

Static Structural and Experimental Stress Analysis of Connecting Rod Using FEA and Photoelasticity

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ABSTRACT -The connecting rod is the connection between the piston and the crankshaft. It joins the piston pin with the crankpin; small end of the connecting rod is connected to the piston and big end to the crank pin. The function of the connecting rod is to convert linear motion of the piston into rotary motion of the crankshaft. The lighter connecting rod and the piston greater than resulting power and less the vibration because of the reciprocating weight is less. The connecting rod carries the power thrust from piston to the crank pin and hence it must be very strong, rigid and as light as possible. The objective of this research is to study the Static structural and Experimental analysis of two-wheeler's Connecting rod using finite Element Analysis and Photoelasticity analysis method. So that a Connecting rod of two-wheeler 100 cc petrol engine is taken for the analysis, Finite element analysis includes the Design and modeling of connecting rod using Creo 2.0 and Ansys 15.0 for the Static Structural analysis. Photoelasticity analysis method includes the casting of Photoelastic sheet using Araldite AY 103 and Hardener HY 991 and then connecting rod model is prepared by laser cutting machine.

KEYWORDS: Connecting rod, FEA, Photoelasticity, Ansys 15.0, Creo .0, Static structural analysis.

I. INTRODUCTION

The connecting rod is a major link inside 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. There are different types of materials and production methods used in the creation of connecting rods. The most common types of Connecting rods are steel and aluminium. The most common types of manufacturing processes are casting, forging and powdered metallurgy. Connecting rods are widely used in variety of engines such as, in-line engines, V engine, opposed cylinder engines, radial engines and opposed-piston engines Its work is to transmit the thrust of piston to the transmission. Connecting rod, automotive should be lighter and lighter, should consume less fuel and at the same time they should provide comfort and safety to passengers, that unfortunately leads to increase in weight of the vehicle. This tendency in vehicle construction led the invention and implementation of quite new materials, which are light and meet design requirements. Lighter connecting rods help to decrease load caused by forces of inertia in engine, as it does not require big balancing weight on crankshaft. Therefore, a connecting rod should be designed in such a way that it can withstand high stresses that are imposed on it. Therefore, its analysis is necessary.

II. LITERATURE REVIEW

The connecting rod is subjected to a complex state of loading. It undergoes 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 of critical importance. Due to these factors, the connecting rod has been the topic of research for different aspects such as production technology, materials, performance simulation, fatigue etc. For the current study, it was necessary to investigate Finite element modelling techniques, optimization techniques,

developments in production technology, new materials, fatigue modelling, and manufacturing cost analysis. This brief literature survey reviews some of these aspects.

Balasubramaniam et al. [1991] reported computational strategy used in Mercedes Benz using examples of engine components. In their opinion, 2D FE models can be used to obtain rapid trend statements, and 3D FE models for more accurate investigation. The various individual loads acting on the connecting rod were used for performing simulation and actual stress distribution was obtained by superposition. The loads included inertia load, firing load, the press fit of the bearing shell, and the bolt forces. No discussions on the optimization or fatigue, in particular, were presented.

In a study reported by Repgen et al. [1998], based on fatigue tests carried out on identical components made of powder metal and C-70 steel (fracture splitting steel), he notes that the fatigue strength of the forged steel part is 21% higher than that of the powder metal component. He also notes that using the fracture splitting technology results in a 25% cost reduction over the conventional steel forging process. These factors suggest that a fracture splitting material would be the material of choice for steel forged connecting rods. He also mentions two other steels that are being tested, modified micro-alloyed steel and modified carbon steel. Other issues discussed by Repgen are the necessity to avoid jig spots along the parting line of the rod and the cap, need of consistency in the chemical composition and manufacturing process to reduce variance in microstructure and production of near net shape rough part.

Shengdun Zhao et al [2012] Effect of process parameters on microstructure and mechanical properties in AlSi9Mg connecting rod fabricated by semi solid squeeze casting. The effects of applied pressure, pouring temperature and die temperature on the micro structure and mechanical properties of connecting rods fabricated by the semi-solid squeeze casting (SSSC) process were investigated. The results show that the non-dendritic primary Al particles distribute uniformly throughout the connecting rods. With the increase of applied squeeze pressure, the size of Al particles decreases while the shape factor increases, which increase the mechanical properties of the connecting rods. when the pouring temperature and die temperature increase, the size and shape factor of primary Al particles increases. However, if the die temperature is higher than 300 1C, the shape factor decreases suddenly. The best microstructure and mechanical properties of connecting rods fabricated by SSSC were obtained at the pouring temperature of 575 1C, die temperature of approximately 250 1C, and squeeze pressure of 100 MPa.

Kumar Chandrakar et al [2014] Fatigue Analysis of Connecting Rod Using Finite Element Analysis to Explore Weight and Cost Reduction Opportunities for a Production of Forged Steel Connecting Rod, This research project investigated weight and cost reduction opportunities that steel forged connecting rods offer. An OEM supplied the connecting rod chosen for this project belonged to a mid-size sedan. First, the connecting rod was digitized. Load analysis was performed based on the input from OEM, which comprised of the crank radius, piston diameter, the piston assembly mass, and the pressure-crank angle diagram, using analytical techniques and computer-based mechanism simulation tools. Quasi-dynamic FEA was then performed using the results from load analysis to gain insight on the structural behaviour of the connecting rod and to determine the design loads for optimization.

Weijun Hui et al [2014] Effect of vanadium on the high-cycle fatigue fracture properties of medium-carbon micro alloyed steel for fracture splitting connecting rod, The present investigation effort was made to study the effect of even higher addition of V up to 0.45% on the fatigue properties of medium-carbon MA steel, for the development of new crackle MA steel to fabricate fracture splitting connecting rod with excellent fatigue properties. 37MnSiVS steel with three levels of V (0.15%, 0.28% and 0.45%) and conventional medium carbon MA steel 38MnVS for comparison in the as forged condition were used.

Mattie Pujjati et al [2014] Fretting initiated fatigue in large bore engines connecting rods, the fatigue failure of connecting rods initiated by fretting damage described. Fracture mechanics and Hertz theory were employed to assess the main parameters controlling the damage and to define thus appropriate corrective actions. Connecting rods, which were considered susceptible to fatigue crack propagation were subsequently monitored through a tailored ultrasonic testing procedure.

III. OBJECTIVE

Objective of this research work is to study the static structural and stress analysis of two-wheeler's connecting rod by using finite element analysis and experimental analysis to find different stresses occurs in connecting rod at different sections. The objective of this work also includes the identification of problem behind the failure of two wheeler connecting rod at different loading conditions so that the existing design of connecting rod is considered and connecting rod is analysed theoretically, numerically and experimentally.

IV. METHODOLOGY

Methodology of this research consist three types of analysis such as Theoretical analysis, static structural analysis and Experimental analysis of connecting rod using photoelasticity, in which for the static structural analysis we used creo 2.0 modeling software and Ansys 15.0 analysis software and experimental analysis is carried out on connecting rod specimen in laboratory to find the maximum principle stresses. While conducting the analysis using different method we considered the major occurring stresses in the connecting rod such as compressive load and tensile loads at the both ends of connecting rod.

V. THEORETICAL ANALYSIS OF CONNECTING ROD

A connecting rod is a machine member, which subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore, the cross-section of the connecting rod is designed as a strut and the Rankin formula is used. A connecting rod subjected to an axial load W may buckle with x -axis as neutral axis in the plane of motion of the connecting rod, or y -axis is a neutral axis. The connecting rod is considered as both ends hinged for buckling about x -axis and both ends fixed for buckling about y -axis. A connecting rod should be equally strong in buckling about either axis.

Let,

A = cross sectional area of the connecting rod.

L = length of the connecting rod.

σ_c = compressive yield stress.

W_{cr} = crippling or buckling load

I_{xx} and I_{yy} = moment of inertia of the section about x -axis and y -axis respectively.

K_{xx} and K_{yy} = radius of gyration of the section about x -axis and y -axis respectively.

Rankin formula = $(I_{xx} = 4I_{yy})$.

Pressure calculation for Bajaj Discover 100CC petrol engine

Engine type- Single cylinder 4-stroke air-cooled

Bore \times Stroke (mm) = 47×54.4

Displacement = 94.38CC

Maximum Power = 7.7 PS @ 7500 rpm

Maximum Torque = 7.78 Nm @ 5000 rpm

Compression Ratio = 9.8 + 0.3:1

Density of Petrol C_8H_{18} = 737.22 kg/m³
= 737.22×10^{-9} kg/mm³

Temperature = 60F = 288.855K

Mass = Density \times Volume
= $737.22 \times 10^{-9} \times 94.38 \times 10^3$
= 0.06957 kg

Molecular Weight of Petrol 114.228 g/mole

Gas constant R = 8.3143

From Gas Equation, PV=Mrt

$R_{sp} = R/M$

$$= 8.3143/0.114228$$

$$= 72.7868$$

$$P = (0.06957 \times 72.7868 \times 288.85) / 94.38 \times 10^3$$

$$P = 15.4976 \text{ Mpa.}$$

$$\begin{aligned} \text{Maximum Gas force} &= \pi D^2 / 4 \times P_{\max} \\ &= (3.14 \times 47^2) / 4 \times 15.4976 \\ &= 26887.47 \text{ N} \end{aligned}$$

Dimensions and material specification of connecting rod is taken from the actual model available in the market as shown below.

Stress calculation for Steel 16MnCr5

For the analysis purpose we used a maximum gas force of piston on connecting rod is 26.88 KN

Compressive loading stress

$$\begin{aligned} \text{Big end } \sigma_{co} &= 26887.47 / 14.25 \times 16.50 \times \sqrt{3} \\ &= 66.06 \text{ Mpa} \end{aligned}$$

$$\begin{aligned} \text{Small end } \sigma_{co} &= 26887.47 / 5.75 \times 11.25 \times \sqrt{3} \\ &= 239.97 \text{ Mpa} \end{aligned}$$

Tensile loading stress

$$\begin{aligned} \text{Big end } \sigma_{co} &= 26887.47 / 14.25 \times 16.50 \times (\pi/2) \\ &= 72.79 \text{ Mpa} \end{aligned}$$

$$\begin{aligned} \text{Small end } \sigma_{co} &= 26887.47 / 5.75 \times 11.25 \times (\pi/2) \\ &= 264.61 \text{ Mpa} \end{aligned}$$

Position	Parameters	16MnCr5
Piston end	Inner diameter	11.5
	Outer diameter	18.5
	Height (H ₁)	13.50
Crank end	Inner diameter	28.5
	Outer diameter	39
	Height(H ₂)	16.50
	Totallength	110

Sr.No.	Content	16MnCr5 (%)
01	C	0.181
02	Mg	1.07
03	Cr	1.04
04	Ni	1.01
05	Mo	0.005
06	S	0.012
07	P	0.011
08	Si	0.23
14	Iron	Balance

VI. FINITE ELEMENT ANALYSIS OF CONNECTING ROD

This is a static structural analysis of two-wheeler connecting rod in which modeling of the existing connecting rod is carried out using the modeling software creo parameter 2.0 and then it is imported to the analysis software Ansys 15.0 and then static structural analysis is carried out on the existing connecting rod in both compressive and tensile loading conditions. 2D Drawing and solid model of connecting rod as shown below

While meshing here element size is found out to be 2mm for working in convergence zone. Total No of element was 119022 and Nodes were 178843. Shown below is meshed model of connecting rod.



Figure: 01 Connecting rod Model

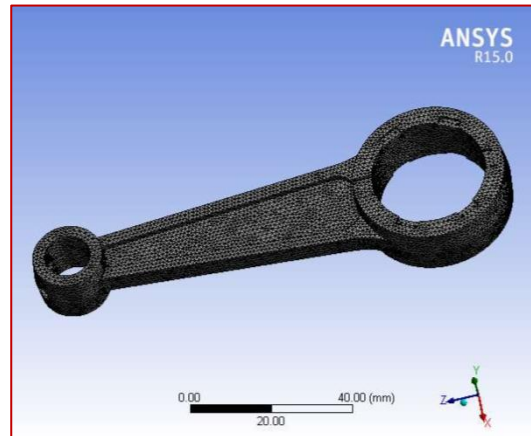
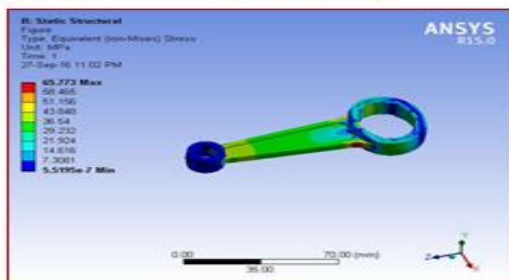


Figure: 02 Meshed Model of Connecting rod

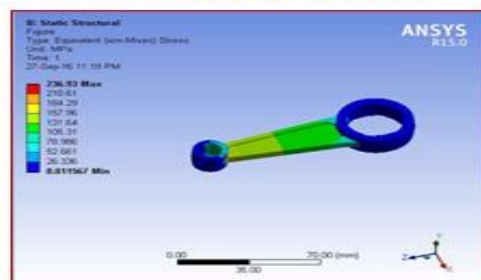
A 3D model of connecting used for analysis in ANSYS 15.0. The loading conditions are assumed static under compressive and tensile. Analysis done with pressure load applied at the big end and restrained at the small end or other load applied at the small end and restrained at the big end. The elements choose is SOLID 187; it was used with the tetrahedral option, making it a 10-node element with 3 degrees of freedom at each node. The finite element analysis is carried out on existing material steel 16MnCr5 connecting rod from the analysis the equivalent von mises stress, elastic strain and displacements are determined.

Two cases are analysed for each case, one with load applied at the big end and restrained at the small end of connecting rod, and the other with load applied at the small end and restrained at the big end. In the analysis carried out, the axial loads were 26 KN in both compressive and tensile loading.

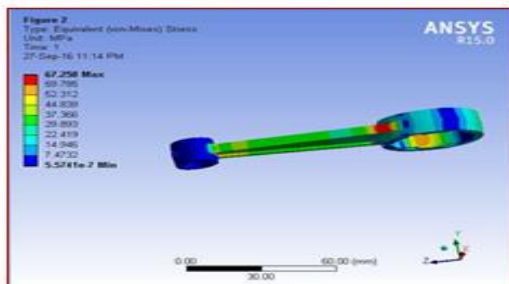
**For Steel 16MnCr5
Compressive load at Big End**



Compressive load at small End



Tensile Load at Big End



Tensile Load at small End

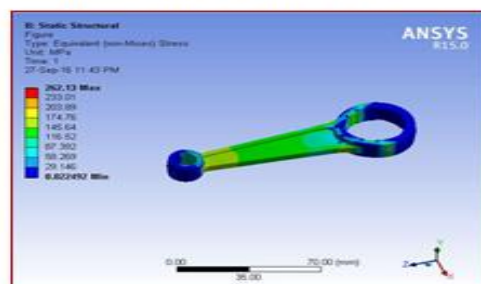


Figure: 03 FEA of connecting rod

Table: 1 Equivalent stresses in connecting rod theoretically

Method	Equivalent Stresses (Mpa)			
	Compressive		Tensile	
	Big end	Small end	Big end	Small end
Theoretical	66.06	239.97	72.79	264.61
FEA	65.06	236.93	67.25	262.13

VII. EXPERIMENTAL ANALYSIS OF CONNECTING ROD USING PHOTOELASTICITY

The Photoelastic model of two wheeler connecting rod with required specification is prepared using Araldite AY 103 and Hardener HY 991 using Photoelastic sheet and then experimentally stress analysis is carried out in SAE lab on experimental setup of Photoelastic stress analysis Equipment; For the analysis of two wheeler connecting rod the most critical area and the major stresses like compressive and tensile stress is considered The different dimensions of the connecting rod are shown in the figure. Three loads, 70kg, 85kg and 100kg are applied at the both ends of connecting rod under the compressive and tensile loading conditions. These stresses calculated experimentally by Photoelasticity.

Photoelasticity stress analysis equipment setup as shown in figure contains the analyser, polarizer, measuring scales digital load indicator, digital camera and jigs and fixtures arrangement for holding or fixing the model of connecting rod.



Figure: 04 Connecting rod Specimen, Experimental setup

While conducting this stress analysis we get the different fringe pattern on the both ends of connecting rod at different loading condition and we get the different fringe order for different magnitude and at each loading condition with the help of this fringe order we calculated the maximum principle stress at the both ends of connecting rod for both compressive as well as tensile loads.

Maximum principle stress can be calculated using the following formulas

Material fringe value ($F\sigma$) = 13.05N/mm

Model thickness (h) = 6mm

Maximum principal stress $\max \sigma = \frac{NF\sigma}{h}$ N/mm²

Fringes developed on connecting rod specimen at both ends and at compressive as well as tensile stress shown below

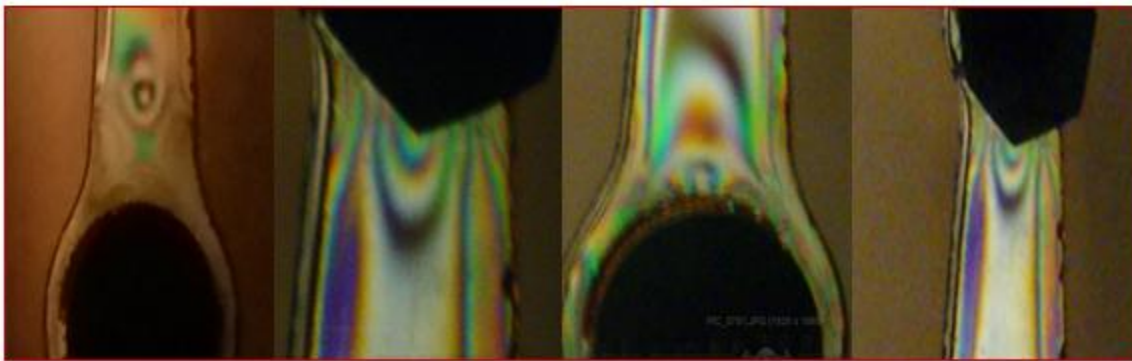


Figure: 05 Fringes Developed on Connecting rod Specimen

Table: 2 Comparative results of connecting rod specimen experimentally

Sr.no	Load Applied (P) (N)	Maximum Principle Stress at compressive loading (6 _p) N/mm ²		Maximum Principle Stress at Tensile loading (6 _p) N/mm ²	
		Big End	Small End	Big End	Small End
01	70	5.24	8.85	5.24	8.10
02	85	6.31	10.69	6.31	9.85
03	100	7.47	12.61	7.47	11.60

VIII. CONCLUSION

This research work investigated Static structural and experimental stress analysis of two wheeler connecting rod using by theoretically, Finite element analysis and using Photoelasticity method in this research paper static structural analysis is carried out to find the von mises stresses and Stress analysis is carried out to find maximum principle stress and reason behind the failure of connecting rod. Following conclusion can be drawn from this study.

[1]. it is been observed that the maximum stresses are induces at the fillet section of both ends of the connecting rod and Chances of the failure of the connecting rod is found at the fillet sections of both ends of connecting rod. Therefore, to avoid that stresses and failure material need to be added at the fillet sections of connecting rod.

[2] By observing the different fringes developed in the connecting rod specimen and by calculating the maximum principle stress at that section we can say that the stresses induced in the small end of the connecting rod are greater than the stresses induced at the big end.

[3] Form the Photoelasticity analysis it is found that the stress concentration effect exist at both small end and big end and it is negligible in the middle portion of the connecting rod. Therefore, the chances of failure of the connecting rod may be at fillet section of both ends.

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