# Study & Analysis of Connecting Rod of Different Material used in 4S-SI Engine

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Abstract—Connecting rod is one of the most important part in engine assembly which transfers energy from piston to crankshaft and convert the reciprocating motion of a piston into the rotary motion of a crankshaft. Connecting rod is the intermediate link between the piston and the crank. Connecting rod is high volume production of automobile side so connecting rod subjected to more stress than the other component of engine. Considering these facts, present research is devoted to the investigations of connecting rods using different materials by static analysis. 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.

Keywords—Connecting Rod, Internal Combustion Engines, Materials, CATIA

#### I. INTRODUCTION

Connecting rods are widely used in variety of car engines. The function of connecting rod is to transmit the thrust of the piston to the crankshaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. It consists of a long shank small end and a big end. Stress analysis of connection rod by finite element method using ANSYS work bench software. And analyzed that the stress induced in the piston end of the connecting rod are greater than the stresses induced at the crank end. So that piston end more fractures compare to crank end. These rods face complex type of loading conditions, and may undergo cyclic loads of the order of around 10<sup>8</sup> to 10<sup>9</sup> 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 cast iron, stainless steel, High Strength Carbon Fibre Aluminum Alloy 7075, 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. ANALYSIS USED IN RESEARCH WORK

In present research work, static structural and modal analysis were used the details of which are presented as follows.

#### A. Static Structural Analysis

Static structural analysis is used to determine the response of a structure subjected to static loading conditions. The loads in this type of analysis are assumed to produce no or negligible based loading characteristics. Under this type of analysis displacement, stresses, and deformations of structure under static loading conditions can be investigated. Following steps are involved in performing static structural analysis on ANSYS 14.0 software.

- a) Develop a model in design modular or import from modeling software;
- b) Define material for the model;
- c) Define meshing attributes;
- d) Generate a mesh for the model;
- e) Assign boundary conditions;
- f) Assign loading conditions;
- g) Perform analysis; and
- h) Analyze different results and interpret conclusion.

#### B. Modal Analysis

Modal analysis is used to calculate the vibration characteristics such as natural frequency and failure mode shapes of a structure or machine element. The output of the modal analysis can be further used as input for the harmonic and transient analyses. The following steps are involved in performing the modal analysis.

- a) Stet the analysis preference;
- b) Create or import the geometry into ANSYS workbench;
- c) Define element attributes;
- d) Define meshing attributes;
- e) Generate a mesh for the model;
- f) Specify the analysis type, analysis options, and apply loading conditions;
- g) Analyze different results and interpret conclusion

#### III. FORCES IN CONNECTING ROD

#### A. Model Formulation

Following are the specifications of the automobile used in research work

S.No	Input Parameter	Value
	Vehicle Model	Maruti Alto 800 (Std)
	Diameter of Piston (d)	65.8 mm

Displacement volume (Vs)	796 сс
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). 1) Brake Power

B. P = 
$$\frac{2\pi NT}{60 \times 1000}$$
 KW = 25.28 KW (3.1)

2) Indicated Power  
I. P = 
$$\frac{B.P}{\eta_m}$$
 = 29.74 KW (3.2)

) Mean Effective Pressure  

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

4) Maximum Gas Pressure  

$$P_{max} = 10 \times P_{imep} = 12.80 \text{ MPa}$$
 (3.4)  
5) Maximum Gas Force

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

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

Figure 3.1 shows different forces applied to the connecting rod.

## Details of different forces are presented as follows.

6) Force on connecting rod due to gas pressure

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Fig. 3.1: Forces in the Connecting Rod 7) Inertia Forces of Reciprocating Parts

$$F_1 = \text{Mass} \times \text{Acceleration}$$
(3.7)

$$\times (\cos\theta + \cos 2\theta/n)$$

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

$$F_{\rm P} = F_{\rm L} \mp F_{\rm I} \pm W_{\rm R} \tag{3.8}$$

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

 $F_P = F_L - F_I + W_R$ (3.9)10) Force acting along connecting rod (its maximum value is taken as equal to  $F_L$ )

$$F_{\rm C} = F_{\rm L} = p \times \frac{\pi}{4} \times D^2 \tag{3.10}$$

Force due to friction of piston rings and piston

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

- Maximum pressure of gas p =
- Diameter of piston D =

- A =Cross section area of piston
- Mass of reciprocating parts = Mass of piston,  $m_R =$ gudgeon pin, etc. + 1/3 rd mass of connecting rod = 540 grams
- Angular speed of crank  $\omega =$
- Angle of inclination of crank from TDC  $\theta =$
- Crank radius = 39 mmr =
- Length of connecting rod = 113.5 mm1 =
- Ratio of length of connecting rod to that of crank n =
- Weight of connecting rod W<sub>R</sub>

On investigating the values of forces following results were obtained.

- Force on connecting rod due to gas pressure 1)  $F_L = F_C = 47147.72 \text{ N}$
- 2) Inertia forces of reciprocating parts  $F_I = 3797.46 \text{ N}$
- 3) Net force acting on the piston considering weight

of reciprocating parts :  $F_P = 43355.56 \text{ N}$ 

### B. Model Solution

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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.



Fig. 3.2: Connecting Rod of Targeted Automobile Figure 3.3 shows the model of connecting rod.



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. Figure 3.4 shows the meshed structure of connecting rod.



Fig. 3.4: Meshed Connecting Rod

		Properties			
S.No	Material	Young's	Poisson	Density	
		Modulus	Ratio	Density	
	Stainless Steel	200 GPa	0.3	7850kg/m <sup>3</sup>	
	Cast iron	17.8 GPa	0.3	7197 kg/m <sup>3</sup>	
	Aluminum Alloy 7075	71.7 GPa	0.33	2700kg/m <sup>3</sup>	
	High Strength Carbon Fibre	100 GPa	0.10	1600kg/m <sup>3</sup>	
	Al fly ash silicon composite	70GPa	0.33	2611.61kg/m <sup>3</sup>	
	AISI 4340 Steel alloy material	210 Gpa	0.27	7850 kg/m <sup>3</sup>	
Table 2.2: Datails of Material Assignments					

In	next	step in	the	research	following	materials
were assign	ned to	the soft	ware	for the pu	rpose of an	alysis.

Table 3.2: Details of Material Assignments

In next step loads of 3 N ( $F_N$ ) and 90000 N ( $F_P$  + F<sub>c</sub>) 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** 

		Static Analysis Parameters		
S.No	Material	Von-misses	Total	
		stresses	deformation	
	Stainless Steel	743.77	0.00031176	
	Cast iron	743.55	0.00035018	
	Aluminum Alloy 7075	735.96	0.00086745	
	High Strength Carbon Fibre	802	0.00063181	
1	Al fly ash silicon composite	735	0.00088852	
	AISI 4340 Steel alloy material	751.96	0.00029762	

Table 4.1: Summary of Results

From table 4.1 shows the result of stress and total deformation in connecting rod. We can find that the stainless steel actual maximum stresses generated in the connecting rod are 743.77 MPa. These stresses are generated near the small end of the connecting rod. Both small and big ends show minimum stresses. The maximum von misses stresses generated in the cast iron are 743.55 MPa, while minimum stresses generated in the material are at small ends and big ends. In this manner one can analyze that for all materials minimum von misses stresses are generated near small end. For aluminum alloy maximum von misses stresses generated are 735.96 MPa. On this criteria high strength carbon fibre shows maximum von misses stresses as 802 MPa, Al fly ash silicon composite shows maximum stresses generated as 735 MPa, and Al Si 4340 alloy shows maximum stresses as 751.96 MPa.

On comparing values of maximum von misses stresses generated in the materials with ultimate strengths, it

was found that the stresses	s generated	were	in permissible
limits. Following are the det	ails.		

	U			
S.No	Material	Specifications	Ult. Strength	Maximum Von misses stresses (MPa)
	Stainless Steel	15 Cr16Ni2	1030 MPa	743.77
	Cast iron	Ni Cr Alloy Ni 0.75 Cr 0.30 C 3.40 Si 1.90 Mn 0.65	1080 Mpa	743.55
	Aluminum Alloy 7075		752 MPa	735.96
	High Strength Carbon Fibre		5.5 GPa	802
	Al fly ash silicon composite		745 Mpa	735
	AISI 4340 Steel alloy		1110 Mpa	751.96

Table 4.2: Comparison of Results of Von misses stresses with Ultimate Strengths

On analyzing deformation results, one can find that deformations in all the members are negligible, and at small end. Maximum values of deformations for are stainless steel 0.000311 mm, cast iron 0.000350 mm, Al alloy 0.000867 mm, high strength carbon fibre 0.000631 mm, Al fly ash silicon composite 0.000888 mm, and AlSi 4340 alloy material is 0.000 0.000297 mm. Deformation graphs for different materials show that deformations are minimum at big end.

On analyzing modal analysis results one can find that for stainless steel maximum total deformation of 7108 mm occurs at mode shape 3, where natural frequency is 3707 Hz, and minimum deformation mode shape 5, of 4055 mm with natural frequency of 5842.2 Hz. At this mode, connecting rod also shows buckling behavior. Mode shapes for cast iron show maximum total deformation of 7424 mm with natural frequency of 3652.6 Hz; whereas minimum total deformation is shown by mode shape 5, of amount 4235 mm with natural frequency 5756.1 Hz. Al alloy shows maximum total deformation of 8786 mm with natural frequency of 3743.8 Hz, and minimum deformation 6925 mm with natural frequency 5966.6 Hz, with buckling effect. High strength carbon fibre also shows maximum total deformation of 158333 mm and natural frequency 6292.9 Hz and minimum total deformation 8899.5 mm with natural frequency 9156.3 Hz and buckling effect at mode 5. Rest other materials also show similar results. Al fly ash silicon composite maximum total deformation 12321 mm with natural frequency 3761.2 Hz at mode 3, and minimum deformation of 7046 mm with natural frequency 5994.4 Hz, at mode 5 with buckling effect, and AlSi 4340 composite shows maximum deformation of 7111 mm with natural frequency of 384.5 Hz at mode shape 3 and minimum deformation of 413 mm with natural frequency of 1055.7 Hz

materials can be myestigated.					
S.No	Material	Von-misses stresses (MPa)	Ranking		
	Stainless Steel	743.77	II		
	Cast iron	743.55	II		
	Aluminum Alloy 7075	735.96	Ι		
	High Strength Carbon Fiber	802	IV		
	Al fly ash silicon composite	735	Ι		
	AISI 4340 Steel alloy material	751.96	III		

at mode 5 with buckling effect. On the basis of von misses stresses generated in the materials following rankings of the materials can be investigated.

Table 4.3: Rankings of Materials on the basis of Von misses Stresses Generated



Fig. 4.1: Von misses stresses in Materials On the basis of total deformations in the materials following rankings of the materials can be investigated.

S. No	Material	Total deformatin (m)	Total deformation (mm)	Rank
	Stainless Steel	0.00031176	0.31176	П
	Cast iron	0.00035018	0.35018	III
	Aluminum Alloy 7075	0.00086745	0.86745	v
	High Strength Carbon Fiber	0.00063181	0.63181	IV
	Al fly ash silicon composite	0.00088852	0.88852	VI
	AISI 4340 Steel alloy material	0.00029762	0.29762	Ι

Table 4.4: Rankings of Materials on the basis of Total Deformation

Figure 4.2 shows the Graphical Representation of the Results



Fig. 4.2: Von misses stresses in Materials

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 4.5, 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.

On the basis of above discussion following rankings, for the materials are suggested.

	0	66	
S.	Motorial	Von-misses	Overall
No	Iviaterial	stresses (MPa)	Ranking
	Stainless Steel	743.77	II
	Cast iron	743.55	II
	Aluminum Alloy 7075	735.96	Ι
	High Strength Carbon Fiber	802	IV
2	Al fly ash silicon composite	735	Ι
-	AISI 4340 Steel alloy material	751.96	III

 Table 4.5: Overall Rankings of Materials considering both

 Criteria

On investigating the RPM generated in the system nder different modes, following results were obtained.

S.	Material	Mode	Natural	RPM
No		shape	frequency	1000
	Stainless	First	636.86	38211.6
	Steel	Second	1021.7	61302
		Third	3707.2	222432
		Forth	4209.1	252546
		Fifth	5842.2	350532
		sixth	10314	618840
	Cast iron	First	627.48	37648.8
		Second	1006.7	60402
		Third	3652.6	219156
	1.	Forth	4147.1	248826
		Fifth	5756.1	345366
		sixth	10162	609720
	Aluminum	First	651.1	39066
	Alloy 7075	Second	1043.7	62622
		Third	3748.8	224928
		Forth	4302.7	258162
		Fifth	5966.6	357996
		sixth	10543	632580
	High	First	991.99	59519.4

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Strength	Second	1597.2	95832
Carbon Fibre	Third	6292.9	377574
	Forth	6567.6	394056
	Fifth	9156.3	549378
	sixth	16059	963540
Al fly ash	First	654.13	39247.8
silicon	Second	1048.5	62910
composite	Third	3761.2	225672
	Forth	4322.7	259362
	Fifth	5994.4	359664
	sixth	10592	635520
AISI 4340	First	65.178	3910.68
Steel alloy	Second	104.65	6279
material	Third	384.15	23049
	Forth	430.84	25850.4
	Fifth	598.51	35910.6
	sixth	1055.7	63342

Table 4.6: RPM generated during Different Modes As the RPM generated are much more as compared to excitation RPM (3500 rpm) or natural frequencies are

much more than excitation frequencies, no material shall fail dynamically under frequency domain.

#### V. CONCLUSION

Following points represent the conclusion of present research work.

- 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;
- 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.

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