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Design and Analysis of Connecting Rod for Different Material

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Abstract— **Connecting Rods are used practically generally used in all varieties of automobile engines acting as an intermediate link between the piston and the crankshaft of an engine of an automobile. It is responsible for transmission the up and down motion of the piston to the crankshaft of the engine, by converting the reciprocating motion of the piston to the rotary motion of crankshaft. While the one end, small end the connecting rod is connecting to the piston of the engine by the means of piston pin,the other end, the bigger end being connected to the crankshaft with lower end big end bearing by generally two bolts. 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. The present paper attempts to design and analyzethe connecting rod used in a diesel engine in context of the lateral bending forces acting along its length during cycle of it The lateral bending stress are commonly called as whipping stress and this whipping stress forms the base of evaluation of performance of various materials that can be used for manufacturing of connecting rod. The conventional material used is steel which is designe using CAD tool which is CATIA V5 and subsequently analysed for bending stress acting on it in the arena of finite element analysis using ANSYS workbench 14.5 and this procedure is followed for different material which are aluminium 7075 , aluminium 6061 and High Strength Carbon**

Index Terms— **Connecting Rod, Analysis, FEA**

I. INTRODUCTION

The conversion of heat energy into mechanical energy is achieved by device called as internal combustion engine and connecting rod forms an integral part of this engine. The function of connecting rod is to transmit the gas pressure available at piston end to crank end for efficient conversion of heat energy into mechanical energy. During this process of energy conversion various forces and corresponding stresses are generated on the body of connecting rod and it forms the most stressed part of I. C engines. The two forces acting on connecting rod can be classified as buckling load due to gas pressure and lateral bending due to inertia forces. The inertia forces cause bending of connecting rod which causes whipping stress acting on it.

In this project the conventionalmaterial used for manufacturing of connecting that is steel is replaced by aluminium alloys such as 7075 and 6061 and High Strength carbon fiber. The lateral bending of connecting rod occurring on each materials are evaluated analytically and using FEA approach.Computers employingmicroelectronics technology are called for aiding the geometric modeling of connecting rod which would provide the model for subjecting it to various materials .The calculation of whipping stress due to inertia is first calculated for each material using analytical approiach.Geometricallymodeled connecting rod in CATIA V5 is subjected to diffrent materials and the equivalent stress results are calculated by FEA software named as ANSYS which are compared with the equivalent stress acting on the conventional connecting rod material that is steel to provide a platform for evaluation and validation of design.

II. MATERIAL FOR CONNECTING ROD

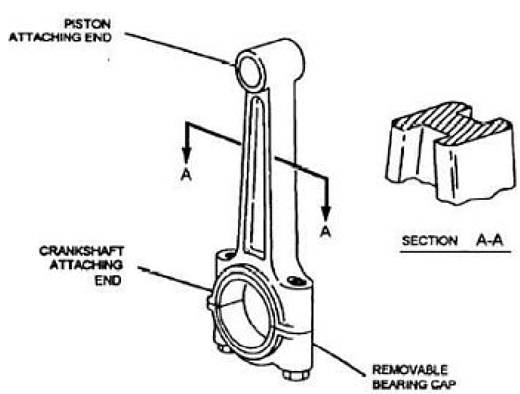

Fig.no.1. Connecting rod assembly

The most common type of production methods is casting,forging,and powdered metallurgy.Connecting rod must withstand a complex state of loading.It need to undergo high cyclic loads of the order of 10^8 to 10^9 cycles,which range from high compressive loads due to combustion,to high tensile loads due to inertia.Therefore,durability of this component is vital.Due to these factors,automotive connecting rods have been the topic of research for different aspects such as production technologymaterials,performance,simulation,fatigue,etc.In modern automotive cylinder engines,the connecting rods are most usually made of forged steel for production engines. Connecting rods for automotive applications are typically

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manufactured by forging from either wrought or powdered forged.They could also be cast.Between the forging processes,powder forged or drop forged,each process has its own advantages and disadvantages.Powder metal manufactured blanks have the advantage of near net shape and saving materials.However,the cost of the blank is high due to the high material cost and sophisticated manufacturing techniques.With steel forging,the material is cheap and the drop forging manufacturing process is cost effective..Due to its large volume production,it is only logical that optimization of the connecting rod for its weight or volume will result in large-scale savings.It can also achieve the objective of reducing the weight of the engine component,thus reducing inertia loads,reducingengine weight and improving engine performance and fuel economy

III. RESEARCH PROBLEM DEFINITION

The present work provides an insight of bending stress acting along the body of connecting rod due to inertia forces acting on the connecting rod which are known by name of whipping stress. The bending moment is dependent on material selected for connecting rod and is used to evaluate the bending stress acting on steel, Al7075, Al6061 and high strength carbon fiber. The comparative study of bending stress parameter provides the best material to be selected for connecting rod of diesel engine

IV. METHODOLOGY

[4.1] To design the connecting rod for a diesel engine so as to determine the section thickness of connecting rod.
[4.2] To geometrically model the connecting rod as per the dimensions generated from the process of design procedure followed.
[4.3] To analyse the whipping load which is bending stress due to inertia forces acting on each material of connecting rod
[4.4] To analyse the bending stress usin FEA approach on each material selected for study.
[4.5] To plot the results for bending stress acting on Al7075, Al6061 and high strength carbon fiber and comparing this with bending stress acting on conventional material.

V. DESIGN OF CONNECTING ROD

The connecting rod is designed for TATA Sumo Four wheeler which uses a diesel engine and its specification can be given as follows

Engine type Air cooled 4- stroke
Bore * Stroke (mm)=83* 90
Displacement = 2956 cc
Maximum power =80.1 at the rate of 2200rpm
Compression ratio =19.1/1
Density of Diesel = 832 kg/m3
Temperature = 60F

Thickness of section of connecting rod is calculated as follows
Thickness of flange & web of the section = t

Width of section B = 4t

Height of section H = 5t
Area of section A= 2(4t*t) +3t*t = 11t2
MI of section about x axis:
Ixx = 1\12 (4t (5t) 3-3t (3t) 3) = 419\12t4
MI of section about y axis:
Iyy = (2+1\12t(4t)3+1\12(3t) t3) = 131\12 t4
Ixx\ Iyy = 3.2
Length of connecting rod (L) = 2 times the stroke
L = 180
Buckling load Wb = maximum gas force × F.O.S
W_b = (σc*A) /1+ [a*(L\Kxx)2] = 37663
σc = compressive yield stress = 610MPa
Kxx = Ixx\A
Kxx = 1.78t
A = σc\Π
A = $11t^2$
a = 0.0002
By substituting σc, A, a, L, Kxx on WB then

$4565t^4-37663t^2-81639.46=0$
$t^2=53.29$;
t= 7.3 mm

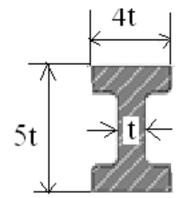

Fig.no2.Section of connecting Rod.

Sr. No	Parameters
1	Thickness of the connecting rod (t) = 7.3mm
2	Width of the section (B = 4t) = 29.2mm
3	Height of the section(H = 5t) = 36.5mm
4	Height at the big end = (1.1 to 1.125)H =41.0625mm
5	Height at the small end = 0.9H to 0.75H=27.37mm
6	Inner diameter of the small end = 51mm
7	Outer diameter of the small end = 65mm
8	Inner diameter of the big end = 65mm
9	Outer diameter of the big end = 87mm

Table.no.1. Specification of connecting rod

VI. GEOMETRIC MODELLING IN CATIA V5

[6.1]The various components for the assembly of connecting rod are designed as per the rating of a diesel engine used in

TATA Sumo four wheeler .the dimensions are determined from above process and various components are modeled and subsequently assembled as final product that can be illustrated here.

[6.2] The first component to be modeled is the connecting rod with a section thicknes of 7.3 mm and height of 36.5mm which can be shown below

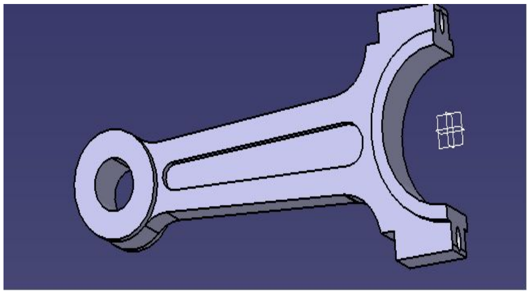

Fig.no.3. Geometric Modeling of connecting rod

[6.3] The next part modeling deals with geometrically designing the upper cap of connecting rod which is used for fixing the crank end of connecting rod .the dimensions of this components are same as upper section of connecting rod and can be depicted as follows

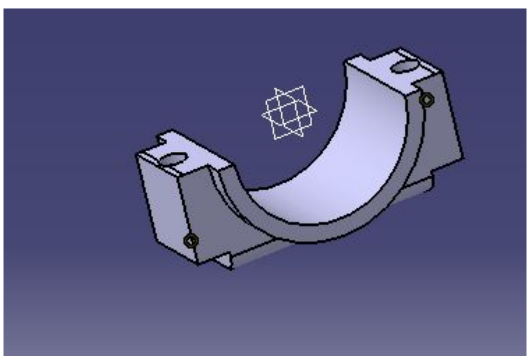

Fig.no.4. Geometric modeling of Upper cap of crank end

[6.4**]** The last component is a bolt of 12 mm which is metric in standard and is used for clamping of crank end to assemble the complete connecting rod

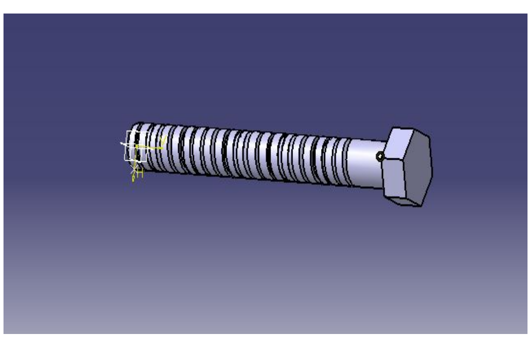

Fig.no.5. Geometric modeling of Upper cap of crank end

[6.5**]** All the components modeled previously are assembled as single product to provide the design of connecting rod. The constraint provided are geometrical constraint which are used to define the relation of various components with each other as shown below

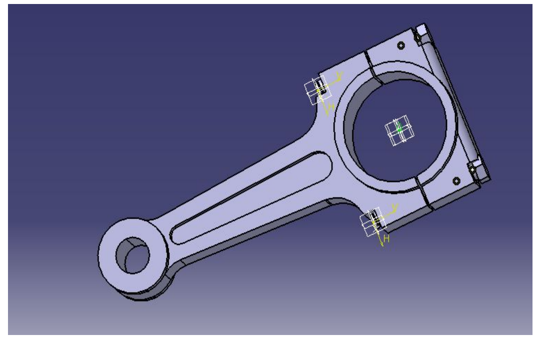

Fig.no.6. Assembly of connecting rod

VII. ANALYSIS OF SYSTEM

7.1 The term internal combustion engine refers to the engine in which working fluid is inside the work producing chamber and in most of IC engines this mixture in terms of air and fue is inducted during suction stroke. Further explosion of the mixture leads to generation of various gases and consequent pushing of piston in downward direction . This downward motion is is transmitted to the crank shaft by means of connecting rod and thus the transmitting member i.e connecting rod must be a rigid link ideally. As rigidity cannot be achieved in practice, the deformation produced on connecting rod must be very small which can be evaluated by studying the type of forces acting on connecting

7.2 Connecting rod is subjected to gas pressure and inertia forces of which inertia force contributes to bending of connecting rod. This lateral bending leads to generation of bending stress known by name of whipping stress acting on connecting rod during it's cycle of operation. This bending stress is dependent on bending moment which acts on the length of connecting rod and is function of density of connecting rod used. Thus variation in material can produce certain results in terms of bending stress acting on the connecting rod and can help to optimize the material than can be used in application of connecting rods .From the domain of various materials that can be implied for construction of connecting rod following four materials are used for calculation of bending or whipping stress acting on them so as to choose the best material which would tend to reduce the whipping load and hence the vibrations of engine during its cycle of operation.The process of analytical analysis is initiated by calculating the maximum bending moment or which is termed as whipping load acting on connecting rod of each material and subsequently calculating the corresponding values of bending stress or whipping stress on connecting rod of each material

The mass of connecting rod per metre length is given by,

Is m_l= volume x density

= area x length x density

Hence $m_l = A \times 1 \times \rho$

And $m_l = A \times \rho$

Here ρ= density of material of connecting rod

As form design consideration we know that $A= 11t^2$

Hence $m_l = 11t^2 \times \rho$

The value of Maximum bending moment can be shown as

$M_b = m \times \omega^2 \times r \times L / 9 \times 3^{0.5}$

Here m = mass of connecting rod

And r = crank radius

L= length of connecting rod

Substituting $m = m_l \times L$ in above expression

$M_b = m_l \times \omega^2 \times r \times L^2 / 9 \times 3^{0.5}$

$I_{xx} = 34.91 \times t^4$ and $y = 2.5t$

Hence the bending stress

$\sigma_b = (M_b \times y) / I$

Thus above relation is used for calculating the bending stress or the value of whipping stress for different materials

MATERIAL	Bending Moment N-m
Steel	5.716
Al7075	1.98
Al6061	1.914
High strength carbon fiber	1.17

Table.no.2. Bending moment acting on different materials

[7.3] The connecting rod geometries of different materials are subjected above bending moment acting on the connecting rods and corresponding values of bending stress which are the von mises stresses calculated for each material and this can be shown as follows.

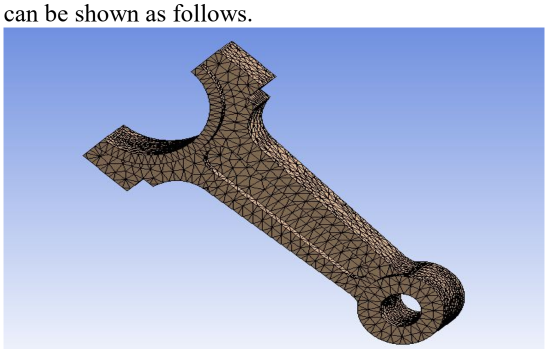

Fig.no.7Meshing of Connecting Rod

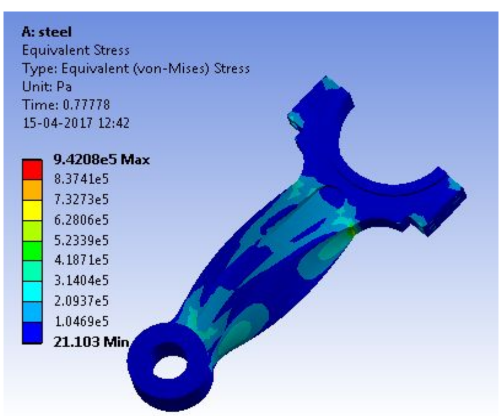

Fig.no.8 Bending stress on steel connecting rod

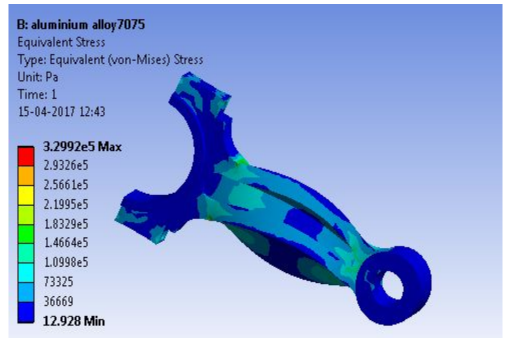

Fig.no.9 Bending stress on Al7075 connecting rod

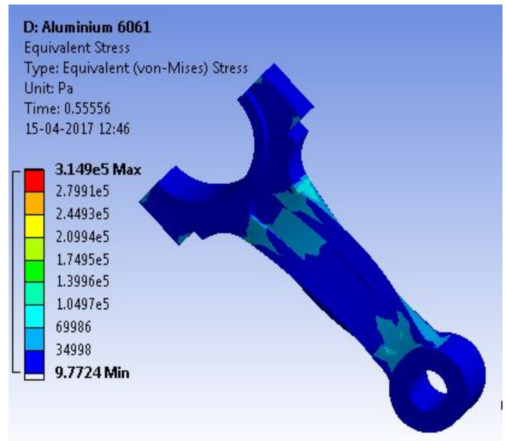

Fig.no.10 Bending stress on Al6061 connecting rod

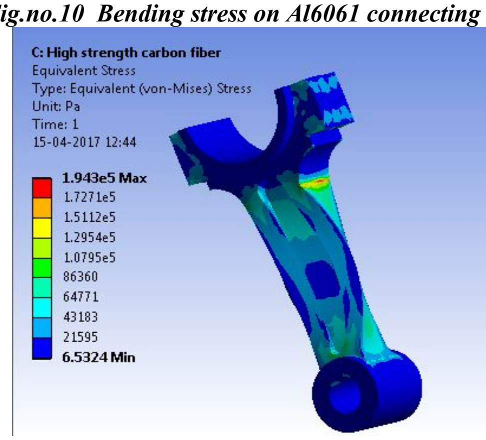

Fig.no.11 Bending stress on High strength carbon fiber connecting rod

8. RESULTS AND COMPARISON

[8.1]The process of designing and analyzing the system with relevant parameters of study is followed by inferences generated by evaluation process of the data obtained during the process of analysis. The connecting rod of various material other than conventional material is subjected to various moment ratings which where analytical values employed for analysis of connecting rod and were used to study the behavior of the connecting rod with materials under consideration. The results calculated can be drawn on the lines of effect of Maximum bending moment which is bending stress in this case. The various input values which are used for connecting rod are presented and the variation in the effect due to material variation in the system can be presented as follows

Property	Analytical Analysis			
Material of connecting rod	Structural Steel	Aluminium Alloy 7075	Aluminium Alloy 6061	High Strength Carbon Fiber
Bending Moment in N-m	5.716	1.98	1.914	1.17
Boundary condition	Fixed support on piston end and crank end	Fixed support on piston end and crank end	Fixed support on piston end and crank end	Fixed support on piston end and crank end
R.P.M	2200	2200	2200	2200
Bending Stress on connecting rod (in N/m^2)	8.636×10^5	2.993×10^5	2.8916×10^5	1.767×10^5

Table.no.3. Analytical Values of Bending stress

Property	Finite Element Analysis			
Material of connecting rod	Structural Steel	Al 7075	Al 6061	High Strength Carbon Fiber
Bending Moment in N-m	5.716	1.98	1.914	1.17
Boundary condition	Fixed support on piston end and crank end	Fixed support on piston end and crank end	Fixed support on piston end and crank end	Fixed support on piston end and crank end
R.P.M	2200	2200	2200	2200
Bending Stress on connecting rod (in N/m^2)	9.4208×10^5	3.299×10^5	3.149×10^5	1.945×10^5

Table.no.4. FEA values of Bending stress

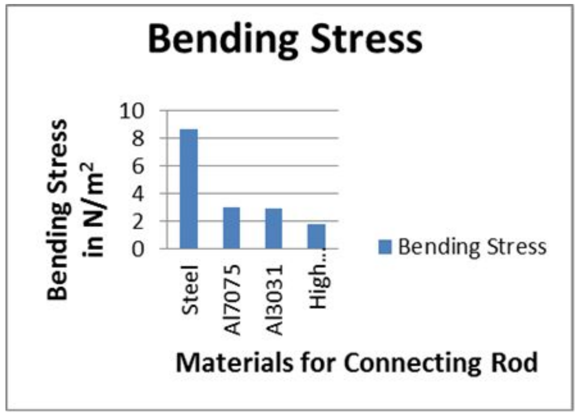

Fig.no.12. Comparison of analytical values of bending stress for materials under study

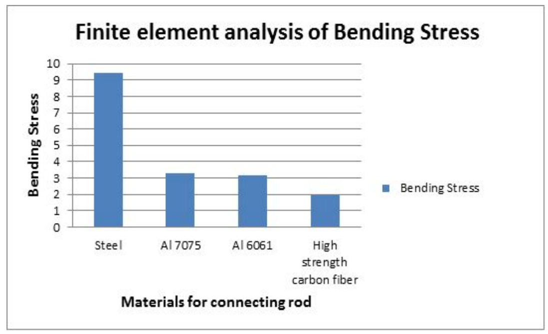

Fig.no.13. Comparison of FEA values of bending stress for materials under study

CONCLUSION

[9.1]Thus it can be inferred that this paper projects a work to determine the best material that can be used for manufacturing of connecting rods. The geometric model generated with the aid of specification of design procedure is consequently analysed for bending stress which is caused by bending moment due to ineria of connecting rod . The FEA approach helps to evaluate the approximate values of bending stress acting on different material such as Al 7075, Al6061 and High strength carbon fiber which are used to compare with the conventional material employed which is steel. The connecting rod of high strength carbon fiber suffers lesser in context of bending due to inertia and thus can be best suited for connecting rod of diesel engine.

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