# Fea Analysis of Connecting Rod of Different Materials

B. Sriharsha, Dr. P. SudhakarRao, MdYunus khan, Gurwindersingh,
*Mechanical Engineering Department, NITTTR, Chandigarh*

**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. This paper presents design and finite element analysis of connecting rod. Model of the connecting rod is designed with the help of INVENTOR and analysis is performed by using ANSYS. Four different materials viz., Ti alloy, Al alloy, structural steel and forged steel are selected for the connecting rod. Von mises stress, factor of safety and fatigue life of connecting rod of different materials is calculated and compared.**

**Keywords: Finite element analysis, ANSYS, Connecting rod, INVENTOR.**

## I. INTRODUCTION

Connecting rod is one of the main components of the engine which connects the piston to the crankshaft and converts the reciprocal motion of the piston into the rotation of the crankshaft. The connecting rod must be sturdy enough to withstand the piston force during the combustion cycle. During its life expectancy, it faces a great deal of tensile and compressive loads. CR consists of small end, shank and big end. The piston is linked by gudgeon pin or wrist pin to the small end of the connecting rod and the big end of the connecting rod attaches to the crankpin on the crank shaft. Some connecting rod's big end split into two halves so that it can be fastened around the crank journal. The shank of the connecting rod may have numerous cross sections, such as circular section, I- section, H- section. Connecting rod configuration depends on engine speed. High speed engines use I-Section connecting rod and low speed engines use circular cross-section connecting rods. The connecting rod should have sufficient strength with minimal weight. Steel and aluminum are the most commonly used materials for producing the connecting rod. Certain materials, such as titanium alloy, magnesium alloy and beryllium, were also used in connecting rod production. Material used to produce the connecting rod is engine based. Medium carbon steel is used in industrial engines for producing connecting rods. Automobile engines uses alloy steel connecting rods.

Forces acting on connecting rod are

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

## II. LITERATURE REVIEW

Table - 1 Literature Review

| S.No. | Ref. No. | Authors | Softwares | Conclusions |
|---|---|---|---|---|
| **1** | **1** | **Adnan et al.** | • **Modeling: SOLID WORKS.**<br>• **ANSYS: 15.0** | • **By comparing various materials like Aluminium alloys, carbon steel and Titanium alloy for connecting rod, authors concluded that Ti alloy is best for the production of connecting rod.** |
| **2** | **2** | **Nilam et al.** | • **Modeling: CATIA**<br>• **Analysis: ANSYS** | • **Authors concluded that weight reduction can be obtained by using composite materials.** |
| **3** | **3** | **Vinayak et al.** | • **Modeling: NX 6.0.**<br>• **Analysis: ANSYS 14.5** | • **Optimized the design without altering the main dimensions.** |
| **4** | **4** | **Nilam et al.** | • **Review paper** | • **Authors observed that there is a lot of work done on steel connecting rod, so there is a scope to try other materials.** |
| **5** | **5** | **Magesh Kumar and AnkushBiradar** | • **Modeling: UG NX 7.0**<br>• **Analysis: ANSYS 15.0.** | • **Results and weight of connecting rod for different materials and their combinations were observed.**<br>• **Combination of Steel Ti or Al Ti has a better strength than any individual metal.** |
| **6** | **6** | **MansiSatbhai and Talmale** | • **Review paper** | • **Methodology is formulated .** |
| **7** | **7** | **Wankhade and SuchitaIngale** | • **Modeling: CATIA V5.**<br>• **Analysis: ANSYS** | • **By comparing different materials like Al alloys, high strength carbon fiber and steel, authors suggested high strength carbon fiber for diesel engine connecting rod.** |
| **8** | **8** | **GantaKrishnarjuna Reddy and BaddeNaik** | • **Modeling: SOLID WORKS 2016**<br>• **Static structural analysis: ANSYS 14.5.** | • **Materials with low stress values and low cost are favored for connecting rod development.** |
| **9** | **9** | **DipaleeBedse** | • **Modeling: CATIA.**<br>• **FEA was done by using HYPER MESH and FEMFAT.** | • **Connecting rod's fatigue life can be improved by small changes in the geometry. Here authors modified neck radius thickness.** |
| **10** | **10** | **Vikas et al.** | • **Modeling: SOLID WORKS – 2016 Analysis: ANSYS 16.2** | • **Authors observed that the material can be removed from the portions where stress value is minimum.**<br>• **Suggested beryllium alloy connecting rod by comparing different data.** |
| **11** | **11** | **SatishWable and DattatrayGalhe** | • **Modeling: CATIA**<br>• **Analysis: ANSYS 14.** | • **Aluminium MMC connecting rod isshowing less stresses and light in weight than carbon steel connecting rod.** |
| **12** | **12** | **Harshit Mishra and KuldeepNarwat** | • **Modeling: SOLID WORKS 2014**<br>• **Analysis: ANSYS 14.5.** | • **Analysed Al alloy, Grey CI, Stainless Steel Connecting rods and models was safe during analysis by providing factor of safety value more than 1.** |

| | | | | |
|---|---|---|---|---|
| **13** | **13** | **Vijaya et al.** | **Modeling: CREO PARAMETRIC 2.0 Analysis: ANSYS** | **Peak stress for Ti and chrome steel is within the acceptable stress limit.** |
| **14** | **14** | **Lingaraj et al.** | **Modeling: SOLID EDGE Analysis: ANSYS** | **The mass of the connecting rod is reduced by 4% based on shape optimization.** |
| **15** | **15** | **Mithilesh et al.** | **Modeling: INVENTOR Analysis: ANSYS 15.0.** | **Authors suggested Carbon fiber can be used for manufacturing connecting rod but carbon fiber is expensive.** |
| **16** | **16** | **SHIVA PRASAD KERALAPURA BASAVARAJU** | **ANSYS** | **Forged Steel is better material than Al alloy.** |

The weight and size of the connecting rod influences the performance of a vehicle. Changing the connecting rod material and changing the design of the connecting rod will result in weight and stress variations induced therein.

## III. MODELLING

Model of the connecting rod was created with the help of INVENTOR software. Fig. 1 shows the 3Dmodel of the connecting rod.

Figure 1. Connecting rod model

## IV. FINITE ELEMENT ANALYSIS

Finite element analysis was done by using ANSYS. The prepared 3D model of connecting rod is imported in ANSYS for analysis. Materials used for the analysis are Titanium alloy, AISI 4340 and Aluminium alloy. Properties of materials are given in the Table II.

Table- 2 Material Properties

| Material | Young's Modulus (GPa) | Poison's Ratio | Density (kg/m$^3$) | Tensile Yield Strength (MPa) |
|---|---|---|---|---|
| **AISI 4340** | **205** | **0.29** | **7850** | **710** |
| **Al alloy** | **71** | **0.33** | **2770** | **280** |
| **Ti alloy** | **113.8** | **0.34** | **4430** | **880** |

*4.1 Meshed model of connecting rod -*

By applying boundary conditions model was analysed for the four materials. Connecting rod after applying mesh is shown in the fig 2.

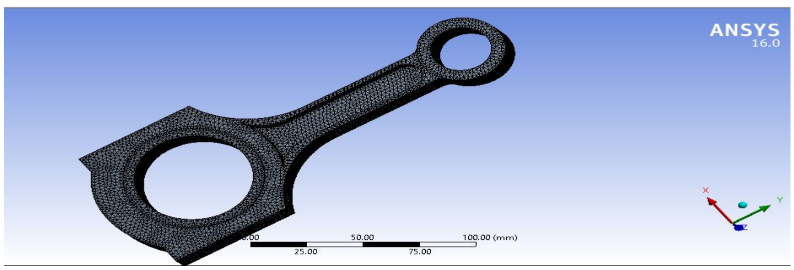



Figure 2. Meshed model

Fixed support: Big end

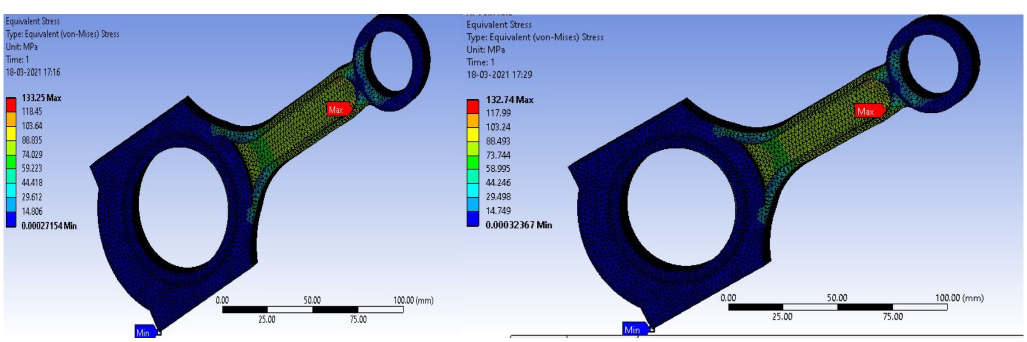
Bearing load of 14kN: Small end

Number of nodes in the mesh: 222323

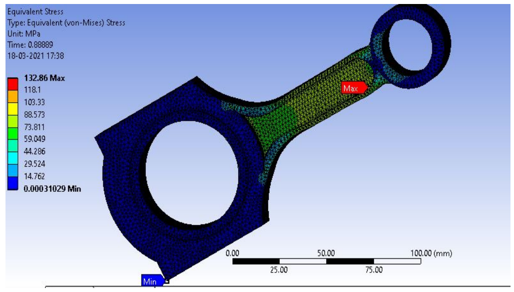
Number of elements in the mesh: 131118

*4.2 Stresses induced in the model -*

For the analysis 14kN of bearing load is applied at small end of the model keeping big end fixed. Induced stresses are shown in Fig. 3.



(a) (b)

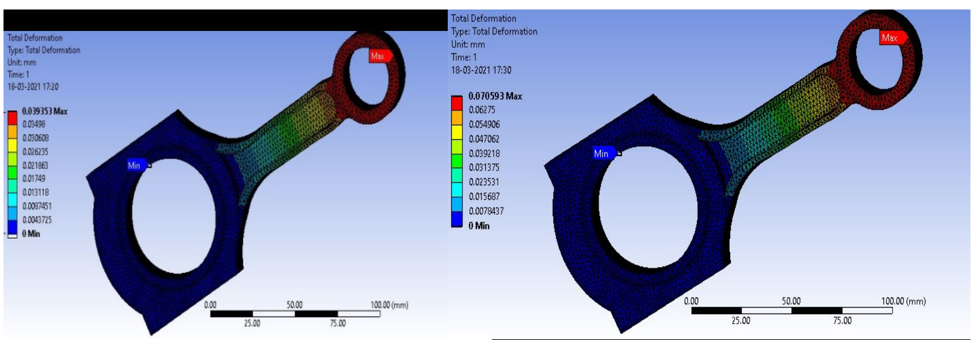



(c)

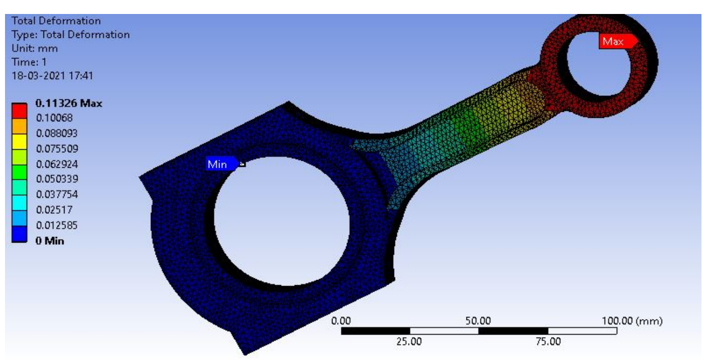
Figure 3. Von mises stresses induced in (a) AISI4340 (b) Ti alloy (c) Al alloy

*4.3 Deformation of the model -*

Total deformation of the connecting rod is determined from static structural analysis. Deformation of connecting rod is shown in Fig. 4.




(a) (b)

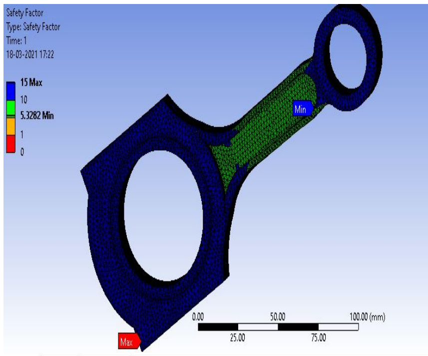


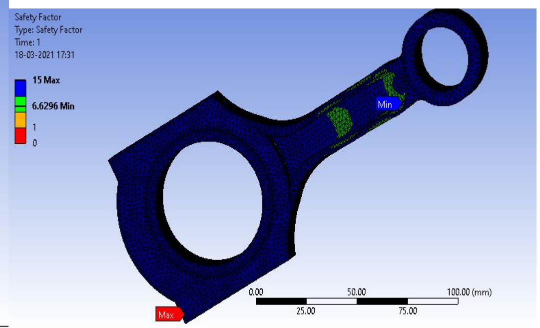

(c)

Figure 4. Total deformation in (a) AISI4340 (b) Ti alloy (c) Al alloy

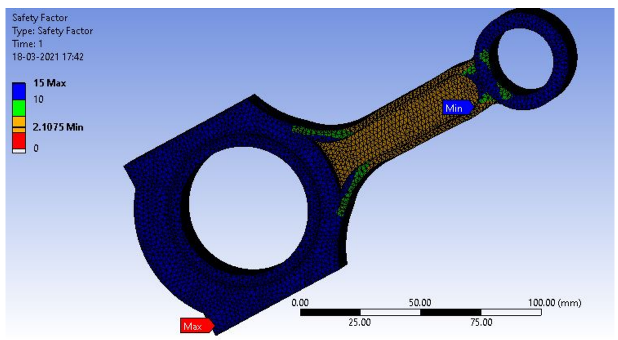
*4.4 Safety Factor of the model (Static)-*

Safety factor of the connecting rod is determined from static structural analysis. FOS of connecting rod is shown in Fig. 5.




(a) (b)

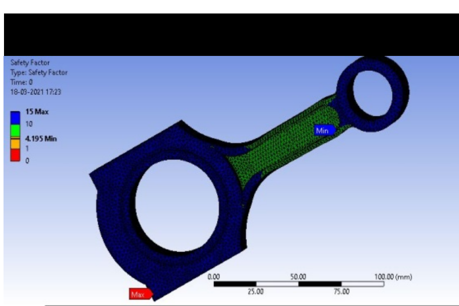


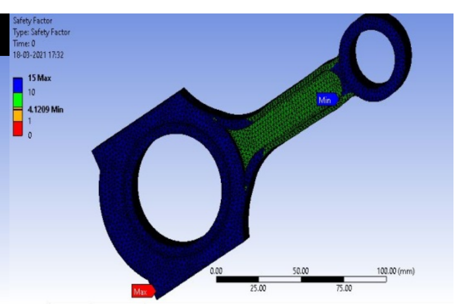

(c)

Figure 5. Safety Factor (Static) in (a) AISI4340 (b) Ti alloy (c) Al alloy

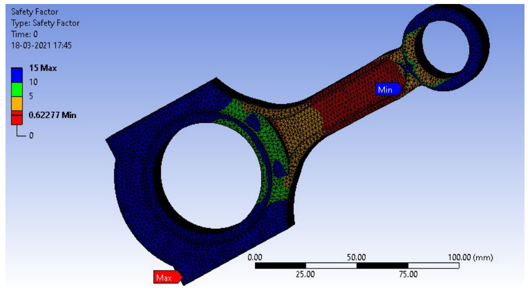
*4.5 Safety Factor of the model-*

Safety Factor of the model can be determined by using Fatigue Tool of ANSYS. Safety Factor of the connecting rod is shown in the Fig. 6.




(a) (b)




(c)

Figure 6. Safety Factor in (a) AISI4340 (b) Ti alloy (c) Al alloy

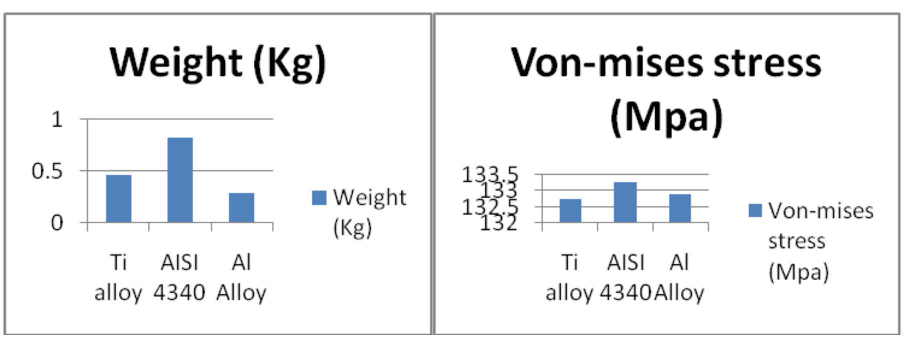
*4.6 Comparison of FEA results and Discussion -*

Results obtained from the analysis of different materials are listed in Table 3.

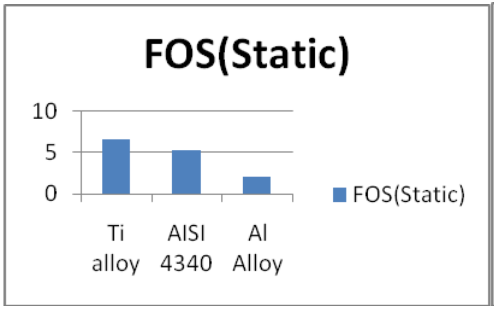
Table- 3 FEA results for different materials

| 14000N bearing load at small end | | | | | |
|---|---|---|---|---|---|
| **Material** | **Weight (Kg)** | **Von-Mises Stress (Mpa)** | **FOS (Static)** | **Total deformation(mm)** | **Safety Factor(Fatigue)** |
| **Ti alloy** | **0.464** | **132.74** | **6.6** | **0.071** | **4.12E+00** |
| **AISI4340** | **0.822** | **133.25** | **5.3** | **0.039** | **4.20E+00** |
| **Al Alloy** | **0.29** | **132.86** | **2.1** | **0.11** | **6.20E-01** |

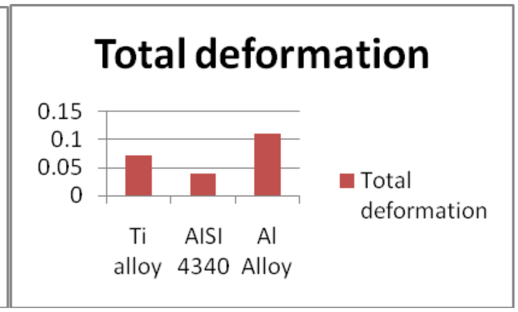
Finite element analysis results obtained for different materials are plotted in the Fig. 6.



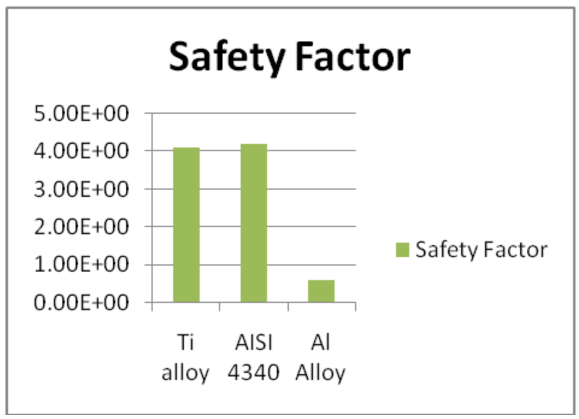

(a) (b)




(c)




(d)




(e) Safety Factor

Figure 6. FEA results plotted for (a) Weight (b) Von mises stress (c) FOS (Static) (d) Total deformation (e) Safety factor

Results obtained from the analysis were tabulated in Table 3 and the plotted results are shown in the Fig 6. By comparing the results we can say thatAl alloy has lowest weight and highest total deformation than other materials for same loading conditions.Factor of Safety is maximum for Ti alloy.From the Fig 6(e), Ti alloy and AISI 4340 showing high factor of safety (fatigue) for the same loading conditions.

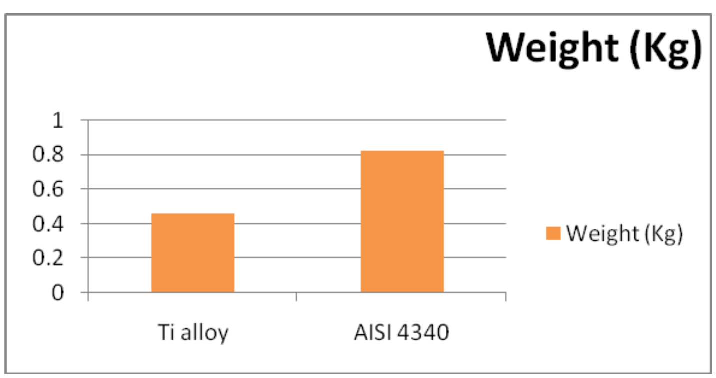



Figure 7. Weight comparison of Ti alloy and AISI 4340 connecting rod

## V. CONCLUSIONS

Analysis was conducted to understand the impact of selecting material in connecting rod design.

Based on the analysis for different material connecting rods,

- Maximum von mises stresses observed near the small end of the connecting rod.
- Minimum Safety Factor is near the small end of the connecting rod.
- Total deformation maximum at small end of the connecting rod.
- Ti alloy and AISI 4340 showing high factor of safety (fatigue) for the same loading conditions but weight of Ti alloy connecting rod is less than the AISI 4340 connecting rod and Safety Factor (fatigue) for Ti alloy and AISI 4340 are nearly equal. But cost per kg of the Ti alloy is more than the cost of AISI 4340.

## REFERENCES


[1] Adnan Ali Haider, Akash Kumar, AjinkyaChowdhury, Moin Khan, P. Suresh, “Design and Structural Analysis of Connecting Rod”, International Research Journal of Engineering and Technology (IRJET), Volume: 05, Issue: 05, May-2018.

[2] NilamPranjalPatilDhande, PundlikPatil, R.Y. Patil, “Analysis of Connecting Rod for Weight Reduction in Case of a CI engine”, IJEDR, Volume 6, Issue 1, 2018.

[3] VinayakChumbre, VinayakKallannavar, AnilkumarShirahatti, RatanPatil, Shirish M. Kerur, “Design and Comparative Analysis of Connecting Rod using Finite Element Analysis”, International Journal for Research in Applied Science & Engineering Technology (IJRASET),Volume 6, Issue IV, April 2018.

[4] Nilam P. Patil, Pundlik N. Patil, Raghunath Y. Patil, “ Design Analysis of Connecting Rod for Weight Reduction in Case of a CI Engine – A Review”, International Journal of Engineering Sciences & Research Technology, September- 2017.

[5] Magesh Kumar, Prof. Ankush K Biradar, “Design, Analysis and Optimization of Connecting Rod”, International Journal of Innovative Research in Science,Engineering and Technology, Volume 6, Special Issue 11, May 2017.

[6] Mansi S. Satbhai, P.S. Talmale, “Review on Design and Analysis of Two Wheeler Connecting Rod”, International Research Journal of Engineering and Technology, Volume: 04, Issue: 09, Sep -2017.

[7] Dr. N. A. Wankhade, SuchitaIngale, “Review on Design and Analysis of Connecting Rod Using DifferentMaterial”, International Journal of Engineering Science and Computing, Volume 7, May 2017.

[8] GantaKrishnarjuna Reddy, BaddeNaikVadithe, “Design and Analysis ofConnecting Rod”, IJRAET,Volume 6, Issue 1, MAY 2017.

[9] Dipalee S. Bedse, “Design Evaluation of Connecting Rod”, International Journal of Recent Engineering Research and Development, Volume 02, Issue 07,July 2017, PP. 203-213.

[10] Vikas Singh, Sumit kr. Verma, Harish Chandra Ray, Vishal kr. Bharti, AbhineshBhaskar – “Design and Analysis of Connecting Rod forDifferent Material Using Ansys Workbench 16.2”, IJRASET, Volume 5, Issue V, May 2017.

[11] SathishWable, Dattatray S. Galhe, “Analysis of Stresses Induced in Connecting Rod of Two Wheeler Engine”, IJARIIE , Volume2, Issue-3, 2016.

[12] Harshit Mishra, Prof. KuldeepNarwat, “Static and Modal Analysis of Connecting Rod”

[13] S.Vijaya Kumar, S.K. Thenadayaal, V.P. Vasanth, V. Vasanthakumar, “Design and Analysis of Two WheelerConnecting Rod”, International Journal of Innovative Research in Science,Engineering and Technology,Volume 4, Special Issue 6, May 2015.

[14] Lingaraj K. Ritti, Pavan Kumar, AmbarishM ,“ Size and Shape Optimization ofaTwo Wheeler Connecting Rod byStructural Analysis”, International Journal of Analytical, Experimental and Finite Element Analysis, Volume 2, Issue 1, March 2015.

*[15]* Mithilesh K Lade, Ritesh P Harode, DeepaliBankar Lade, “Static Load Analysis of Carbon Fiber Connecting Rod”,International Journal of Research in Advent Technology, Volume 3, No.9, September 2015.

[16] CAE ANALYSIS ON A FORD ECOBOOST MUSTANG CONNECTING RODFOR FORGED STEEL, ALUMINUM 7075 byShiva Prasad KeralapuraBasavarajuPresented to the Faculty of the Graduate School of The University of Texas at Arlington

[17] Boini. Sriharsha, P. SudhakarRao, “Design Considerations for Connecting Rod”,International Journal of Engineering and Advanced Technology (IJEAT), Volume-9 Issue-3, February 2020

[18] P.S. Rao, P.K. Jain, D.K. Dwivedi, “Electro Chemical Honing (Ech) Of External Cylindrical Surfaces- An Innovative Step”, Daaam International Vienna Publishers, 09 CHAPTER, DAAAM International Scientific Book (2015), 097-116.

[19] P.S. Rao, P.K. Jain, D.K. Dwivedi, “Electro Chemical Honing (Ech)- A New Paradigm In Hybrid Machining Process”, Daaam International Vienna Publishers, 26 CHAPTER, DAAAM International Scientific Book (2016), 287-306.

[20] P.S. Rao, P.K. Jain, D.K. Dwivedi, “Electro Chemical Honing (ECH) of External Cylindrical Surfaces of Titanium Alloy”, Elsevier Publishers, J. of Procedia engineering, 100 (2015), 936-945.

[21] P.SudhakarRao, P.K. Jain, D.K. Dwivedi, "Precision Finishing of External Cylindrical Surfaces of EN8 Steel by Electro Chemical Honing (ECH) Process using OFAT Technique", Elsevier Publishers, J. of Materials Today Proceedings, 2 (2015), 3220-3229.