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DESIGN AND THERMAL ANALYSIS OF COMPOSITE CONNECTING ROD

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ABSTRACT

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 Evaluation of composite material connecting rod by using Aluminium boron carbide. The connecting rods are commonly used in the internal combustion engines and are subjected to millions of varying stress cycles leading to fatigue failure. While the Composite connecting rods are lighter and may offer better compressive strength, stiffness and fatigue resistance than conventional connecting rods and their design still represents a major technical challenge.

KEYWORDS

Connecting rod, Aluminium-Boron Carbide, ANSYS, Strength, Stiffness and Fatigue Resistance.

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INTRODUCTION[1-6]

Internal combustion engine

The machines that produce power or energy are called engines. The engines work as prime movers meaning "producers of motion". There are other machines which are run by prime movers. Engines have become well known these days because of widespread popularity of automobile - the cars, trucks, buses and motor cycles are machines that are used for transport almost by everybody and everywhere. Doubtless no other engineering wonder can claim such wider use and engines provide the power for automobile. There are of course other uses of these engines also. Engines in general are reciprocating and rotary, the latter are commonly recognized as turbines, though there are some which are not turbine.

Components of internal combustion engine

Even though internal combustion (IC) engines look quite simple, they are highly complex machines. There are hundreds of components which have to perform their functions satisfactorily to produce output power. The major components of the engine and their functions are briefly described below.

Connecting rod

In a reciprocating piston engine, the connecting rod or conrod` connects the piston to the crank or cranks haft. 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.

FORCES ACTING ON CONNECTING ROD

1. Force on the piston due to gas pressure and inertia of the reciprocating parts
2. Force due to inertia of the connecting rod or inertia bending forces
3. Force due to friction of the piston rings and of the piston
4. Forces due to friction of the piston pin bearing and the crank pin bearing.

PURPOSE OF A CONNECTING ROD

Connecting rods are used in numerous situations, most commonly in the engines of automobiles. Connecting rods connect the crankshaft to the pistons and are necessary for the proper functioning of an internal combustion engine. The purpose of a connection rod is to provide fluid movement between pistons and a crankshaft.

APPLICATIONS

Connection rods are widely used in vehicles that are powered by internal combustion engines. All cars and trucks that use this type of engine employ the use of connecting rods. Farm equipment like tractors and combines also use connecting rods. Even construction equipment like bulldozers use internal combustion engines, thus requiring connecting rods.

LITERATURE REVIEW

1. Folgar (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.
2. Sonsino and Esper (1994) have discussed the fatigue design of sintered Connecting Rods. They did not perform optimization of the Connecting Rod. They designed a Connecting Rod with a load amplitude with different regions being designed for different load ratios.
3. Hakan Persson (2005) described about use of a transmission component of a metal matrix composite (MMC) material. The transmission component is made of metal matrix composite material for better performance of fuel consumption, emission, vibration, noise, comfort. This paper also not deals with fatigue analysis of the composite transmission component.
4. Janasrasback, Toyota Company (2009) made a metal matrix composite (aluminum and boron carbide) connecting rod.
5. Ford Company (2008) made a metal matrix composite (aluminum and boron carbide) cylinder liner for car engine.

THE PROJECT OBJECTIVES

1. Increase in fatigue strength
2. Increase the tensile strength
3. Increase the life of connecting rod

FACTORS FOR ANALYSIS

The following factor mainly to be considered for analysis of conventional and MMC connecting rod

MATERIAL

Aluminium boron carbide

The Dow Chemical Company's Aluminum–Boron Carbide Composite (AlBC) is a material which has the density of aluminum combined with significantly improved stiffness, hardness and ability to perform in continuous use at temperatures substantially higher than aluminum. AlBC composite is electrically conductive, has high compressive strength and high heat capacity. AlBC represents a broad family of materials which can be tailored during the manufacturing process to the material requirements of different applications. AlBC composites span the composition range from ceramics to metals in the ratios from 99:1 to 1:99. In the upper range of ceramic content, the properties of AlBC composites are similar to those of ceramics with improved toughness and in the lower range similar to metals but with improved hardness, wear resistance and higher temperature resistance. The upper boundary composition is an alternative to cast iron in weight-sensitive applications that require temperature stability up to 500-600°C.

DETAILED DESCRIPTION

The ABC composite

The aluminum-boron carbide (ABC) composite is comprised of a continuous network of $AlB_{24}C_4$ and boron carbide grains. It is understood that the $AlB_{24}C_4$ and boron carbide (B_4C) may as well understood in the art deviate from stoichiometry (solid solution) and still encompass the invention. For example, the B/Al ratio of the $AlB_{24}C_4$ is typically at least 15 by mole. A continuous network of $AlB_{24}C_4$ and B_4C grains means that individual grains of boron carbide are bonded through the $AlB_{24}C_4$ phase. Thus, starting from one surface of the ABC composite, one can trace an unbroken path to the opposing surface through the $AlB_{24}C_4$ and B_4C phases as shown in Figure No.1. This may be determined by using known metallographic techniques (e.g., see Underwood in Quantitative Stereology, Addison-Wesley, Reading, Mass. (1970)).

The metal is aluminum and alloys of aluminum, such as those that contain one or more of Cu, Mg, Si, Mn, Cr and Zn. Exemplary aluminum alloys include Al--Cu, Al--Mg, Al--Si, Al--Mn--Mg and Al--Cu--Mg--Cr--Zn. Specific examples of aluminum alloys include 6061 alloy, 7075 alloy and 1350 alloy, each available from the Aluminum Company of America, Pittsburgh, Pa.

Preferably, the ceramic-metal composite has a stiffness greater than a composite made lacking the continuous network. Likewise, this is the same with respect to impact resistance of the ABC composite. In a preferred embodiment, the ABC composite preferably has boron carbide grains that have an average grain size that is 25 micrometers in diameter or greater, and even 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225 or 250 micrometers in diameter.

FORMING OF THE ABC COMPOSITE

The ABC composite may be made by infiltrating a porous body comprised of boron carbide powder with an aluminum metal, alloy thereof, or combination thereof.

The porous body to be infiltrated must have a porosity no greater than about 35% so that the continuous network may be formed upon heat-treating. The porosity, however, should not be so small such that the aluminum is not able to infiltrate to make dense infiltrated ABC composite. Generally the porous body has a porosity of at most about 34%, 33%, 32%, 31%, 30%, 29%, 28%, 27%, 26%, 25%, 24%, 23%, 22%, 20%, 19%, 18%, 17%, 16% or even 15% to at least about 5%.

The second heat-treating is at an aluminum depleting temperature of about 700° C. to about 900° C. for a time to form the improved aluminum boron carbide composite having an aluminum concentration of less than 2% by volume said composite. The time may be any sufficient to reduce the amount of metal (e.g., aluminum or aluminum alloy) to less than 2% by volume of the composite. Typically, this is at least about 30 minutes to 100 hours, but may be at least 1, 2, 3 or 4 hours to at most about 50, 25 20, 15, or 10 hours.

MATERIAL PROPERTIES

Conventional

1. Material type : C 40
2. % Carbon : 0.35-0.45
3. % Manganese : 0.60-0.90
4. Young’s Modulus :38 MPa

5. Poisson's Ratio : 0.3
6. Density :8000 kg / m^3
7. Ultimate Tensile Strength : 750 N/mm^2
8. Refer design data book page no 1.12

MATERIAL DATA: al-b$_4$c

al-b$_4$c> Constants

Density	2.6e-012 kg mm^-3

al-b$_4$c> Tensile Ultimate Strength

Tensile Ultimate Strength MPa
350

al-b$_4$c> Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	1.95e+005	0.3	1.625e+005	75000

CAD/CAE

Computer aided design or CAD has very broad meaning and can be defines as the use of computers in creation, modification, analysis and optimization of a design. CAE Computer Aided Engineering) is referred to computers in Engineering analysis like stress/strain, heat transfer, flow analysis. CAD/CAE is said to have more potential to radically increase productivity than any development since electricity. CAD/CAE builds quality form concept to final product. Instead of bringing in quality control during the final inspection it helps to develop a process in which quality is there through the life cycle of the product.

ENGINEERING DESIGN

Creo Elements/Pro offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development. We created model Connecting Rod using CREO software. The models are shown below…

ANSYS

ANSYS is the usually preferred analysis software package because of its functionality. In this interface, you can apply forces, pressures, torques, etc on the models and see how the stresses develop. The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex multi-physics analyses with drag-and-drop simplicity.

Acoustics / Vibration Analysis

ANSYS is capable of modeling and analyzing vibrating systems in order to that vibrate in order to analyze. Acoustics is the study of the generation, propagation, absorption, and reflection of pressure waves in a fluid medium. Applications for acoustics include the following:

- Sonar - the acoustic counterpart of radar
- Design of concert halls, where an even distribution of sound pressure is desired
- Noise minimization in machine shops
- Noise cancellation in automobiles
- Underwater acoustics
- Design of speakers, speaker housings, acoustic filters, mufflers, and many other similar devices.
- Geophysical exploration

Coupled Fields Analysis

A coupled-field analysis is an analysis that takes into account the interaction (coupling) between two or more disciplines (fields) of engineering. A piezoelectric analysis, for example, handles the interaction between the structural and electric fields: it solves for the voltage distribution due to applied displacements, or vice versa. Other examples of coupled-field analysis are thermal-stress analysis, thermal-electric analysis, and fluid-structure analysis. Some of the applications in which coupled-field analysis may be required are pressure vessels (thermal-stress analysis), fluid flow constrictions (fluid-structure analysis), induction heating (magnetic-thermal analysis), ultrasonic transducers (piezoelectric analysis), magnetic forming (magnetostructural analysis), and micro electro mechanical systems (MEMS).

Modal Analysis

A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis.

Harmonic Analysis

Used extensively by companies who produce rotating machinery, ANSYS Harmonic analysis is used to predict the sustained dynamic behavior of structures to consistent cyclic loading. Examples of rotating machines which produced or are subjected to harmonic loading are:

- Gas Turbines for Aircraft and Power Generation
- Steam Turbines
- Wind Turbine
- Water Turbines
- Turbo pumps
- Internal Combustion engines
- Electric motors and generators
- Gas and fluid pumps
- Disc drives

ADVANTAGES OF FEA

- Applicable to any field problem such as heal transfer stress analysis, magnetic field etc.
- There is no matrix restriction.
- Approximately it is easily improved by grading the mesh so that more elements appear where field gradients are high and more resolution is required.
- Compounds that have different behavior and different mathematical description can be solved.
- FEA structure closely resembles closely the actual body or region to be analyzed.

ANALYSIS USING ANSYS

Analysis results for connecting rod

The following figure shows the imported model of the Connecting Rod.

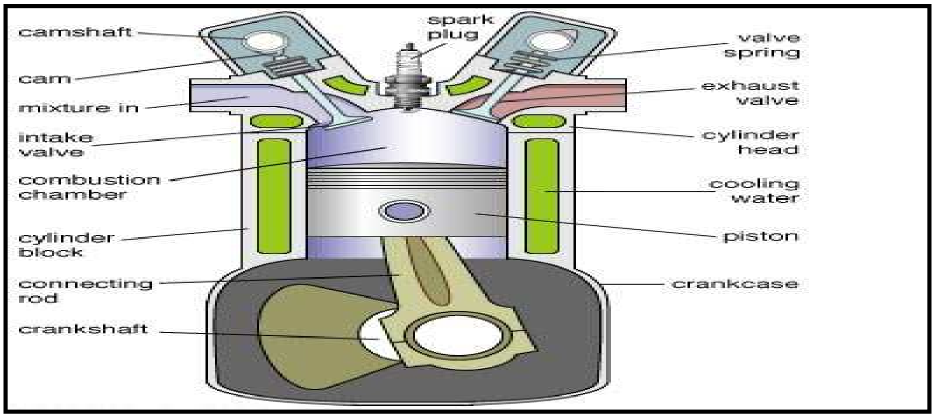
MESHING USING ANSYS

- In preparing the model for analysis, Ansys subdivides the model into many small tetrahedral pieces called elements that share common points called nodes.
- Red dots represent the element's nodes.
- Elements can have straight or curved edges.
- Each node has three unknowns, namely, the translations in the three global directions.
- The process of subdividing the part into small pieces (elements) is called meshing. In general, smaller elements give more accurate results but require more computer resources and time.
- Ansys suggests a global element size and tolerance for meshing. The size is only an average value, actual element sizes may vary from one location to another depending on.
- After meshing the model the boundary conditions are applied properly then the final results are obtained. The following figure shows the final results of structural analysis for different materials like Cast iron, Steel polymer concrete.

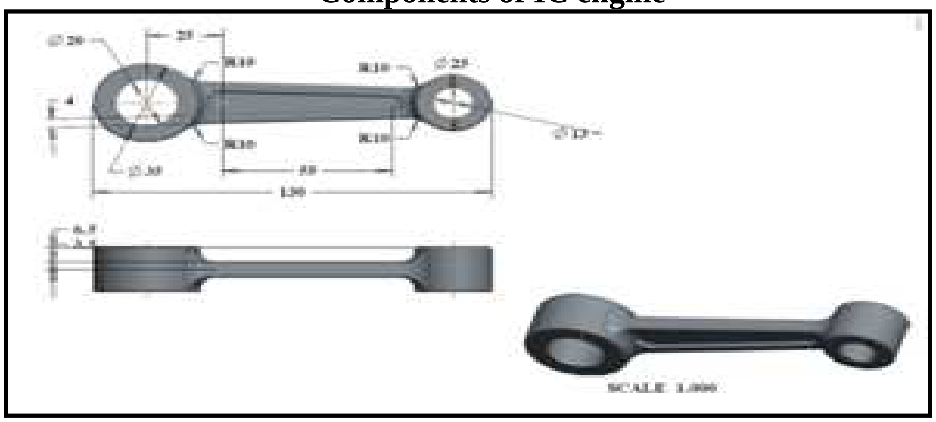
STATIC STRUCTURAL ANALYSIS

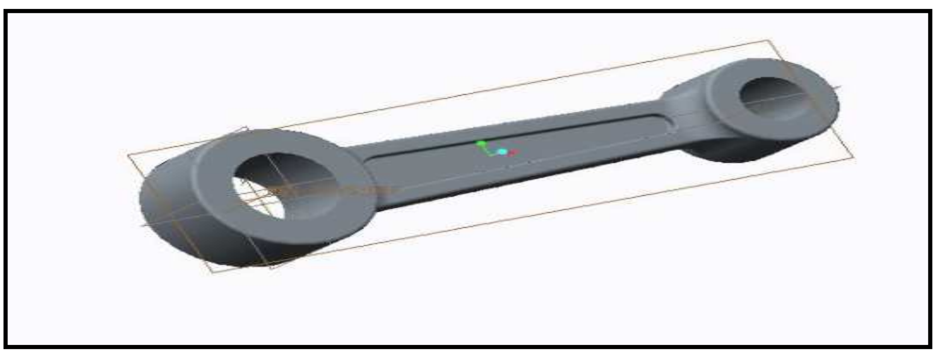
A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed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

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain).

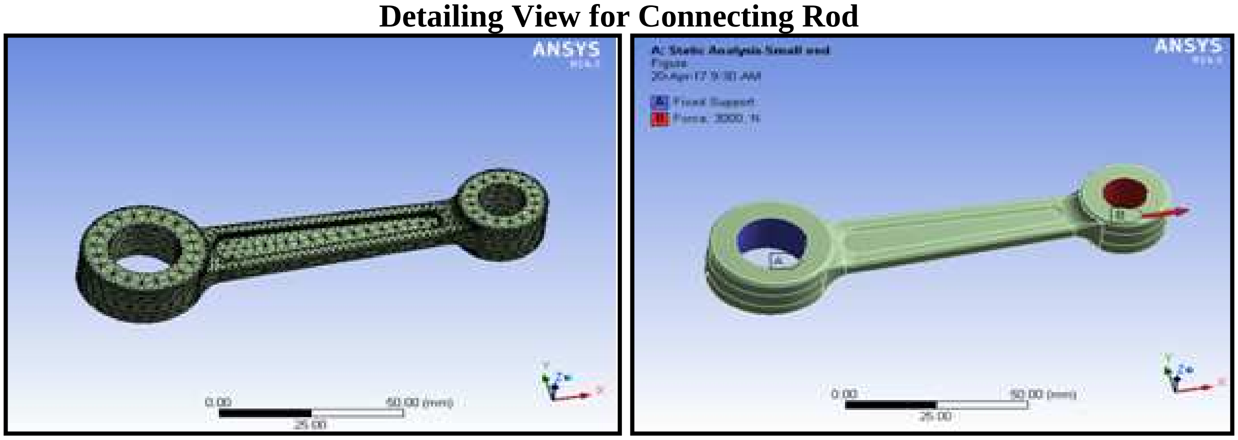


Components of IC engine

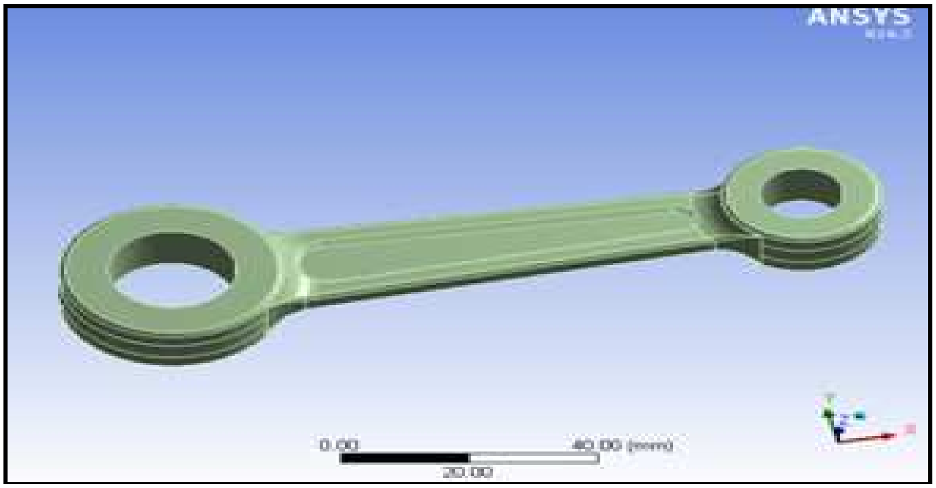




Detailing View for Connecting Rod



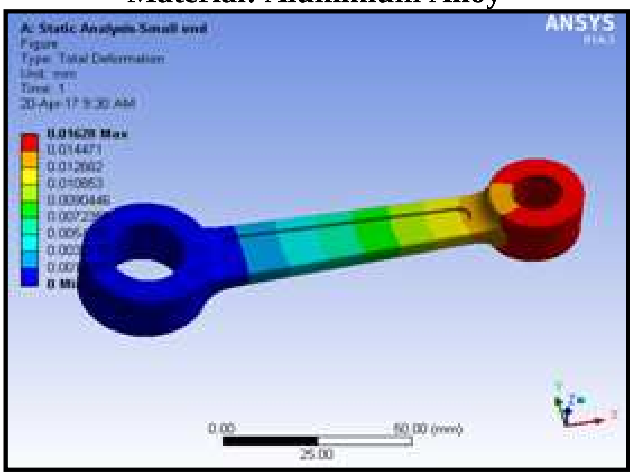
Shows the Mesh Model Pressure acting on the small end of connecting rod



Shows the Imported Model of Connecting Rod

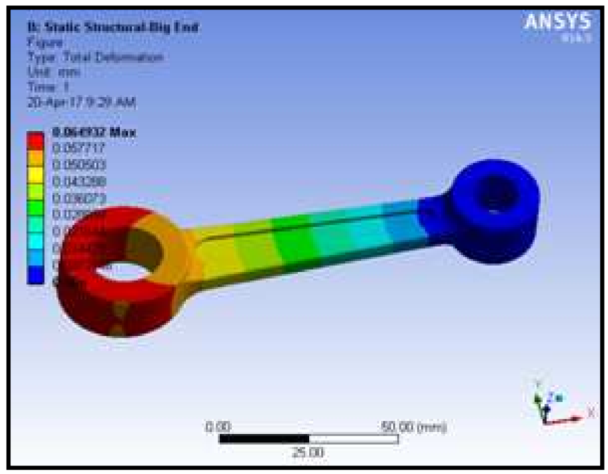
Total Deformation on Connecting Rod

Material: Aluminium Alloy



Total Deformation on Aluminium Alloy Connecting rod

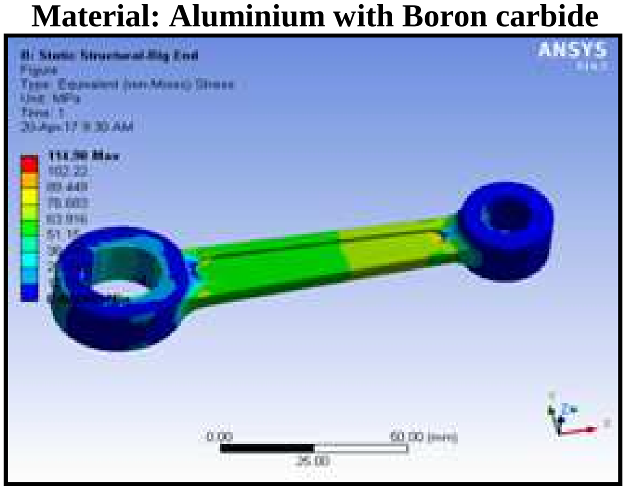
Material: Aluminium with Silicon carbide



Total Deformation on Aluminium with Silicon carbide Connecting rod

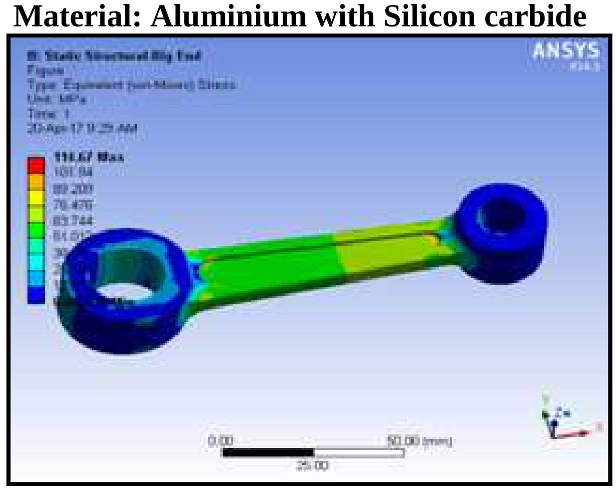
Equivalent Stress on Connecting Rod

Material: Aluminium with Boron carbide



Equivalent Stress on Aluminium with Boron carbide Connecting rod

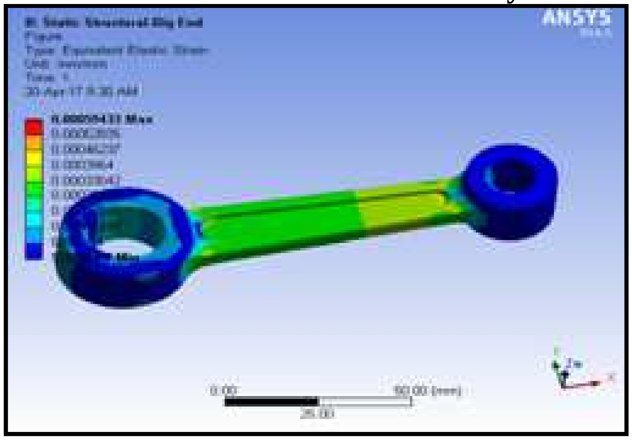
Material: Aluminium with Silicon carbide

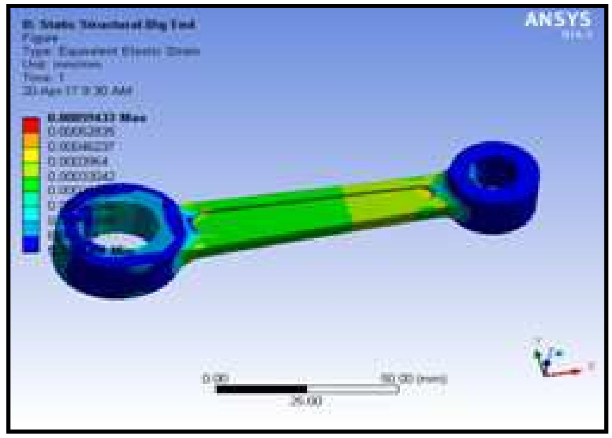


Equivalent Stress on Aluminium with Silicon carbide Connecting rod

Equivalent Strain on Connecting Rod

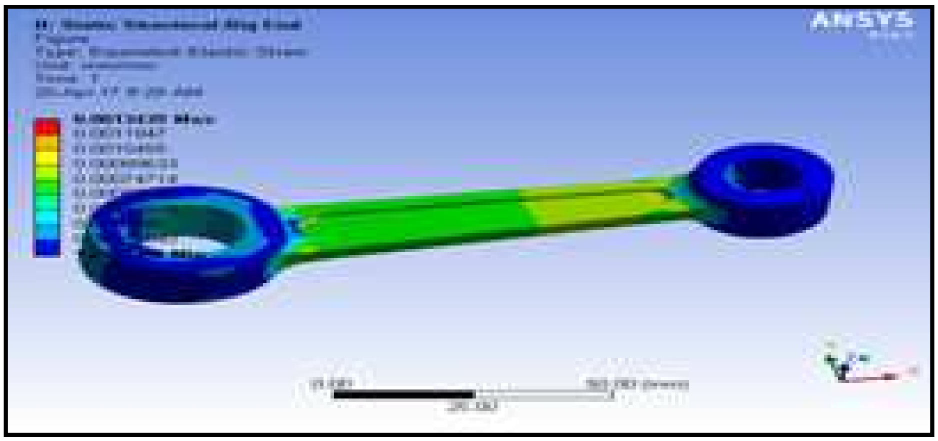
Material: Aluminium Alloy Material: Aluminium with Boron carbide





Equivalent Strain on Aluminium Alloy Connecting rod Equivalent Strain on Aluminium with Boron carbide Connecting rod

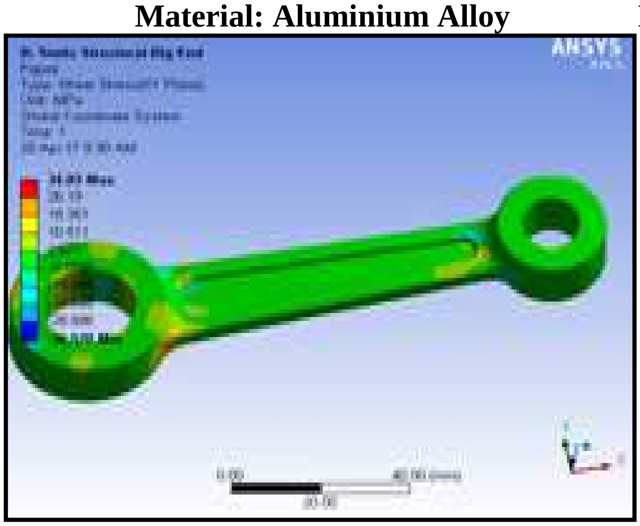
Material: Aluminium with Silicon carbide

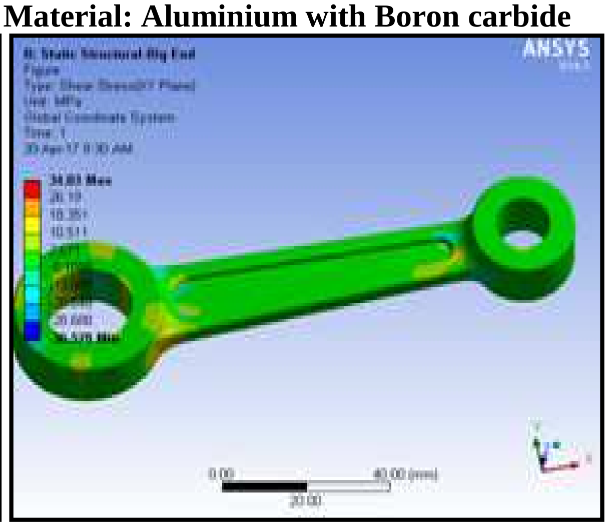


Equivalent Strain on Aluminium with Silicon carbide Connecting rod

Shear Stress on Connecting Rod

Material: Aluminium Alloy **Material: Aluminium with Boron carbide**

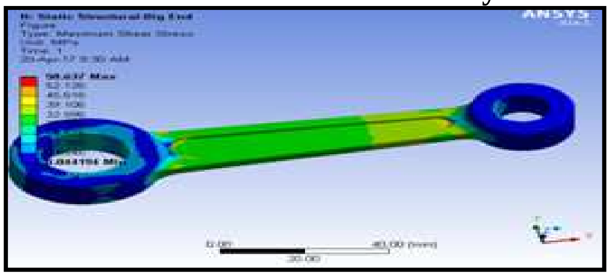




Shear Stress on Aluminium Alloy Connecting rod Shear Stress on Aluminium with Boron carbide Connecting rod

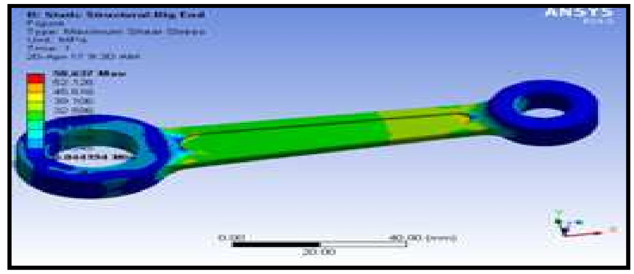
Maximum Shear Stress on Connecting Rod

Material: Aluminium Alloy



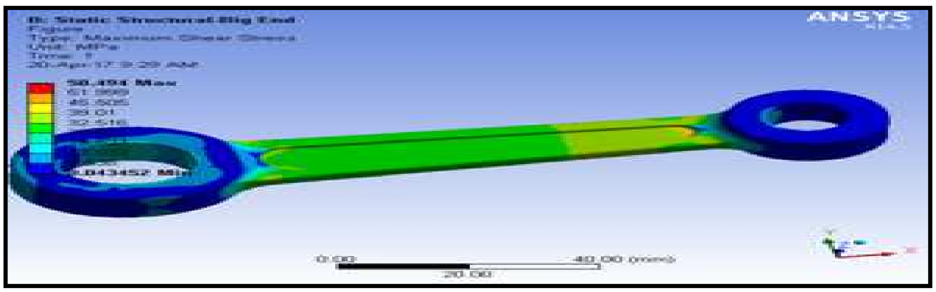
Maximum Shear Stress on Aluminium Alloy Connecting rod

Material: Aluminium with Boron carbide



Maximum Shear Stress on Aluminium with Boron carbide Connecting rod

Material: Aluminium with Silicon carbide



Maximum Shear Stress on Aluminium with Silicon carbide Connecting rod

CONCLUSION

The conventional connecting rod used in the engines was replaced with a composite connecting rod. The connecting rod modeled by using Pro-E (Creo). The conventional connecting rod and the Composite connecting rod going to analyzed by finite element methods.

ACKNOWLEDGEMENT

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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