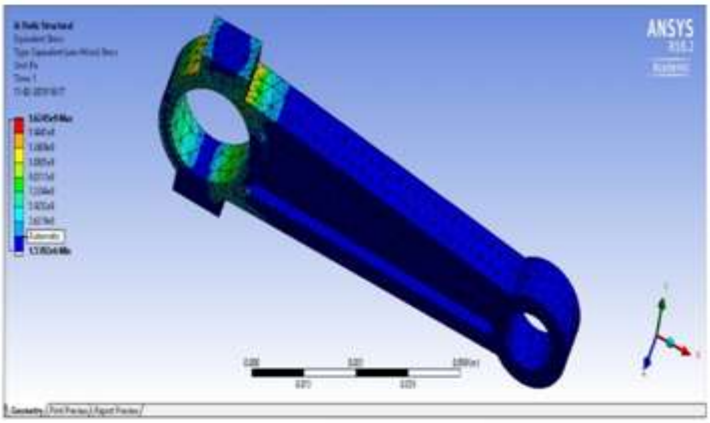
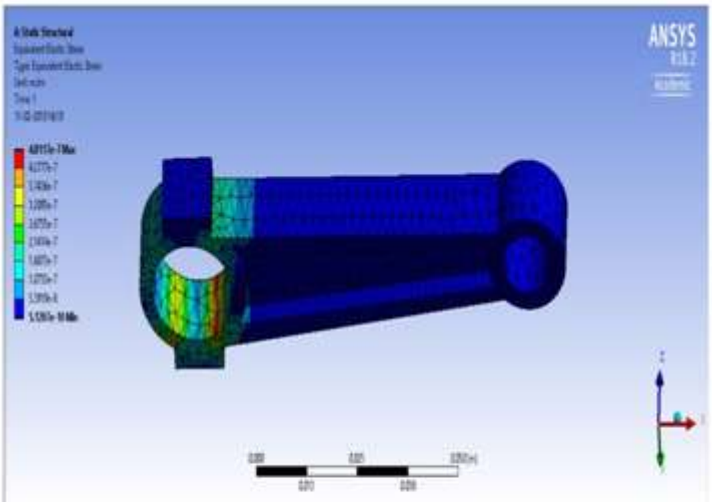
10.3.3 Total deformation



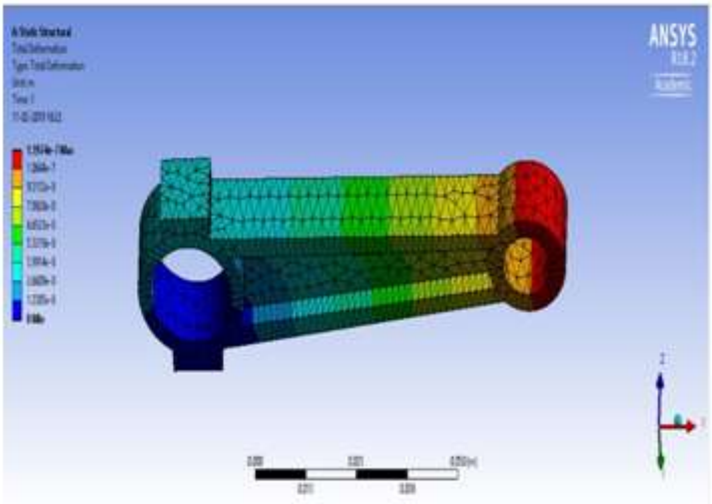
10.4 MATERIAL:ALUMINIUM SILICON CARBIDE
10.4.1 Von mises stress



10.4.2 Von mises strain



10.4.3 Total deformation



XI. 11. COMPARISON OF RESULT STATIC ANALYSIS IN CONNECTING ROD

11.1 CHARPY TEST

S. NO	MATERIAL	CHARPY		IMPACT STRENGTH
		INITIAL E1 (J)	FINAL E2 (j)	E/A (J/mm^2)
1	Al6061	0	162	2.314
2	Al6061+ SiC	0	188	2.625

11.2 IZOD TEST

S.NO	MATERIAL	IZOD		IMPACT STRENGTH
		INITIAL E1 (J)	FINAL E2 (j)	E/A (J/mm^2)
1	Al6061	0	70	1
2	Al6061+SiC	0	120	1.715

11.3 ROCKWELL HARDNESS TEST

S.NO	MATERIAL	LOAD APPLIED	TYPE OF INDENT	SCALE	ROCKWELL HARDNESS NUMBER
1	Al6061	**150**	**Ball**	**C**	**0.89**
2	Al6061+ SiC	**150**	**ball**	**C**	**0.79**

XII. RESULT COMPARISON

S. NO	**Material**	**MAXIMUM LOAD**			**MINIMUM LOAD**		
		Stress (Pa)	Displac-ement (m)	Strain	Stress (Pa)	Displac-ement (m)	Strain
1	Al6061	33672	0.0025182	0.0083787	35.845	0	7.6961e-6
2	Al6061+ SiC	1.6245e9	1.1974e-7	4.8117e-7	35.845	0	5.1207e-10

XIII. CONCLUSION

The forces were applied on the piston head and the effect of it on the connecting rod was studied in this analysis. The pressure developed in the big end/crank end of the connecting rod is analyzed in two different parts i.e. Crank end Bearing Lower half and connecting rod for displacement, von-misses stress and strain intensity output. The results or conclusion thus that can made on the bases of the output results by ANSYS can be as followed:

The present material used for connecting rod Al6061 is high deformation when compare to Al6061+SiC. So Al6061+BSiC have low deformation, the result is increasing the life time of the connecting rod.

Al6061 connecting rod has low von misses stress, so the result is low strength. So conclude Al6061+SiC connecting rod has high von misses stress, so it has high strength.Aluminium 6061+SiC has a greater hardness than Aluminium 6061.

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International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 03 Issue: 03 DOI: 10.35629/5252

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