Evaluation of Connecting Rods of Different Materials used in 4S-SI Engines

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Abstract— In present scenario internal combustion engines play crucial role in energy saving, and in this context, importance of connecting rod cannot be overlooked. Considering these facts, present research is devoted to the investigations of connecting rods using different materials. For this purpose connecting rod of an automobile was chosen and static and modal analysis on the rod was carried out. The selected materials were stainless steel, cast iron, Aluminum Alloy 7075, High Strength Carbon Fiber, Al fly ash silicon composite, and AISI 4340 Steel alloy material. Modal analysis governs the suitability of all the materials for the applications. For the purpose of model development CATIA software was used, and analysis was done on ANSYS 14.0 software.

Key words: Connecting Rod, Internal Combustion Engines, Materials, ANSYS

I. INTRODUCTION

Connecting rods are considered as one of the vital parts of automobiles. These rods are used to make a linkage between piston and crank. These rods face complex type of loading conditions, and may undergo cyclic loads of the order of around 10^8 to 10^9 cycles, which comprise high amount of tensile loads due to inertia of reciprocating parts as well as high compressive loads due to expansion. Therefore, durability of this component is of vital importance. Due to these factors, the connecting rod has been the topic of research for different aspects and so therefore, present research is devoted to the connecting rod. In present research, performance evaluation of correcting rods made up of different materials is proposed. For this purpose, simulation approach is targeted under which static and modal analysis is proposed. The research work is limited to the selection of the engine. The engine used is a 4 – stroke water cooled multi cylinder spark ignition engine.

In present research work, connecting rods of *six* different materials, namely, stainless steel, cast iron, Aluminum Alloy 7075, High Strength Carbon Fibre, Al fly ash silicon composite, and AISI 4340 Steel alloy material. Under static analysis, evaluation of von misses stresses is performed while under modal analysis, investigations about different natural frequency modes as well as total deformations are carried out. Modeling is performed in CATIA V5i software where for the purpose of analysis, ANSYS 14.0 is used.

II. LITERATURE REVIEWS

In 2016 Apasi, A., Abdulkareem, S. and Yawas D. S. study with the performance of metal matrix composite connecting rod and also the regular carbon steel connecting rod. The analysis work commenced with casting of the Metal Matrix Composite sample rod by stir-casting technique and buying the Regular (carbon steel) rod to serve as control. A performance check of the 2 sample connecting rods was dispensed employing a Toyota starlet Engine of twelve valve model E series. The experimental result obtained showed that the duration and rate of fuel consumption for the regular rod varied from 0.3 to 0.636kw/h, whereas that of the composite rod, varied from 0.33 to 0.58kw/h. but for each connecting rods as the speed increases the brake horse power conjointly enhanced. Jeevabharathi and Praveen kumar (2016) In the present research work, traditional connecting rod was replaced with a composite connecting rod, and analyzed by FEA techniques Reduced weight by 31.5% and reduce stresses generated and Enhanced fuel economy. Pathan and Wasekar (2015) In the present research work, existing AB60 connecting rod is replaced by Aluminum Fly ash silicon composite which shows higher degree of strength. The composite rod is manufactured using industrial waste including fly ash. Patil and Chhapkhan (2015) In the research work, the connecting rod of different materials, AISI4340 steel alloy, AISI7068 and Titanium alloy were evaluated for weight reduction, and axial loading capacity. As the result of research, following results were obtained.Von misses stresses generated for the Ti alloy is greater than AISI4340 alloy steel.Titanium alloy material connecting rod is lighter than the existing AISI 4340 alloy.Ti alloy connecting rod shows enhanced axial load capacity as compared to AISI4340 connecting rod. Parkash, O., Gupta, V., & Mittal, V. (2013) In the present research work, dimensions of connecting rod of an engine used in tractors were changed, and static loading analysis as well as fatigue analysis was carried out. The critical regions under both fatigue and static analysis were identified and improved. The connecting rod was modeled and optimized for manufacturability, reduced weight and enhanced life. For same material significant changes were observed in Von misses stresses. Results of the research concluded that not only materials but also design parameters can be considered for optimization.

A. Gap in the Research

Following gaps are being identified on the basis of above mentioned literature survey:

a) There is almost nil research available which compares a comprehensive set of alternative materials on the basis of static analysis and modal analysis; and
b) There is almost nil research available which ranks different materials on the basis of static analysis as well as modal analysis.

On the basis of gaps in research, objectives of present research work are being formulated.

III. FORCES IN CONNECTING ROD

Following are the specifications of the automobile used in research work.

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Sr. No	Input Parameter	Value
	Vehicle Model	Maruti Alto 800 (Std)
	Diameter of Piston (d)	65.8 mm
	Displacement volume (Vs)	796 cc
	Number of cylinder (K)	3
	Swept volume per cylinder	0.0002653 m3
	Length of connecting rod (l)	125 mm
	Torque (T)	69 N-m @ 3500 rpm
	Speed (N)	3500 rpm

Table 3.1: Specifications of Automobile

From above data following parameters were investigated (by assuming mechanical efficiency85%, and max. Pressure to be 10 times of mean effective pressure).

Brake Power

$$B.P = \frac{2\pi NT}{60\times1000}\ \text{KW} = 8.42\ \text{KW} \quad (3.1)$$

Indicated Power

$$I.P = \frac{B.P}{\eta m} = 9.912\ \text{KW} \quad (3.2)$$

Mean Effective Pressure

$$P_{imep} = \frac{I.P \times 60 \times 1000 \times 2}{L\times A\times n\times K} = 1.28\ \text{MPa} \quad (3.3)$$

Maximum Gas Pressure

$$P_{max} = 10 \times P_{imep} = 12.80\ \text{MPa} \quad (3.4)$$

Maximum Gas Force

$$F_{max} = P_{max}\times A = 47147.72\ \text{N} \quad (3.5)$$

In order to solve the research problem, first of all investigations about forces were made.

Figure 4.1 shows different forces applied to the connecting rod.

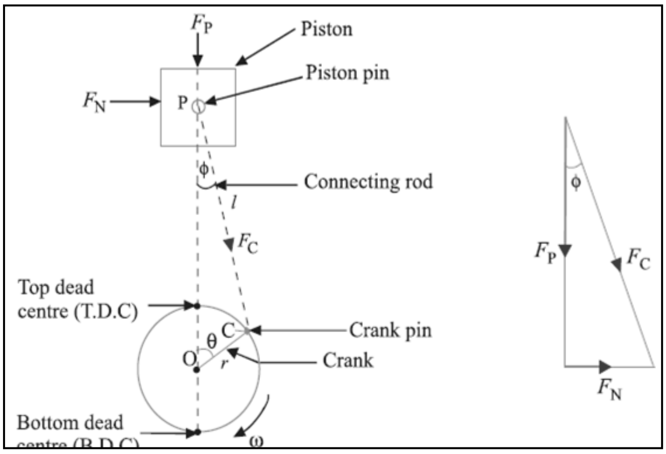

Fig. 4.1: Forces in the Connecting Rod

Details of different forces are presented as follows.

1) Force on connecting rod due to gas pressure

$$F_L = Pressure \times Area = p \times \frac{\pi}{4} \times D^2 \quad (3.6)$$

2) Inertia forces of reciprocating parts

$$F_I = Mass \times Acceleration = m_R \times \omega^2 \times r \times (cos\theta + cos2\theta/n) \quad (3.7)$$

3) Net force acting on the piston considering weight of reciprocating parts

$$F_P = F_L \mp F_I \pm W_R \quad (3.8)$$

In present research work, it is assumed that as the piston is at TDC to move downwards, therefore

$$F_P = F_L - F_I + W_R \quad (3.9)$$

4) Force acting along connecting rod (its maximum *value is taken as equal to* F_L)

$$F_C = F_L = p \times \frac{\pi}{4} \times D^2 \quad (3.10)$$

5) Force due to friction of piston rings and piston

$$F_N = \pi \times D \times t_R \times n_R \times p_r \times \mu \quad (3.11)$$

…..where

- p = Maximum pressure of gas
- D = Diameter of piston
- A = Cross section area of piston
- m_R = Mass of reciprocating parts = Mass of piston, gudgeon pin, etc. + 1/3 rd mass of connecting rod = 540 grams
- ω = Angular speed of crank
- θ = Angle of inclination of crank from TDC
- r = Crank radius = 39 mm
- l = Length of connecting rod = 113.5 mm
- n = Ratio of length of connecting rod to that of crank
- W_R = Weight of connecting rod

On investigating the values of forces following results were obtained.

1) Force on connecting rod due to gas pressure:FL= FC = 47147.72 N
2) Inertia forces of reciprocating parts: FI = 3797.46 N
3) Net force acting on the piston considering weight of reciprocating parts:FP = 43355.56 N
4) Force due to friction of piston rings and piston:FN = 3 N

A. *Model Formulation & Solution*

In order to perform different analysis on connecting rod, first of all its model was designed on modeling software. Figure 3.2 shows the actual connecting rod of targeted automobile.

Figure 3.2: Connecting Rod of Targeted Automobile

Figure 3.3 shows the model of connecting rod.

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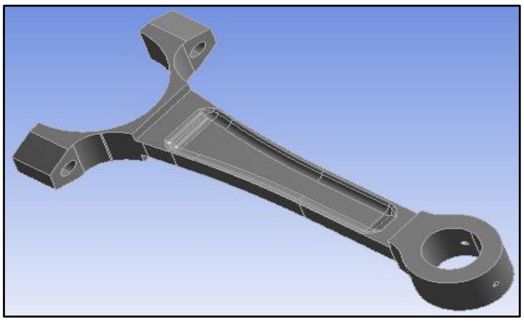


Fig. 3.3: Model of Connecting Rod

In next step, model was solved using well known simulation software ANSYS 14.0. For this purpose, model was first imported to the software. Next step was meshing. Objective of meshing is to make the body deformable. Table 3.2 shows the details of meshing parameters.

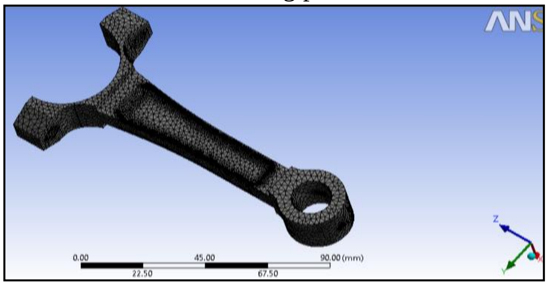


Fig. 3.4: Meshed Connecting Rod

In next step in the research following materials were assigned to the software for the purpose of analysis.

S.No	Material	Properties		
		Young's Modulus	Poisson Ratio	Density
	Stainless Steel	200 GPa	0.3	7850kg/m^3
	Cast iron	17.8 GPa	0.3	7197 kg/m^3
	Aluminum Alloy 7075	71.7 GPa	0.33	2700kg/m^3
	High Strength Carbon Fibre	100 GPa	0.10	1600kg/m^3
	Al fly ash silicon composite	70GPa	0.33	2611.61kg/m^3
	AISI 4340 Steel alloy material	210 Gpa	0.27	7850 kg/m^3

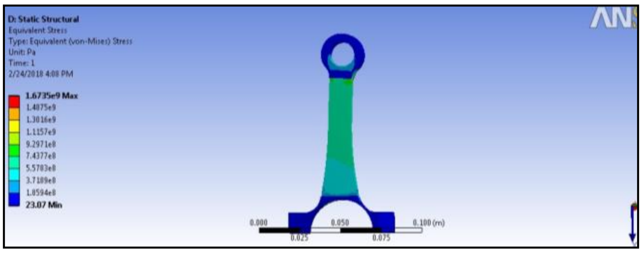
Table 3.3: Details of Material Assignments

In next step loads of 3 N (F_N) and 90000 N ($F_P + F_C$) were applied to the model. On performing static structural analysis of the model different results were obtained the details of which are presented in upcoming sections.

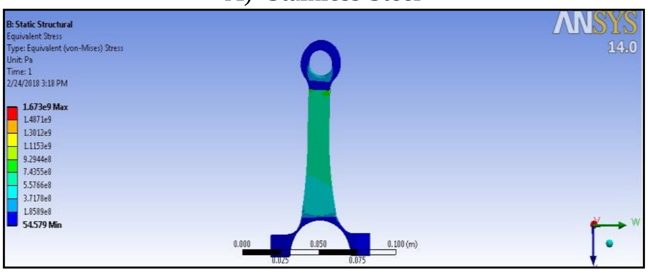
IV. RESULT & DISCUSSION

Present section is devoted to the results obtained from the research work and associated discussion, the details of which are presented in upcoming sections

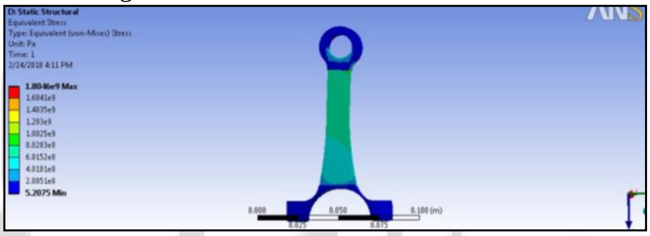
A. Equivalent Von Mises Stress



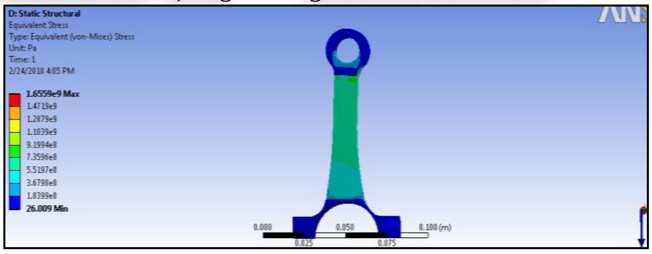
A) Stainless Steel



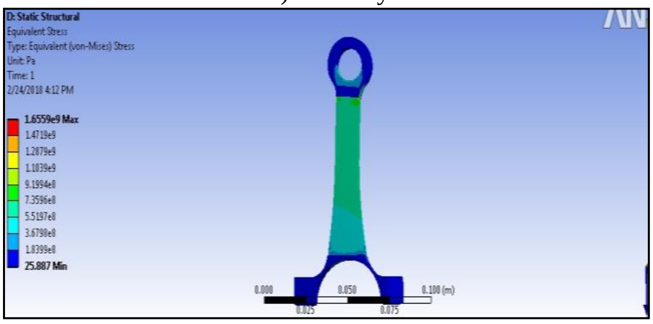
B) Cast Iron



C) High Strength Carbon Fibre



D) Al Alloy



E) Al Fly Ash Silicon Composite

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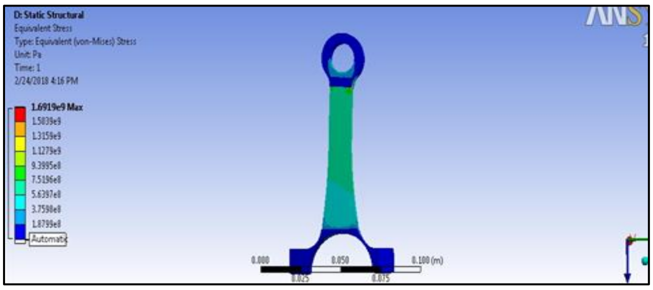


F) Aisi 4340 Alloy Material

Fig. 4.1: Vonmises Stresses in Different Materials

The results of six materials are shown in fig 4.1(a,b,c,d,e,f,) The maximum von mises stress is generated in stainless steel 1.6735E9 . Cast iron material is 1.673E9, Aluminum Alloy 7075 material is 1.6559E9, High Strength Carbon Fibre material is 1.8046E9, Al fly ash silicon composite material is 1.6599E9 and AISI 4340 Steel alloy material is 1.6919E9 after having same meshing and boundary condition.

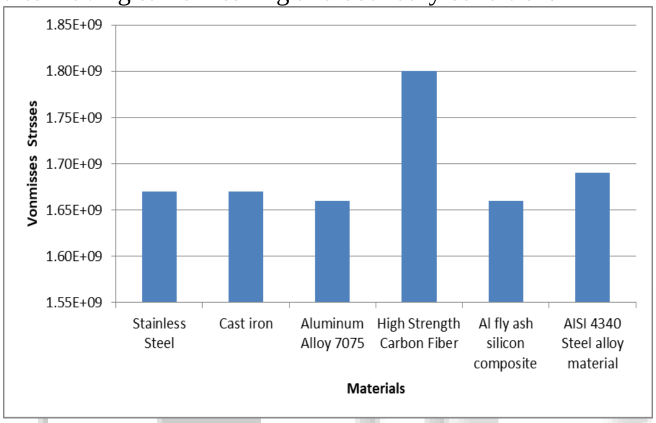
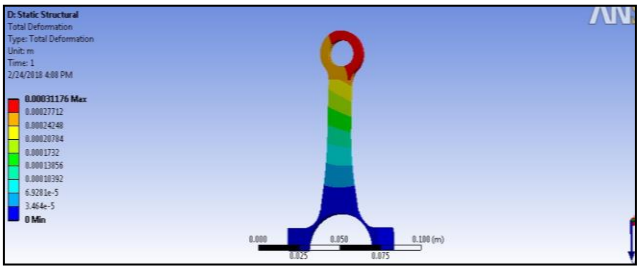


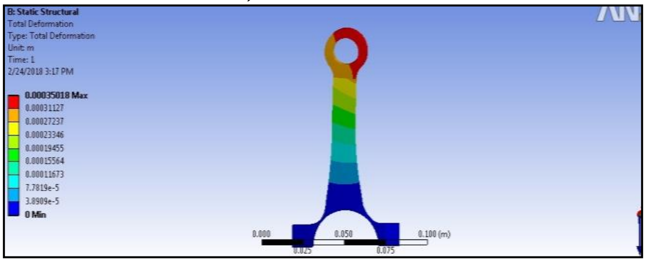
Fig. 4.2: Result of Von Misses Stresses Graph of Various Materials

B. Total Deformation

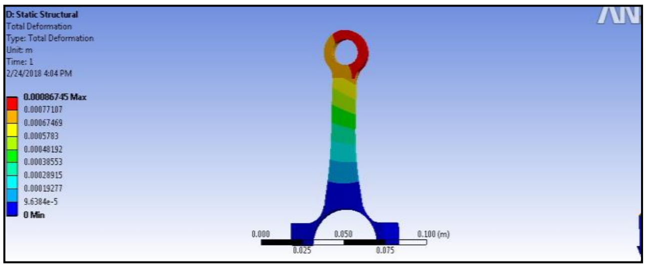
Details of results obtained for total deformations are as follows.



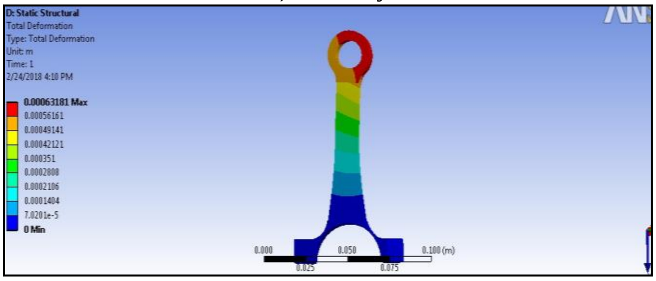
A) Stainless Steel



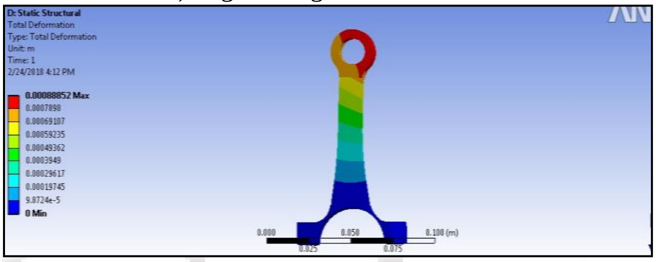
B) Cast Iron



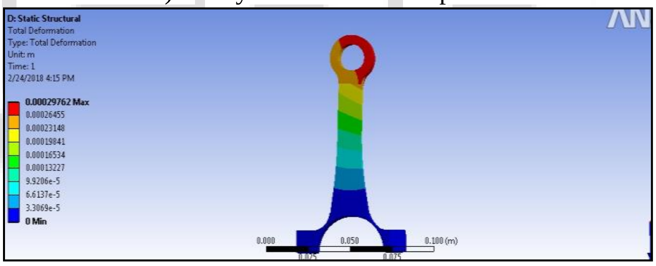
C) Al Alloy



D) High Strength Carbon Fibre



E) Al Fly Ash Silicon Composite



F) Aisi 4340 Alloy Material

Fig. 4.3: Total Deformations in Different Materials

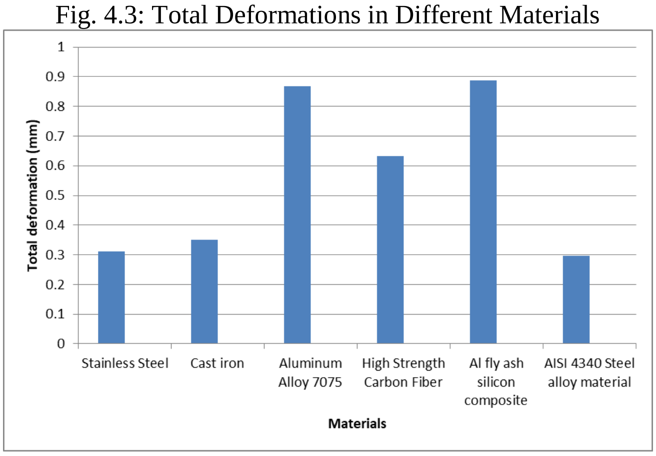


Fig. 4.4: Result of Total Deformation Graph of Various Materials

The results of six materials are shown in fig 5.1(a,b,c,d,e,f,) The maximum Total Deformation is generated in stainless steel 0.00031176m . Cast iron material is 0.00035018m, Aluminum Alloy 7075 material maximum Total deformation is 0.00086745m, High Strength Carbon Fibre material

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maximum Total Deformation 0.00063181m, Al fly ash silicon composite material maximum Total Deformation is 0.00088852m and AISI 4340 Steel alloy material Total Deformation is 0.00029762m after having same meshing and boundary condition

Table 4.1 shows the summary of the obtained results.

S.No	Material	Static Analysis Parameters	
		Von-misses stresses	Total deformation(m)
	Stainless Steel	1.6735E9	0.00031176
	Cast iron	1.673E9	0.00035018
	Aluminum Alloy 7075	1.6559E9	0.00086745
	High Strength Carbon Fibre	1.8046E9	0.00063181
	Al fly ash silicon composite	1.6599E9	0.00088852
	AISI 4340 Steel alloy material	1.6919E9	0.00029762

Table 4.1: Summary of Results

S.No	Material	Von-misses stresses (MPa)	Ranking	Total deformation (mm)	Ranking
	Stainless Steel	1.67E+09	II	0.31176	II
	Cast iron	1.67E+09	II	0.35018	III
	Aluminum Alloy 7075	1.66E+09	I	0.86745	V
	High Strength Carbon Fiber	1.80E+09	IV	0.63181	IV
	Al fly ash silicon composite	1.66E+09	I	0.88852	VI
	AISI 4340 Steel alloy material	1.69E+09	III	0.29762	I

Table 4.2: Combined Rankings of Materials

Figure shows the graphical representation of the results.

As the applied load for all the materials is same, therefore the material with lesser amount of von misses stresses as well as deformations were considered best for the application. But from Table 4.1, one can realize that value of total deformations for all the materials are very less and are less than 1 mm, and can be considered equal. Considering this fact, ranking of the materials can be done on the basis of von misses stresses.

V. CONCLUSION

Following points represent the conclusion of present research work.

1) Considering the criterion of von misses stresses generated, material Al fly ash silicon composite and Aluminum Alloy 7075scores first rank in all the alternatives;
2) For second rank, stainless steel, and cast iron may be chosen;
3) AISI 4340 Steel alloy scores the third rank;
4) If only strength criteria is chosen, materials, Al fly ash silicon composite and Aluminum Alloy 7075 score first rank;
5) All the materials are capable of facing dynamic loading conditions under frequency domain.

VI. LIMITATIONS & FUTURE SCOPE OF THE RESEARCH

Following are the limitations and associated future scope of the present research work.

1) The research work is limited to analysis of simple connecting rod only;
2) Present research work is limited to particular set of materials; and
3) The research work is also limited to investigations on a limited set of properties.
4) Following points indicate the future scope of the research work.
5) An extensive research in the field of different designs of connecting rods is still pending;
6) A comprehensive research work considering a vast set of materials can be undertaken; and
7) A detailed research considering a detailed set of properties can also be initiated.

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