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Design Considerations for Connecting Rod

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Abstract: ***Connecting rod is one of the engine's key components which connect the piston to the crankshaft and converts the piston's reciprocating motion into the crankshaft's rotation. Connecting rod must be sufficiently strong to withstand the thrust from the piston during the combustion process. During its lifespan, it faces a lot of tensile and compressive loads. The objective of this paper is to modify the connecting rod design and changing the material of connecting rod for weight reduction possibilities. Model of the connecting rod is designed with the help of INVENTOR and analysis was performed by using ANSYS.***

Keywords: ANSYS, Connecting rod, INVENTOR, Piston.

I. INTRODUCTION

Connecting rod is one of the engine's key components which connect the piston to the crankshaft and converts the piston's reciprocating motion into the crankshaft's rotation [1]. Connecting rod must be sufficiently strong to withstand the thrust from the piston during the combustion process [1]. During its lifespan, it faces a lot of tensile and compressive loads. Connecting rod consists of small end, shank and big end [4]. The piston is connected to the small end of the connecting rod by gudgeon pin or wrist pin and the big end of connecting rod connects to the crankpin on the crank shaft [4]. Big end of some connecting rods split into two halves so that it can be clamped around the crank journal. The connecting rod's shank can have different cross sections such as circular section, I- section, H- section and rectangular section [4].With minimum weight, the connecting rod should have sufficient strength [11].Steel and aluminum are the materials most widely used to produce the connecting rod [13]. Certain materials, such as titanium alloy, magnesium alloy and beryllium, were also used in the fabrication of the connecting rod. Gas pressure causes compressive stresses and inertia causes tensile stresses in it. Gas pressure is responsible for the maximum force on connecting rod [19].

Forces acting on connecting rod are [19]

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

Design of connecting rod depends upon the speed of the engine. High speed engines uses connecting rod of I-Section and low speed engines uses connecting rod circular cross section [20].

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Casting, forging and powder metallurgy are manufacturing processes for the connecting rods. Material used to fabricate the connecting rod depends on the engine. In industrial engines medium carbon steel is used for making connecting rods. Automobile engines uses alloy steel connecting rods [28]. Reducing the weight of the connecting rod is one way to reduce the inertia forces on a connecting rod for that we can use aluminum material. Bending and axial stresses are induced in the connecting rod during engine operation.

Fatigue, pin failure, over revving, less lubrication, hydrostatic lock causes the failure of a connecting rod.

II. LITERATURE REVIEW

Table- I: Literature Review

S.No.	Ref. No.	Authors	Objectives	Softwares	Conclusions
1	[1]	Vinayak et al.	In this study authors analyzed the connecting rod with different materials and compared the results.	• The 3D connecting rod model was created with NX 6.0. • ANSYS 14.5 was used to perform static structural analysis.	• Weight reduction in the connecting rod was observed in the optimized design where they modified the connecting rod dimensions without altering the main dimensions.
2	[2]	Nilam et al.	To suggest weight reduction opportunity for connecting rod by analysing it with different materials.	• The 3D connecting rod model was created with CATIA. • Analysis was conducted using ANSYS.	• Authors concluded that connecting rod weight reduction can be accomplished through the use of composite materials such as carbon fiber.
3	[3]	Adnan et al.	Computation of strength and deformation characteristics of connecting rod.	• SOLID WORKS was used to develop cad model of connecting rod. • Analysis was performed on ANSYS 15.0.	• Authors suggested Titanium alloy for manufacturing of connecting rod.
4	[4]	Vikas et al.	To determine best material for connecting rod.	• Using SOLID WORKS – 2016, connecting rod model was developed. • Analysis was conducted using ANSYS 16.2.	• Authors concluded that from portions where stress is minimal, material can be curtailed. • Suggested beryllium alloy for production of connecting rod.
5	[5]	Magesh Kumar and Ankush Biradar	To optimize the weight of steel connecting rod.	• UG NX 7.0 was used to build the connecting rod cad model. • Analysis was performed on ANSYS 15.0.	• Use of composite materials reduces the weight of component.
6	[6]	Dipalee Bedse	Design evaluation with the help of FEA for fatigue life of connecting rod.	• Connecting rod model has been developed using CATIA. • FEA was done by using HYPER MESH and FEMFAT.	• Minor changes in the connecting rod geometry like increasing neck radius, etc., improves the connecting rod's fatigue life.
7	[7]	Ganta Krishnarjuna Reddy and Badde Naik	Static structural analysis of connecting rod of various materials.	• SOLID WORKS 2016 was used to develop connecting rod model. • Static structural analysis for various materials was performed on ANSYS 14.5.	• Materials with low stress values are preferable for the production of connecting rod.
8	[8]	Wankhade and Suchita Ingale	To determine the best material that can be used for manufacturing of connecting rod.	• The connecting rod model was created using CATIA V5. • FEA was conducted with ANSYS 14.5.	• Authors suggested Carbon fiber material for connecting rod of diesel engine.
9	[9]	Nilam et al.	It is a review paper about connecting rod design analysis for weight reduction.	• Review paper	• Authors concluded that there is a scope to try other materials than forged steel for manufacturing connecting rods.
10	[10]	Mansi Satbhai and Talmale	It is a review paper associated with design and analysis of connecting rod.	• Review paper	• Authors framed a methodology for designing a connecting rod.

11	[11]	SatishWable and Dattatray S. Galhe	The main objective of this study is to optimize the weight of connecting rod.	• CATIA has been used to build connecting rod model. • Analysis was performed on ANSYS 14.	• Aluminium MMC connecting rod is light in weight and showing less stress than current carbon steel connecting rod for weight optimization.
12	[12]	Harshit Mishra and prof. Kuldeep Narwat	The main objective of this paper is to perform static and modal analysis of connecting rod.	• By using SOLID WORKS 2014, solid modeling of the connecting rod was built. • Analysis was conducted using ANSYS 14.5.	• Connecting rod model was safe during structural analysis by providing factor of safety value more than 1 for all the analyzed materials.
13	[13]	Mithilesh et al.	This paper was about design and analysis of connecting rod of different materials.	• INVENTOR was used to develop the parametric model of the connecting rod. • Analysis was done with ANSYS 15.0.	• Authors suggested Carbon fiber can be used for manufacturing connecting rod.
14	[14]	Lingaraj et al.	To optimize size and shape of connecting rod.	• SOLID EDGE was used to develop cad model. • Analysis was performed on ANSYS.	• Web thickness of connecting rod is reduced. • By shape optimization mass of connecting rod is reduced by 4%.
15	[15]	Vijaya et al.	In this paper connecting rod of Yamaha Fz-s bike replaced by other materials like Chrome Steel and Titanium for analysis.	• Using CREO PARAMETRIC 2.0, connecting rod model was developed. • Using ANSYS, FEA was performed.	• As per the authors, the peak stress for titanium and chrome steel materials is within the acceptable stress limit.
16	[16]	Fanil et al.	Investigating the stress acting on connecting rod at different loading conditions.	• ANSYS was used to build the cad model of connecting rods. • Static structural analysis was also done by using ANSYS.	• Authors concluded that both the experimental and numerical results were closer to each other.
17	[17]	Amit et al.	Design and dynamic analysis of connecting rod using various materials like 20CrMo, 30CrMo and 42CrMo.	• Cad model of connecting rod was developed by using CATIA. • Dynamic analysis was done with the help of ANSYS 14.0.	• Authors concluded that 42CrMo steel alloy requires less material and less dimensions compared with 20CrMo and 30CrMo steel.
18	[18]	Ankit Gupta and Mohd. Nawajish	In this work existed connecting rod material is replaced by other materials to find best alternative.	• PRO-E 4.0 was used to develop cad model. • Analysis was performed on ANSYS 10.0.	• Authors suggested beryllium alloy for connecting rod production.
19	[19]	Naga Malleshwara Rao	In this work author explored weight reduction possibilities in the connecting rod by examining various materials.	• The connecting rod model was built with PRO-E. • FEA was done by using ANSYS.	• We can find that the genetic steel is showing less deformation and stresses than the other materials which are considered during the study.
20	[20]	Anusha et al.	In this study connecting rod of two different materials analyzed.	• The connecting rod model was created with PRO-E. • Static analysis was performed on ANSYS.	• This study shows that the stress is peak at small end of the connecting rod. • Authors concluded that it is better to use structural steel as a connecting rod material for long durability.

21	[21]	Abhinav et al.	Static stress analysis of connecting rod is conducted to find maximum stress point.	• The connecting rod model was created with CATIA V5. • FEA was done with ANSYS 14.0.	• According to the authors, area near the root of the connecting rod's small end is prone to failure.
22	[22]	Leela Krishna and VenuGopal	This paper is about design and analysis of connecting rod.	• The connecting rod model was built with CATIA V5 R19. • ANSYS 13.0 was used for Finite element analysis.	• Forged steel connecting rod showing better results when compared with existing carbon steel connecting rod.
23	[23]	B. K. Roy	Various designs of connecting rod have been analysed to suggest optimum design parameters.	• Using CATIA V5 R19, the connecting rod model was created. • ANSYS 12.0 was used for Finite element analysis.	• Author concluded that careful modification of design parameters can give a good design for connecting rod.

Connecting rod's weight and design affects the performance of a vehicle. Changing the connecting rod material and changing the connecting rod design can result in variations in weight and stresses induced in it. As per the literature survey it is observed that weight reduction of connecting was obtained by

- Removing materials from certain regions where stress values are low [4], [24], [25].
- By modifying the connecting rod dimensions without altering the main dimensions [1], [6], [14], [23].
- Changing the material for manufacturing of connecting rod [2], [5], [11].

III. MODELLING AND ANALYSIS

CASE - I

A. Modifying the connecting rod dimensions

Model of the connecting rod was created with the help of INVENTOR software. Fig. 1 shows the actual model of connecting rod and Fig. 2 shows modified model of the connecting rod.

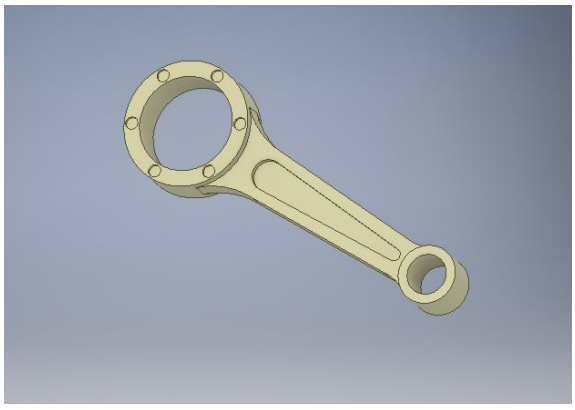

Fig. 1. Connecting rod model

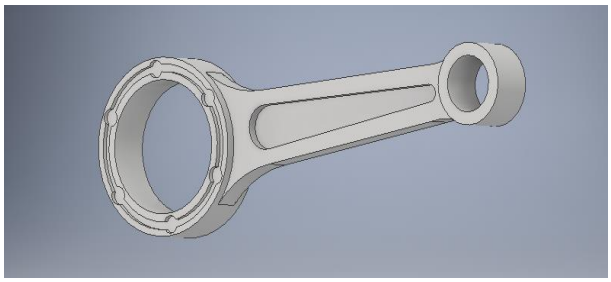

Fig. 2. Modified model of connecting rod

B. Analysis of modifying the connecting rod dimensions

Static structural analysis of the actual and modified model of connecting rod at 15 kN bearing load was performed by using ANSYS. Bearing load is applied at small end of the connecting rod and big end is fixed. Analysis results were showed in the Table-II.

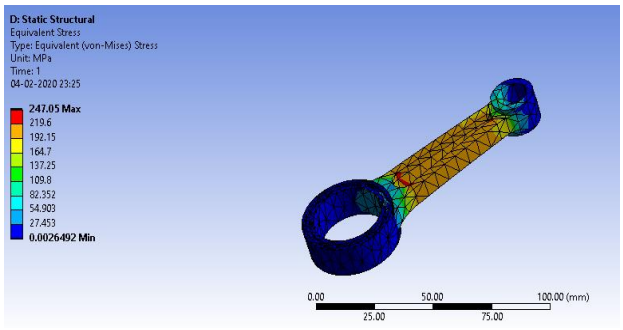

Fig. 3. Von-Mises stresses of Connecting rod

Table- II: Results of analysis of different connecting rod designs

15000N bearing load at small end and bid end is fixed				
Material	**Condition**	**Von-Mises stress (MPa)**	**Factor of safety**	**Weight (grams)**
Structural Steel	Before Modifications	224.5	1.1	127.6
	After Modifications	247	1.1	116

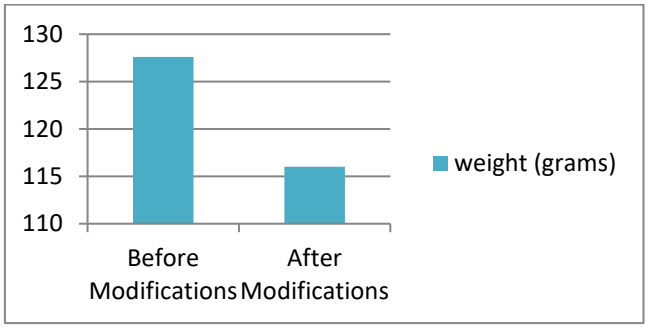

Fig. 4. Weight comparison

By observing Table- II and Fig. 4 we can say that modified design of connecting rod showing less weight than the actual design of connecting rod.

CASE - II

A. Changing the material for connecting rod

Static structural analysis of the connecting rod at 15kN bearing load with different materials was performed by using ANSYS. Materials used for analysis were given in the Table-III.

Table- III: Material Properties [1], [12], [29]

Material	Young's Modulus (GPa)	Poison's Ratio	Density (kg/m^3)
Stainless Steel	193	0.31	7750
Structural Steel	200	0.3	7850
Al 7075	71.7	0.33	2810
Ti-6Al-4V	113.8	0.34	4430

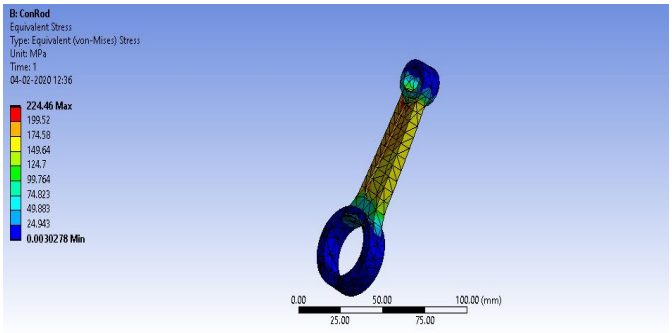

Fig. 5. Von-Mises stresses of Connecting rod

B. Results Analysis of changing the connecting rod material

Results for the various materials at 15000 N bearing load at small end of connecting rod are shown in Table-IV.

Table- IV: Result analysis of connecting rod of different materials

15000N bearing load at small end and bid end is fixed			
Material	**Von-Mises stress (MPa)**	**Factor of Safety**	**Weight (Grams)**
Structural Steel	224.5	1.1	127.6
Stainless Steel	224.5	0.9	126
Ti-6Al-4V	224.5	3.9	72
Al 7075	225	2.6	45.7

1) Weight comparison

By observing Table- IV and Fig. 6 we can say that, Al7075 material has lowest weight than other materials for same loading conditions.

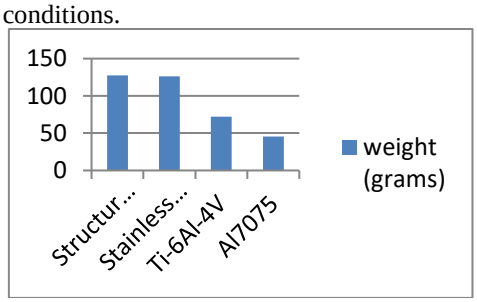

Fig. 6. Weight comparison

2) Factor of safety comparison

By observing Table- IV and Fig. 7 we can say that, Ti-6Al-4V showing high factor of safety for the same loading conditions. So we can remove material from Ti-6Al-4V connecting rod for further decreasing weight of connecting rod.

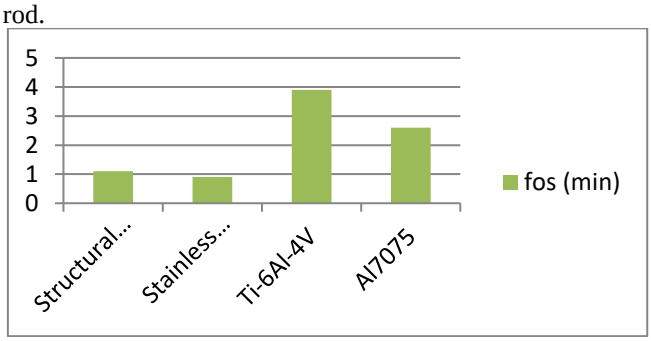

Fig. 7. Factor of Safety comparison

IV. CONCLUSIONS

By observing results analysis tabulated in Table- II and Table- IV we can conclude that weight reduction of the connecting rod was obtained by,

- Removing material from big end of the connecting rod where stress values are low.
- From the Table- II we can say that the modified design of connecting rod showing less weight than the actual design of connecting rod for the same loading conditions. So we can use modified connecting rod instead of actual connecting rod.
- From the Table- IV we can say that, Al7075 material has lowest weight than other materials for the same loading conditions.
- From the Table- IV we can say that, Ti-6Al-4V showing highest factor of safety than other materials for the same loading conditions. So use Al alloy or Ti alloy for the manufacturing of connecting rod.

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