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Modeling & Analysis of Connecting Rod of Composite material using E-Glass, Epoxy, MWCNT & Aluminum

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Abstract - *The main purpose of this paper is to present the idea of designing connecting rod with minimum cost as well as by using different materials such as E-Glass, Epoxy, MWCNT and Aluminum. Here we are using these materials for improving various properties which are better than existing material. In general, forged steel has a wild scope of application for manufacturing of connecting rod. But there are few of the limitations of forged steel which can be recovered with the help of these materials. The overall result of this project is to provide an alternative for existing material.*

***Key Words*: Design, Manufacturing, Composite material, properties of material, connecting rod.**

1. INTRODUCTION

Connecting rod is a mechanical element used to transfer energy from piston to crank. Generally it consists of two ends namely bigger end and small end. Small end is used to connect piston by using gudgeon pin and bigger end is used to connect camshaft.

During each rotation of the crankshaft, a connecting rod is often subject to large and repetitive forces: shear forces due to the angle between the piston and the crankpin, compression forces as the piston moves downwards, and tensile forces as the piston moves upwards. These forces are proportional to the engine speed (RPM) squared.

Failure of a connecting rod, often called "throwing a rod," is one of the most common causes of catastrophic engine failure in cars, frequently driving the broken rod through the side of the crankcase, and thereby rendering the engine irreparable. Common causes of connecting rod failure are tensile failure from high engine speeds, the impact force when the piston hits a valve (due to a valve train problem), rod bearing failure (usually due to a lubrication problem, or incorrect installation of the connecting rod.).

2. LITERATURE REVIEW

Suraj Pal [1] "Design Evaluation and Optimization of Connecting Rod Parameters Using FEM" In this paper Finite element analysis of single cylinder four stroke petrol engines is taken for the study; Structural systems of Connecting rod can be easily analyzed using Finite Element techniques. So firstly a proper Finite Element Model is developed using Cad software Pro/E Wildfire 4.0.Then static analysis is done to determine the von Misses stress, shear stress, elastic strain, total deformation in the present design connecting rod for the given loading conditions using Finite Element Analysis Software ANSYS .In the first part of the study, the static loads acting on the connecting rod, After that the work is carried out for safe design.

G. Naga Malleshwara Rao [2] "Design Optimization and Analysis of a Connecting Rod using ANSYS" The main Objective of this work is to explore weight reduction opportunities in the connecting rod of an I.C. engine by examining various materials such as Genetic Steel, Aluminium, Titanium and Cast Iron. This was entailed by performing a detailed load analysis.

K. Sudershan Kumar [3] "Modeling and Analysis of Two Wheeler Connecting Rod" This paper describes modeling and analysis of connecting rod. In this project connecting rod is replaced by Aluminium reinforced with Boron carbide for SuzukiGS150R motorbike. A 2D drawing is drafted from the calculations. A parametric model of connecting rod is modeled using PRO-E 4.0 software. Analysis is carried out by using ANSYS software.

B. Anusha, C. VijayaBhaskar Reddy [4] "Modeling and Analysis of Two-wheeler Connecting Rod by Using ANSYS" In this paper a static analysis is conducted on a connecting rod of a single cylinder 4-stroke petrol engine. The model is developed using Solid modeling software i.e. PRO/E (Creo-parametric). Further finite element analysis is done to determine the von-misses stresses shear stress and strains for the given loading conditions.

B. Anusha, Dr. C. VijayaBhaskar Reddy [5] "Comparison Of Materials For Two- Wheeler Connecting Rod Using ANSYS" The modeled connecting rod imported to the analysis software i.e. ANSYS. Static analysis is done to determine von-misses stresses, strain, shear stress and total deformation for the given loading conditions using analysis software i.e. ANSYS. In this analysis two materials are selected and analyzed. The software results of two materials are compared and utilized for designing the connecting rod.

Mr. H. B. Ramani [6] "Analysis of Connecting Rod under Different Loading Condition Using ANSYS Software" In this study, detailed load analysis was performed on connecting rod, followed by finite element method in Ansys-13 medium.

In this regard, In order to calculate stress in Different part of connecting rod, the total forces exerted connecting rod were calculated and then it was modeled, meshed and loaded in ANSYS software. The maximum stresses in different parts of connecting rod were determined by Analysis. The maximum pressure stress was between pin end and rod linkages and between bearing cup and connecting rod linkage. The maximum tensile stress was obtained in lower half of pin end and between pin end and rod linkage. It is suggested that the results obtained can be useful to bring about modification in Design of connecting rod.

Dr. N. A. Wankhede, Suchita Ingale [7], admits a paper attempts to design and analyze the 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 design using CAD tool which is CATIA V5 and subsequently analyzed 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 aluminum 7075 , aluminum 6061 and High Strength Carbon.

Bansal [8], conducted a dynamic simulation on a connecting rod made of aluminum alloy using FEA. In this analysis of connecting rod were performed under static load for stress analysis and optimization. Static load analysis was performed to determine the in von-mises stresses of the connecting rod.

3. POPOSED WORK:

In this project we are going to perform following activities,

- Existing material of connecting rod and their properties
- Failure Analysis
- Suggest Alternative material for connecting rod and their properties
- Design of connecting rod by using analytical method
- Modeling of proposed connecting rod with suitable material by using Solidworks
- Analysis of proposed model by using ANSYS.

4. MODELING & ANALYSIS OF PROPOSED DESIGN

Solidworks is a 3D solid modeling package which allows users to develop full solid models in a simulated environment for both design and analysis. In Solidworks, we sketch ideas and experiment with different designs to create 3D models. Solidworks is used by designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings. Designing in a modeling package such as Solidworks is beneficial because it saves time, effort, and money that would otherwise be spent prototyping the design.

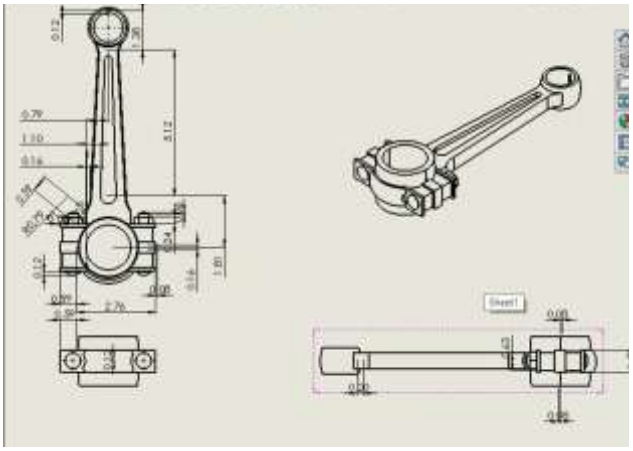

Fig-1: Model of Connecting Rod (Sample Design)

The basis of FEA relies on the decomposition of the domain into a finite number of sub domains (elements) for which the systematic approximate solution is constructed by applying the variation or weighted residual method. In effect, FEA reduces the problem to that of a finite number of unknown by dividing the domains into elements and by expressing the unknown field variable in terms of the assumed approximating function within each element. These functions (also called interpolation functions) are defined in terms of the values of the field variables at specifics points, referred to as nodes. Nodes are usually located along the element boundaries and are connected to adjacent elements. ANSYS Mechanical is a Workbench application that can perform a variety of engineering simulations, including stress, thermal, vibration, thermo-electric, and magneto static simulations. A typical simulation consists of setting up the model and the loads applied to it, solving for the model's response to the loads, the design has 20929 nodes and 11628 elements.

4. MATERIAL SELECTION

In previous chapters, we have seen the properties and analysis of forged steel. Other than forged steel there are few different alloys are used for the production of connecting rod such as; Alloy Steel, Aluminium alloy, Powder Metals etc.

We are going to discuss about comparison of different materials in this chapter,

Properties	Forged Steel	Powder Metal	C-70 Alloy Steel
Young's Modulus	201	199	212
Yield Strength	700	588	574
Ultimate Tensile Strength	938	866	966
Strength Coefficient	1400	1379	1763
Strain Hardening	0.122	0.152	0.193

Exponent			
Density	7.806	7.850	7.700
Poisson's Ratio	0.30	0.29	0.30
Fatigue Strength Coefficient	1188	1493	1303
Fatigue Strength Exponent	-0.0711	-0.1032	-0.0928
Fatigue Ductility Coeff	0.3576	0.1978	0.5646
Fatigue Ductility Exponent	-0.5663	-0.5304	-0.5861
Cyclic Strength Coefficient	1397	2005	1739
Cyclic Strain Hardening Exponent	0.1308	0.1917	0.1919

These are the common materials used for connecting rod. But as we already discussed in previous chapters, these materials have limitations so we are going to select different material with similar properties and strength too. In considerations of above properties we are going to choose a composite material having components like E – Glass, Epoxy, Fly Ash etc. These components have an ability to meet the specifications and properties with desired manner.

The composition of the components is to be deciding after successful testing and analysis of the composite.

There are various materials are to be taken in account for manufacturing of connecting rod by using composite material. We are going to use E Glass, Epoxy, MWCNT, and Aluminium for the production of connecting rod. So let us take a review over the properties of these materials,

Material: E – Glass Fiber
Composition: 54% SiO_2 – 15% Al_2O_3 – 12% CaO

Property	Minimum Value	Maximum Value	Units (S.I.)
Atomic Volume (average)	0.0088	0.009	m^3/kmol
Density	2.55	2.6	Mg/m^3
Energy Content	100	120	MJ/kg
Bulk Modulus	43	50	GPa
Compressive Strength	4000	5000	MPa
Ductility	0.026	0.028	
Elastic Limit	2750	2875	MPa
Endurance Limit	2970	3110	MPa
Fracture Toughness	0.5	1	$MPa.m^{1/2}$
Hardness	3000	6000	MPa
Modulus of Rupture	3300	3450	MPa
Poisson's Ratio	0.21	0.23	
Shear Modulus	30	36	GPa
Tensile Strength	1950	2050	MPa
Young's Modulus	72	85	GPa
Glass Temperature	820	850	K
Maximum Service Temperature	620	630	K
Specific Heat	800	805	J/kg.K
Thermal Conductivity	1.2	1.35	W/m.K
Thermal Expansion	4.9	5.1	10^{-6}/K
Breakdown Potential	15	20	MV/m
Dielectric Constant	6.13	6.33	

Material: MWCNT (Multi Walled Carbon Nanotubes)

Properties of MWNTs

- **Electrical:** MWNTs are highly conductive when properly integrated into a composite structure, however, the outer wall alone has conductive properties, but the inner walls are not instrumental to conductivity.
- **Morphology:** MWNTs have a high aspect ratio with lengths typically more than 100 times the diameter, and in certain cases much higher. Their performance and application are based not just on their aspect ratio, but also on the degree of entanglement and the straightness of the tubes; which in turn is a function of both the degree and dimension of defects in the tubes.
- **Physical:** Defect–free, individual, MWNTs have an excellent tensile strength and when integrated into a composite, such as a thermoplastic or thermosets compound can significantly increase its strength.
- **Thermal:** MWNTs have a thermal stability above 600 ℃, as a result of the level of defects - and to a certain extent on the purity; as a residual catalyst in the product can also accelerate decomposition.
- **Chemical:** MWNTs are an allotrope of sp2 hybridized carbon similar to graphite and fullerenes, and therefore have high chemical stability. However, the Nanotubes can be functionalized to enhance both the strength and dispersibility of composites.

Material: Epoxy

- Low Shrinkage
- High strength
- Excellent adhesion to various substrates
- Effective electrical insulation
- Chemical and solvent resistance, and
- Low cost and low toxicity
- The tensile strength ranges from 90 to 120 MPa

- A tensile modulus ranging from 3100 to 3800 MPa
- Glass transition temperatures (Tg) that range from 150 to 220 ◦C

Epoxies are easily cured, and they are also compatible with most substrates. They tend to wet surfaces easily, making them especially suitable for composite applications. Epoxy resin is also used to modify several polymers such as polyurethane or unsaturated polyesters to enhance their physical and chemical attributes.

Aside from the properties mentioned above, epoxy resins have two main drawbacks which are their brittleness and moisture sensitivity.

Material: Aluminum

Property	Value
Atomic Number	13
Atomic Weight (g/mol)	26.98
Crystal Structure	FCC
Melting Point (□)	660.2
Boiling Point (□)	2480
Mean Specific Heat (0-100□) (cal/g.□)	0.219
Thermal Conductivity (0-100□) (cal/cms. □)	0.57
Co-Efficient of Linear Expansion (0-100□) (x10 $^{-6}$/□)	23.5
Electrical Resistivity at 20°C (Ω.cm)	2.69
Density (g/cm^3)	2.6898
Modulus of Elasticity (GPa)	68.3
Poisson's Ratio	0.34

5. RESULT & DISCUSSION

Connecting rod is a major link which connects the piston to the crankshaft and is responsible for transferring the power from the piston to the crankshaft. In this project Finite element analysis of connecting rod used in single cylinder four stroke petrol engines is taken for the study. Static stress analysis will be conducted on connecting rod made up of two different materials viz. E-glass/Epoxy and Aluminium composite reinforced with Carbon nano tubes. Modeling and comparative analysis of connecting rod is carried out in commercially used FEM software ANSYS Workbench. Static structural analysis will do by fixing the piston end and applying load at the crank end of the connecting rod. Output parameters in static stress analysis are von-Mises stress, Shear stress, total deformation, and equivalent elastic strain for the given loading conditions.

We are going to put the recorded data by testing using ANSYS in the manner of comparison with the previous ones. In this project, we are going to do simple comparison and other relevant analysis for providing the detailed investigation about the topic.

6. CONCLUSION

Solid modeling of connecting rod for four stroke single cylinders has been done using FEA tool ANSYS Workbench. On the basis of this study following conclusion has been made:

- Maximum von-Mises stress for E-Glass/Epoxy and Al-2 CNTs composite should be higher than that of forged steel and powder metal.
- Connecting rod made from Al-MWCNTs will have less weight than that of E-Glass/Epoxy.

This will get after comparing the results obtained from the analysis for two different materials it has been found that the stress induced in the Al-MWCNTs composite is less than the E-Glass/Epoxy.

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