Analysis and Optimization of Connecting Rod used in Heavy Commercial Vehicles

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Abstract- The Connecting rod transmits the piston load to the crank causing the latter to turn, thus converting the reciprocating motion of the piston into a rotary motion of the crankshaft. Connecting rods are subjected to forces generated by mass and fuel combustion. Connecting rod is modeled using CATIA software and FE analysis is carried out using ANSYS Soft ware. Load distribution plays important role in fatigue life of the structure. This paper describes the design and finite element analysis of alternating material for connecting rod of heavy vehicle. The design and finite element analysis is performed by using computer aided design (CAD) software. The objective is to design and analysis the structural stress distribution of connecting rod at the real time condition during process. In the present work, an attempt has been made to investigate the suitable material which is lighter than steel and has fatigue strength, Yield strength and density properties. The optimization is carried out to reduce the stress concentration and weight of the connecting rod for Steel 4340, 42CrMo4, Al 7075-T7 which keeps the upspring mass low thereby increasing the stability of the vehicle. With using computer, aided design (CAD), CATIA V5 software the structural model of connecting rod is developed. The suitable material for the connecting rod is 42CrMo4, Al 7075-T7 and all the values obtained from the analysis are less than their allowable values. Hence, the connecting rod design is safe based on the strength and rigidity criteria. By identifying the true design features, the extended service life and long term, stability is assured.

Keywords: Analysis, Connecting rod, FEA, Static, Optimization, etc.

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1. 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 aluminum. 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. A connecting rod consists of a pin-end, a shank section, and a crank-end. Pin-end and crank-end pinholes at the upper and lower ends are machined to permit accurate fitting of bearings. These holes must be parallel. The upper end of the connecting rod is connected to the piston by the piston pin. If the piston pin is locked in the piston pin bosses or if it floats in the piston and the connecting rod, the upper hole of the connecting rod will have a solid bearing (bushing) of Bronze or a similar material. As the lower end of the connecting rod revolves with the crankshaft, the upper End is forced to turn back and forth on the piston pin. Although this movement is slight hence the bushing is necessary because of the high pressure and temperatures. The lower hole in the connecting rod is split to permit it to be clamped around the crankshaft. The bottom part, or cap, is made of the same material as the rod and is attached by two bolts. The surface that bears on the crankshaft is generally a bearing material in the form of a separate split shell. The two parts of the bearing are positioned in the rod and cap by dowel pins, projections, or short brass screws. Split bearings may be of the precision or semi precision type. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight. The function of connecting rod is to transmit the thrust of the piston to the crankshaft. Role of connecting rod in the conversion of reciprocating motion into rotary motion. A four-stroke engine is the most common type. The four strokes are intake, compression, power, and exhaust. Each stroke requires approximately 180 degrees of crankshaft rotation, so the complete cycle would take 720 degrees. Each stroke plays a very important role in the combustion process. In the intake cycle, while the piston moves downward, one of the valves open. This creates a vacuum, and an air-fuel mixture is sucked into the chamber. During the second stroke compression occurs. In compression, both valves are closed, and the piston moves upward and thus creates a pressure on the piston. The next stroke is power. During this process, the compressed air-fuel mixture is ignited with a spark, causing a tremendous pressure as the fuel burns. The forces exerted by piston transmitted through the connecting rod moves the crankshaft. Finally, the exhaust stroke occurs. In this stroke, the exhaust valve opens, as the piston moves back upwards, it forces all the air out of the chamber and thus which completes the cycle of crankshaft

2. OBJECTIVE

In automotive industries, to achieve reduced fuel consumption as well as greenhouse gas emission is a current issue of utmost importance. To reduce automobile weight and improve fuel efficiency, the auto industry has dramatically increased the use of aluminium in light vehicles in recent years. Aluminium alloy based metal matrix composites (MMCs) with ceramic particulate reinforcement have shown great promise for such applications. These materials having a lower density and higher thermal

conductivity as compared to the conventionally used. Weight reduction of up to 50 – 60 % in the systems. Moreover, these advanced materials have the potential to perform better under severe service conditions like higher speed, higher load etc.
The objective of the present work is to design and analysis of connecting rod made of Aluminium Alloy. Steel materials are used to design the connecting rod. In this project the material (Forged steel) of connecting rod replaced with Aluminium Alloy. Connecting rod was created in CATIA V5 R20. Model is imported in ANSYS 17.0 for analysis. After analysis a comparison is made between existing steel connecting rod viz., A Aluminium Alloy in terms of weight, factor of safety, stiffens, deformation and stress.

3. LITERATURE REVIEW

1] Design of connecting rod for heavy duty Applications produced by different Processes for enhanced fatigue life, Tony George Thomas1, S. Srikari2, M. L. J Suman3 1-M.Sc.[Engg.] Student, 2-Professor, Department of AAE, 3-Senior Lecturer, Department of MME M.S.Ramaiah School of Advanced Studies, Bangalore 560 058.
The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modeled using CATIA V5 R19 software and to that model, analysis is carried out by using ANSYS 13.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz... Forged steel. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two wheeler piston were done in ANSYS software. Forged steel has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With Fatigue analysis we can determine the lifetime of the connecting rod.
2] Design And Analysis of Connecting Rod Using Forged steel, Leela Krishna Vegi1, Venu Gopal Vegi2 Department of Mechanical Engineering Jawaharlal Nehru Technological University, Kakinada, AP, INDIA, International Journal of Scientific & Engineering Research, Volume 4, Issue 6, June-2013 2081 ISSN 2229-5518.
The connecting rod forms an integral part of an internal combustion engine. Different types of loads while undergoing its operation act upon the connecting rod. One of the main reasons contributing to its failure is fatigue. The aim of this study is to redesign the connecting rod by incorporating the manufacturing process effects into the analysis and obtain a better fatigue performance. The redesign is aimed at reducing the weight of the component. Heavy duty application’s connecting rod was selected for the study. The analytically calculated loads acting on the small end of connecting rod were used to carry out the static analysis using ANSYS. A stress concentration was observed near the transition between small end and shank. A piston-crank-connecting rod assembly was simulated for one complete cycle (0.02 seconds) using ADAMS to obtain the loads acting on small end of connecting rod. This force vs. time graph
was converted into an equivalent stress vs. time graph. This stress vs. time graph was used as loading graph for fe-safe. The fatigue life calculated using fe-safe is 6.94×106 cycles and these results are validated with the help of Palmgren-Miner linear damage rule.
3] Analysis and optimization of Connecting rod using alfasic Composites, Kuldeep B1, Arun L.R2, Mohammed Faheem3 P.G. Scholar, Department of Mechanical Engineering, The Oxford college of Engineering , Karnataka, India1,3 Associate Professor, Department of Mechanical Engineering, The Oxford college of Engineering, Karnataka, India, International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 6, June 2013
Connecting rod is the intermediate link between the piston and the crank. And is responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are finding its application in connecting rod. In this work connecting rod is replaced by aluminium based composite
material reinforced with silicon carbide and fly ash. And it also describes the modelling and analysis of connecting rod. FEA analysis was carried out by considering two materials. The parameters like von misses stress, von misses strain and displacement were obtained from ANSYS software. Compared to the former material the new material found to have less weight and better stiffness. It resulted in reduction of 43.48% of weight, with 75% reduction in
displacement.
4] Modeling and Analysis of Two Wheeler Connecting Rod, K. Sudershn Kumar1, Dr. K. Tirupathi Reddy2, Syed Altaf Hussain3 *(PG student, School of Mechanical Engineering RGM College of Engg. & Technology, Nandyal-518501, India, International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.5, Sep-Oct. 2012 pp-3367-3371 ISSN: 2249-6645
The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. Existing connecting rod is manufactured by using Carbon steel. This paper describes modeling and analysis of connecting rod. In this project connecting rod is replaced by Aluminum reinforced with Boron carbide for Suzuki GS150R motorbike. A 2D drawing is drafted from the calculations. A parametric model of connecting rod is modelled using PRO-E 4.0 software. Analysis is carried out by using ANSYS software.
5) Design And Analysis Of Connecting Rod Using Aluminium Alloy 7068 T6, T6511, Mohamed Abdusalam Hussin, et al International Journal of Mechanical Engineering and Technology (IJMET), ISSN 0976 – 6340(Print),
ISSN 0976 – 6359(Online), Volume 5, Issue 10, October (2014), pp. 57-69.
The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using

Forged steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modeled using SOLID WORK software and to that model, analysis is carried out by using ANSYS 15.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz... Aluminium Alloy. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two wheeler piston were done in ANSYS software. Aluminium Alloy has more factor of safety, reduce the weight, reduce the stress and stiffer than other material like Forged Steel. With Fatigue analysis, we can determine the lifetime of the connecting rod.

4. Methodology

The materials selection chart is a very useful tool in comparing a large number of materials at the concept design phase which could be reflected the fundamental relationships among particular material properties and be used to find out a range of materials suitable for a particular application. The main purpose of the present work is to selection of best candidate material for brake disc application and in order to analyse the thermal characteristics of disk brakes, thermal deformation analysis and thermal stress analysis due to heat transfer was carried out through the finite element analysis.

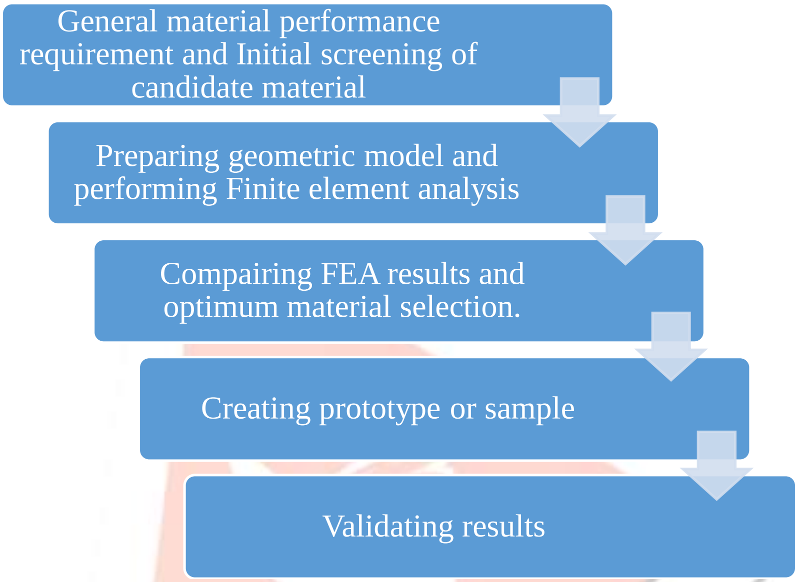


Figure 1: Flow chart of material selection method

5. DESIGN OF THE CONECTING ROD

The first step is development of CAD model according to geometric specifications followed by selection of material. Finite element analysis is done using simulation software for different materials. Deformation, Von Mises stress are investigated by static structural analysis.

5.1 Geometrical Modelling

The model is constructed by using CATIAV5R21, the explode view of the model as shown in Figure

- **Configuration of the engine to which the connecting rod belongs**

Crankshaft radius	48.5 mm
Connecting rod length	141.014 mm
Piston diameter	86 mm
Mass of the piston assembly	0.434 kg
Mass of the connecting rod	0.439 kg
Izz about the centre of gravity	0.00144 kg m
Distance of C.G. from crank end centre	36.44 mm
Maximum gas pressure	37.29 Bar

- **Material Properties:**

	Steel 4340	Aluminium 7075-t651	42crmo4
Young's Modules	205	71.7	210
Poisson's Ratio	0.29	0.33	0.30
Density	7850	2810	7830
Yield strength	760	503	1034
Ultimate strength	1110	572	1200

- **Boundary Conditions:**

The normal pressure on the contact surface is given by:

P = P cos Θ

The load is distributed over an angle of 180⁰. The total resultant load is given by:

$P_t = \int_{-p/2}^{p/2} P_0(\cos^2\Theta)\, r\, t\, d\theta = P_0 r\, t\, \pi/2$

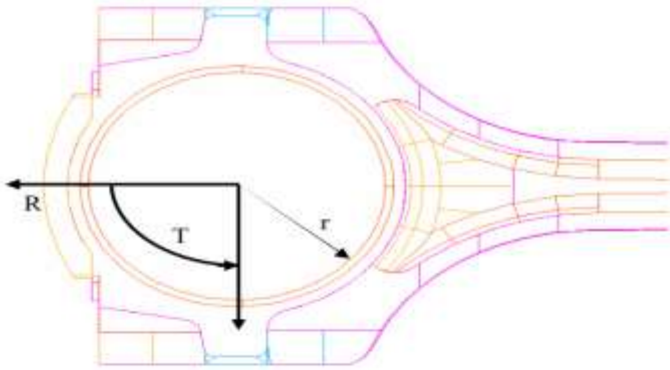


Figure 1.1: Polar co-ordinate system R, Q, Z used. 't' (not shown) is the thickness of the contact surface normal to the plane of paper.

Figure 1.1 describes r, t and Q. The normal pressure constant Po is, therefore, given by:

$$P_0 = \frac{P_t}{(r\, t\, \frac{\pi}{2})}$$

The tensile load acting on the connecting rod, Pt, can be obtained using the expression from the force analysis of the slider crank mechanism.

For compressive loading of the connecting rod, the crank and the piston pin ends are assumed to have a uniformly distributed loading through 120º contact surface (Webster et al. 1983).

The normal pressure is given by:

P = P0

The total resultant load is given by:

$P_c = \int_{-p/3}^{p/3} P_0(\cos\Theta)\, r\, t\, d\theta = P_0 r\, t\sqrt{3}$

The normal pressure constant is then given by:

$$P_0 = \frac{P_c}{(r\, t\sqrt{3})}$$

In this study four finite element models were analysed. FEA for both tensile and compressive loads were conducted. Two cases were analysed for each case, one with load applied at the crank end and restrained at the piston pin end, and the other with load applied at the piston pin end and restrained at the crank end. In the analysis carried out, the axial load was 21.682 kN in both tension and compression. The pressure constants for 21.682 kN are as follows:

Compressive Loading:

1. Crank End: Po = 21682/ (24 x 17.056 x $\sqrt{3}$) = 30.50 MPa

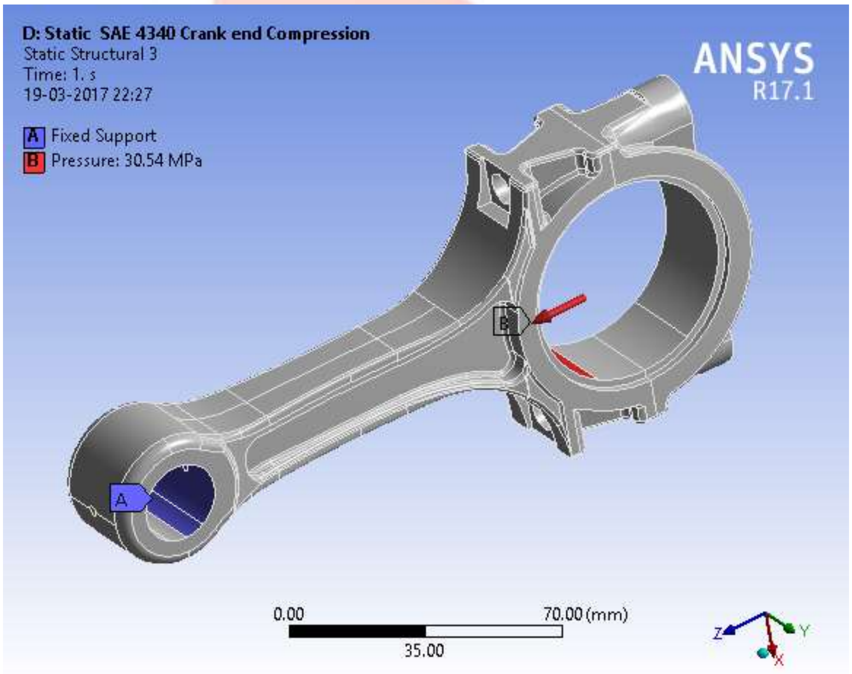


Figure 3: Static analysis boundary condition (Case: Compressive load at Crank end)

2. Piston pin End: Po = 21682/ (11.97 x 18.402 x $\sqrt{3}$) = 56.68 MPa

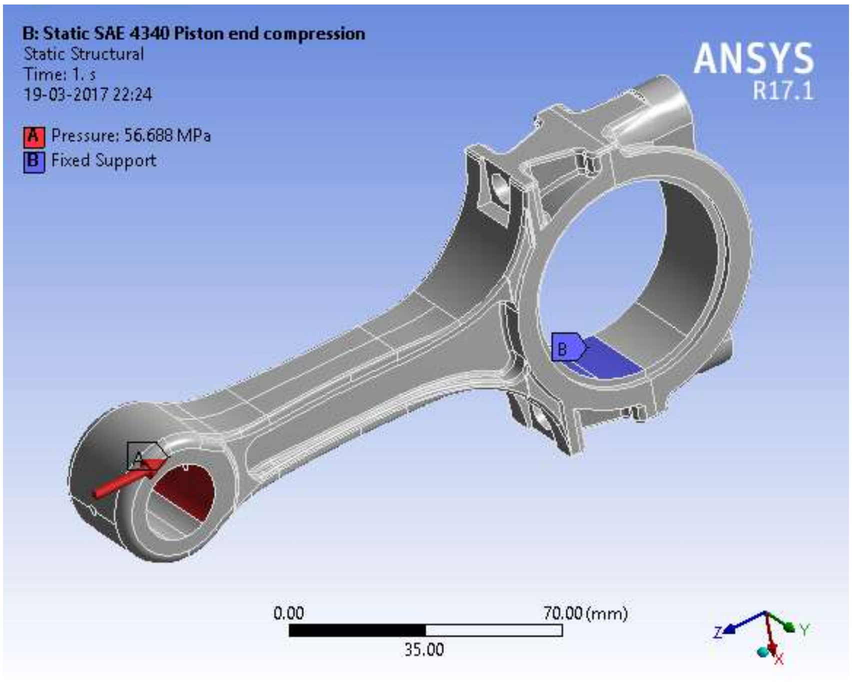


Figure 4: Static analysis boundary condition (Case: Compressive load at Piston end)

Tensile Loading:

1. Crank End: Po = 21682/ [24 x 17.056 x (p/2)] = 33.63 MPa

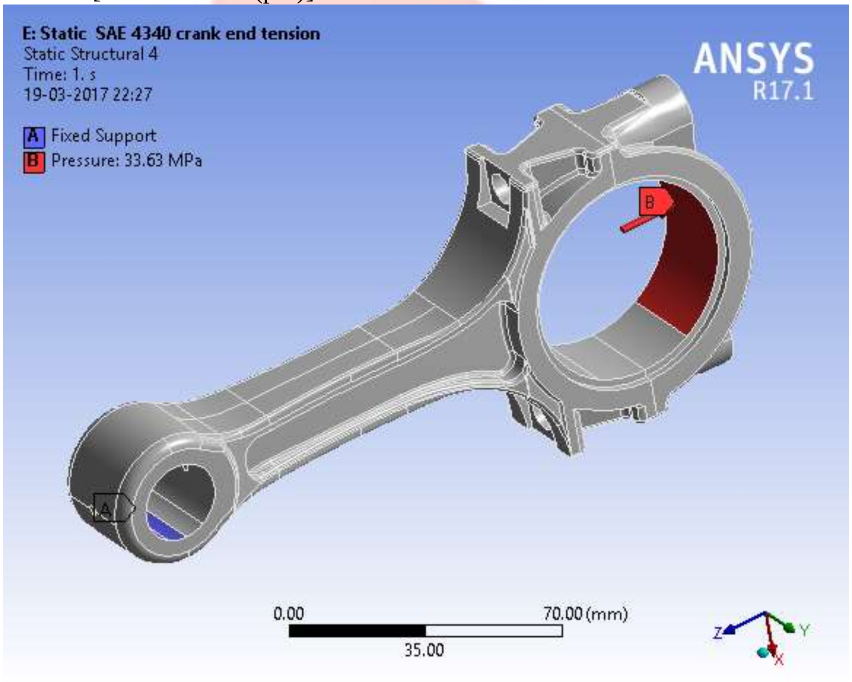


Figure 5: Static analysis boundary condition (Case: Tensile load at Crank end)

2. Piston pin End: Po = 21682/ [11.97 x 18.402 x (p/2)] = 62.50 MPa

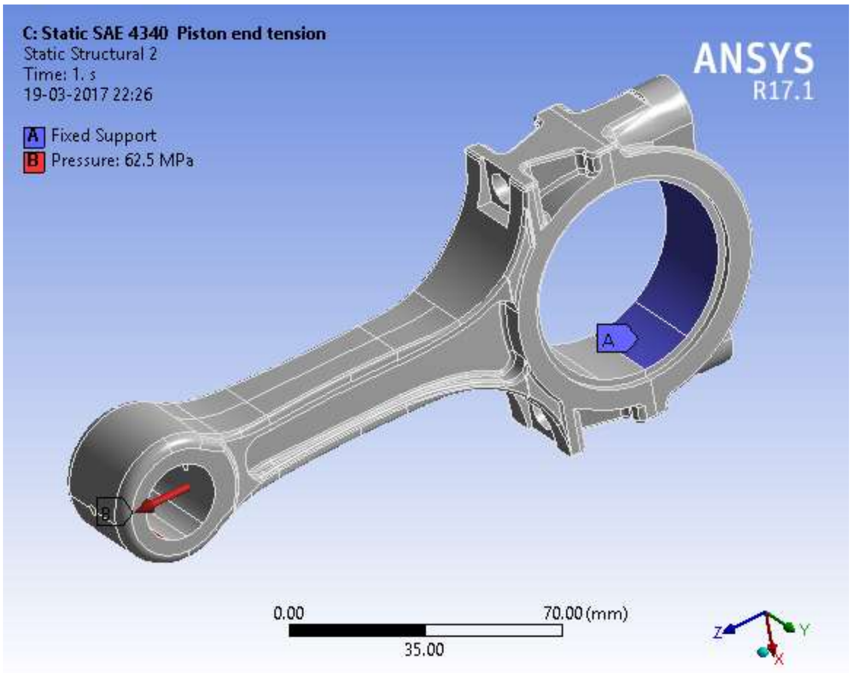


Figure 5: Static analysis boundary condition (Case: Tensile load at Piston end)

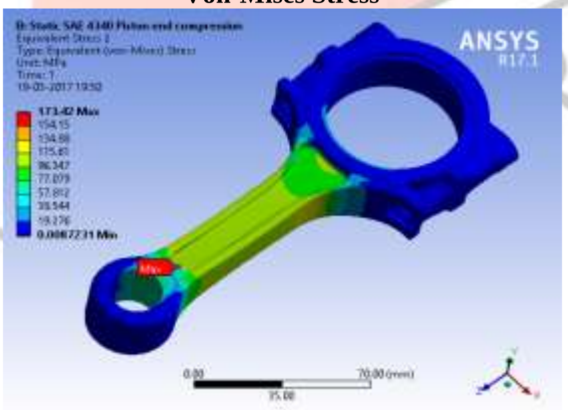
Since the analysis is linear elastic, for static analysis the stress, displacement and strain are proportional to the magnitude of the load. Therefore, the obtained results from FEA readily apply to other elastic load cases by using proportional scaling factor.

6. RESULT OF STATIC ANALYSIS

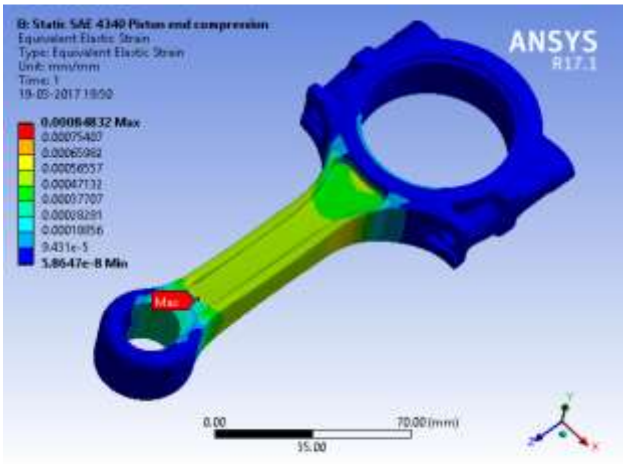
Material 1: SAE 4340

Case 1: Piston End Compression

Von-Mises Stress



Von-Mises Strain



Deformation

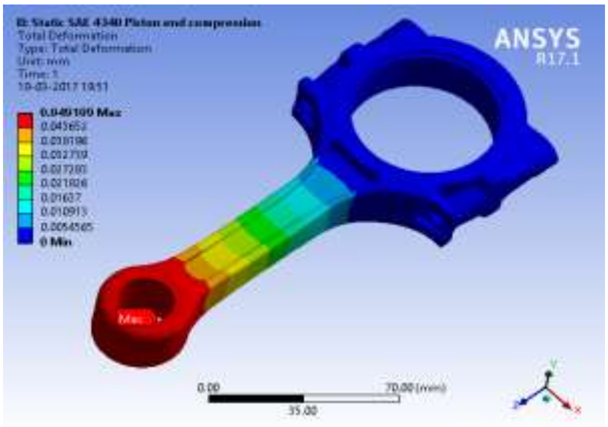
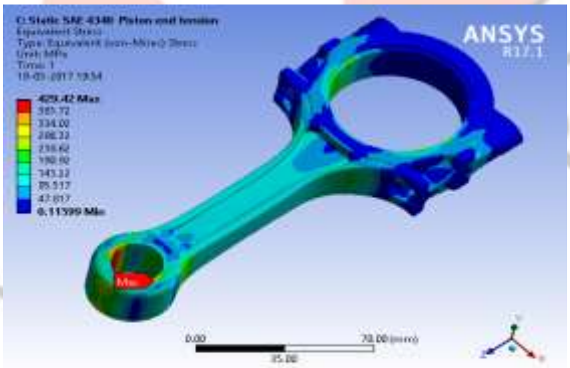


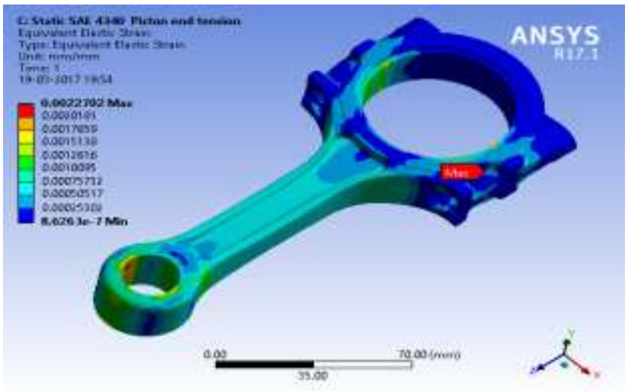
Figure 6: Static analysis result of case 1 for material SAE 4340

Case 2: Piston End Tension Load

Von-Mises Stress



Von-Mises Strain



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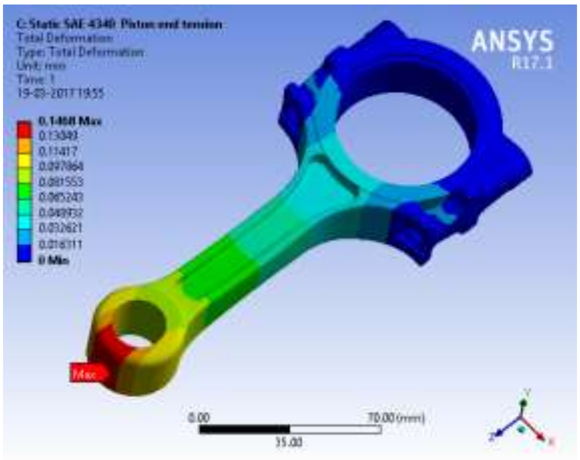
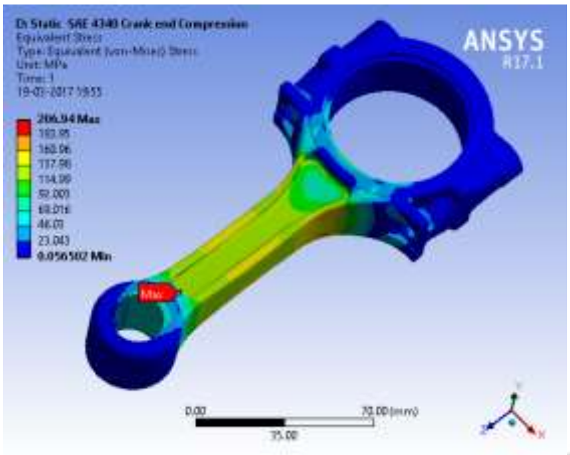


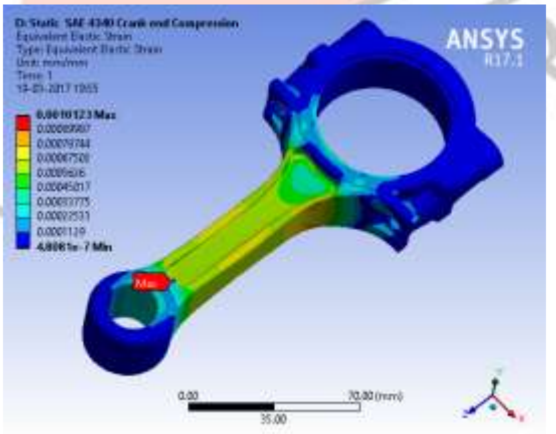
Figure 7: Static analysis result of case 2 for material SAE 4340

Case 3: Crank End Compression Load

Von-Mises Stress



Von-Mises Strain



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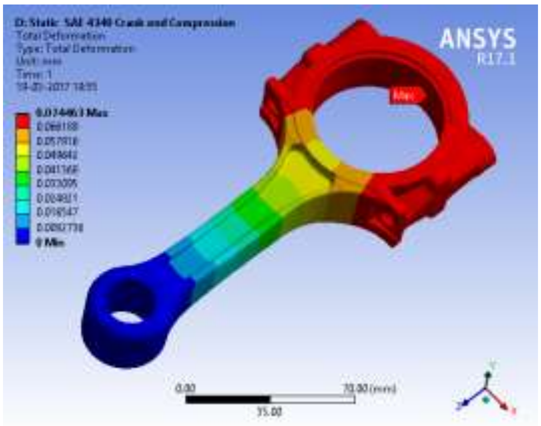
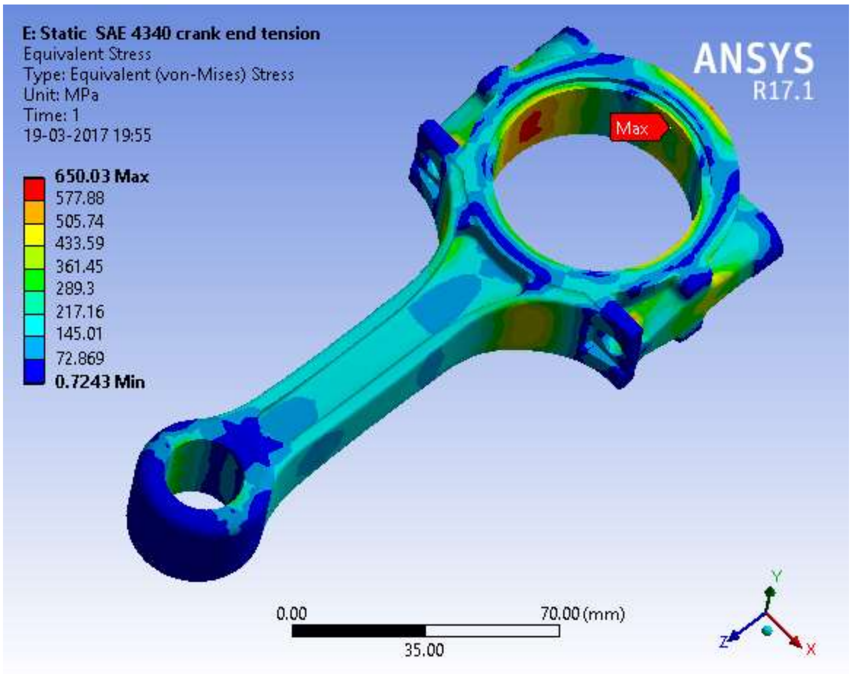


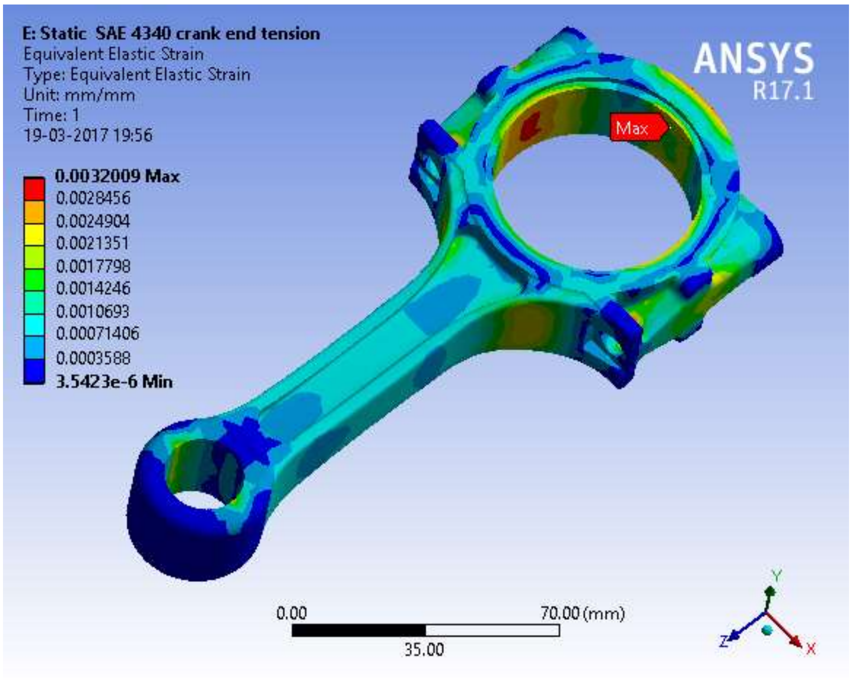
Figure 7: Static analysis result of case 3 for material SAE 4340

Case 4: Piston End Tension Load

Von-Mises Stress



Von-Mises Strain



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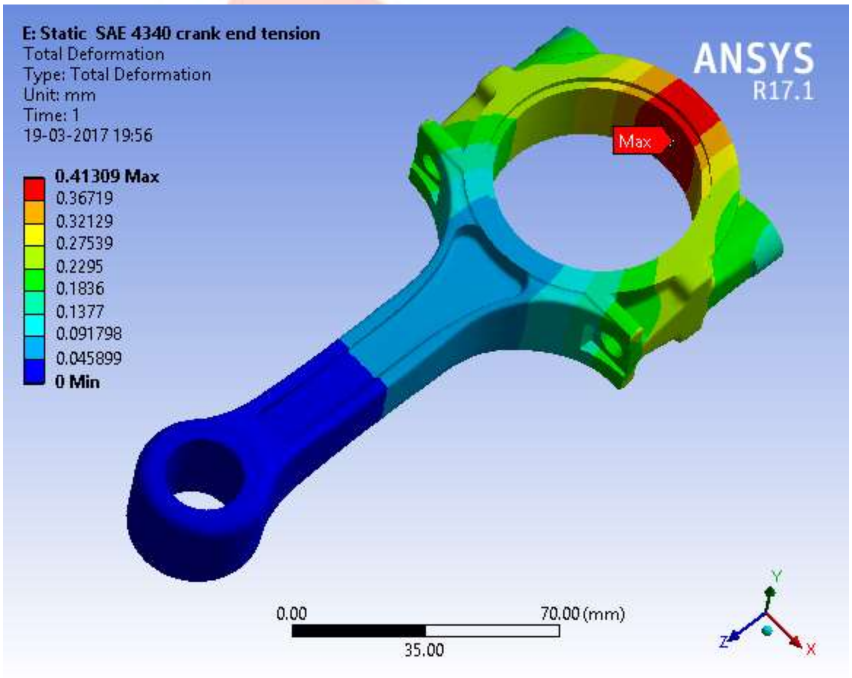
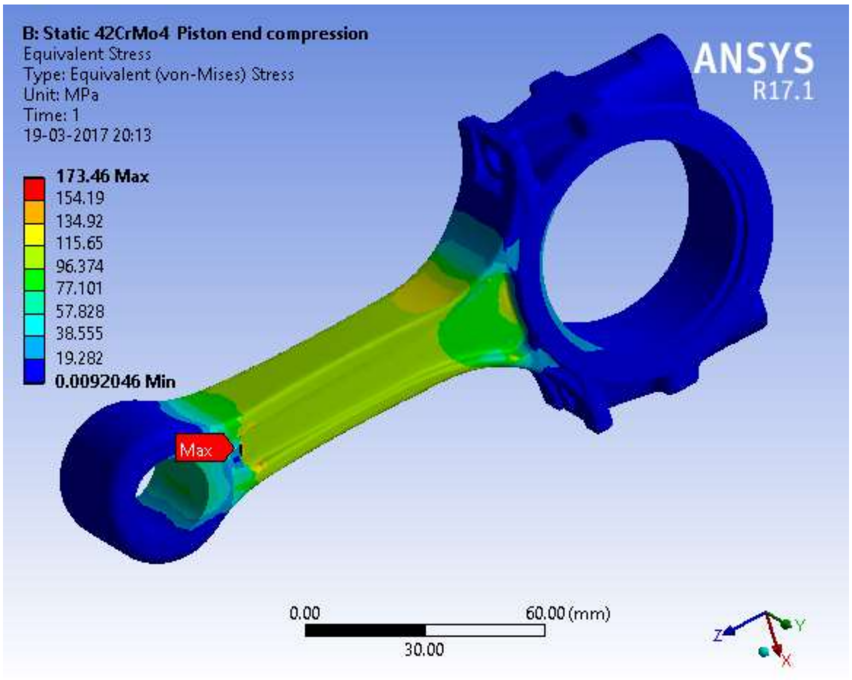


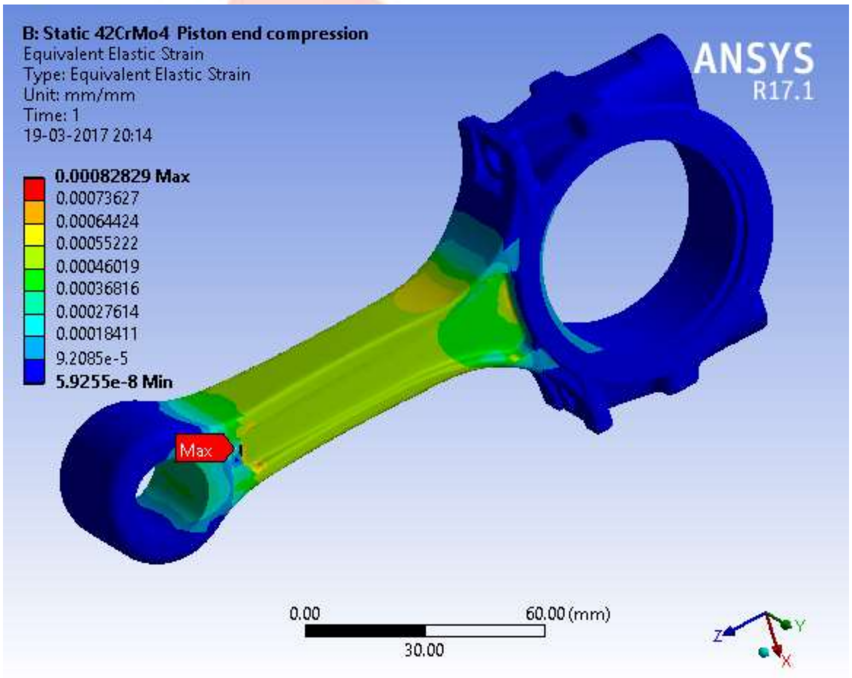
Figure 8: Static analysis result of case 4 for material SAE 4340

Material 2: 42CrMo4
Case 1: Piston End Compression

Von-Mises Stress



Von-Mises Strain



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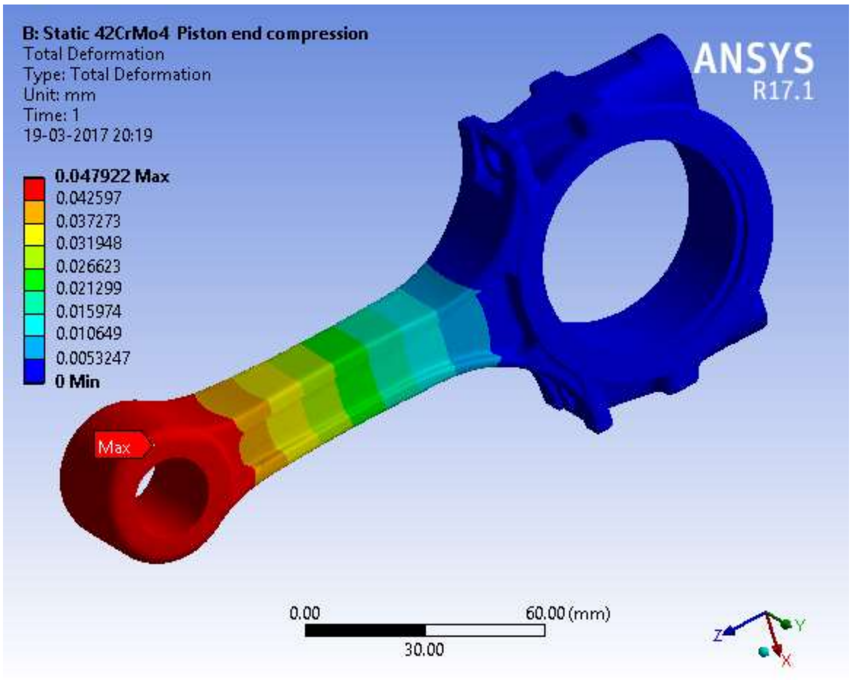
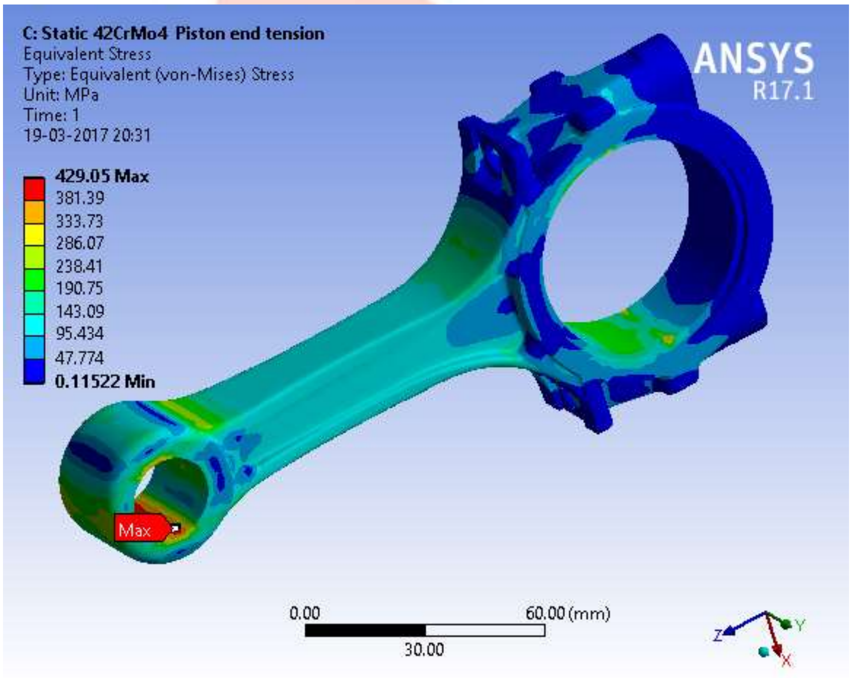


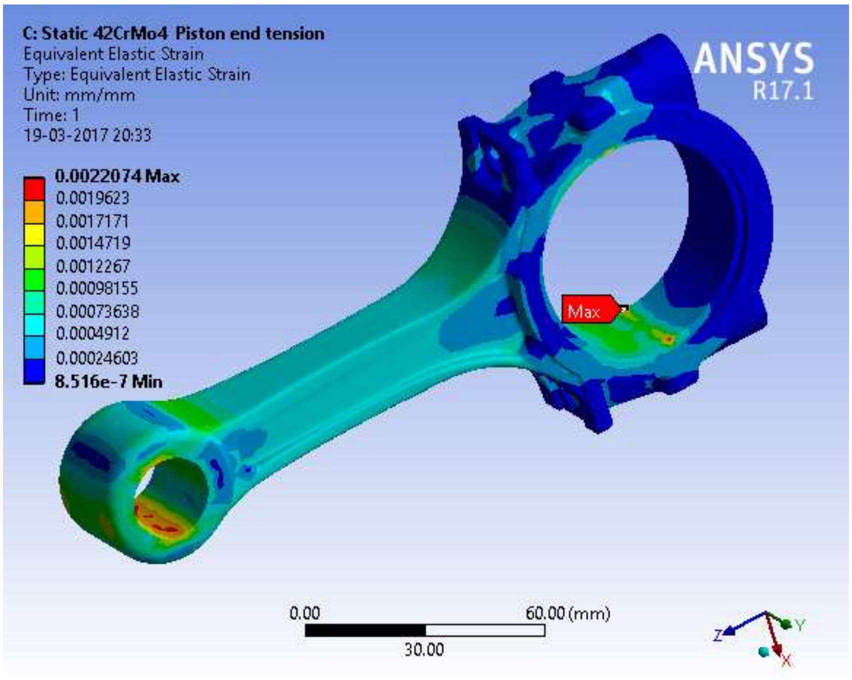
Figure 9: Static analysis result of case 1 for material 42CrMo4

Case 2: Piston End Tension Load

Von-Mises Stress



Von-Mises Strain



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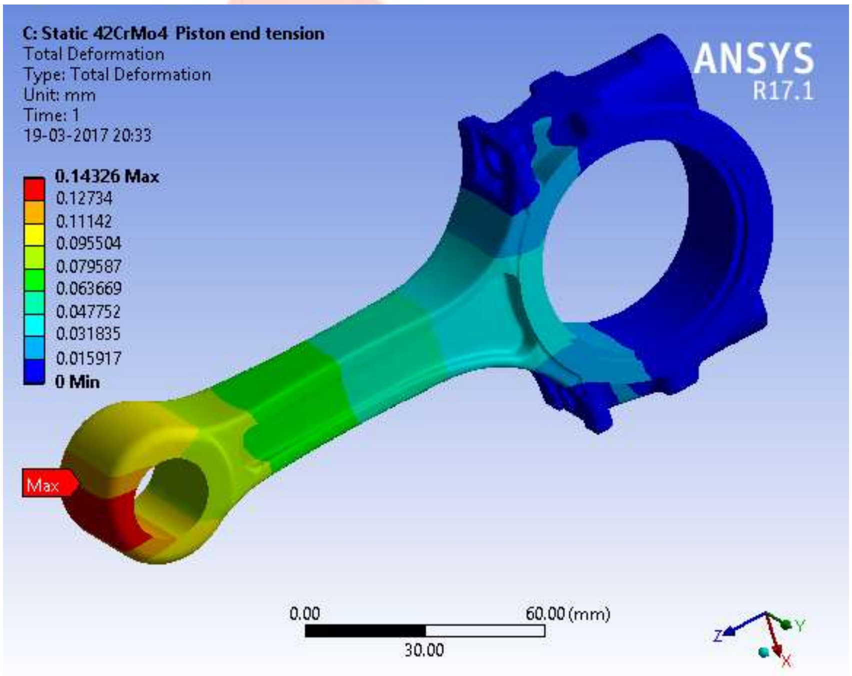
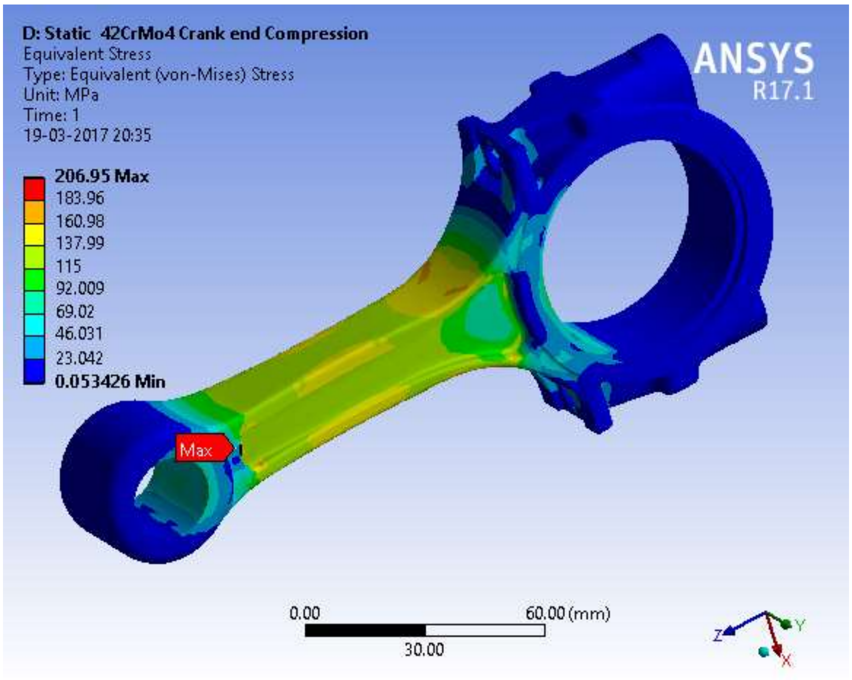


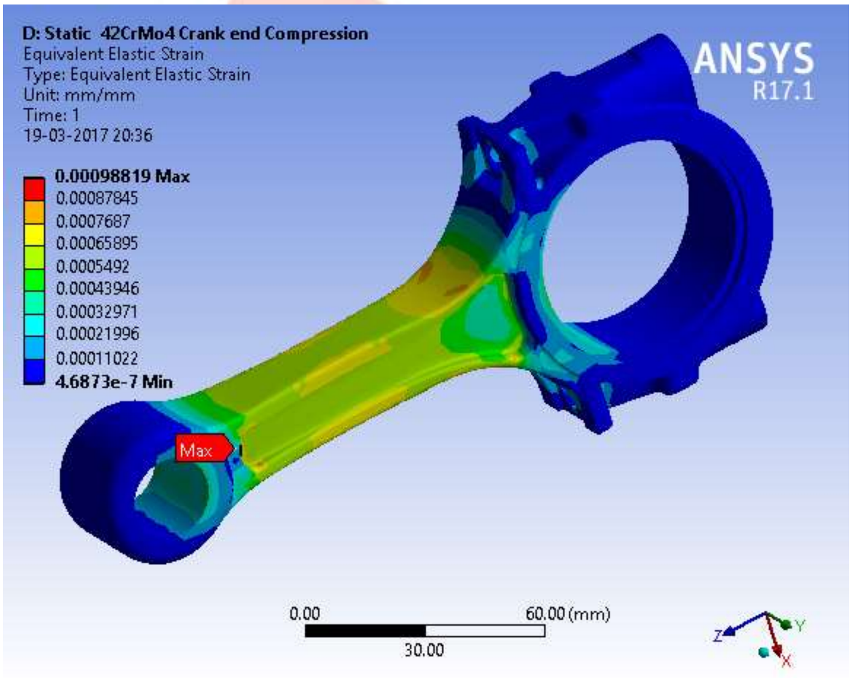
Figure 10: Static analysis result of case 2 for material 42CrMo4

Case 3: Crank End Compression Load

Von-Mises Stress



Von-Mises Strain



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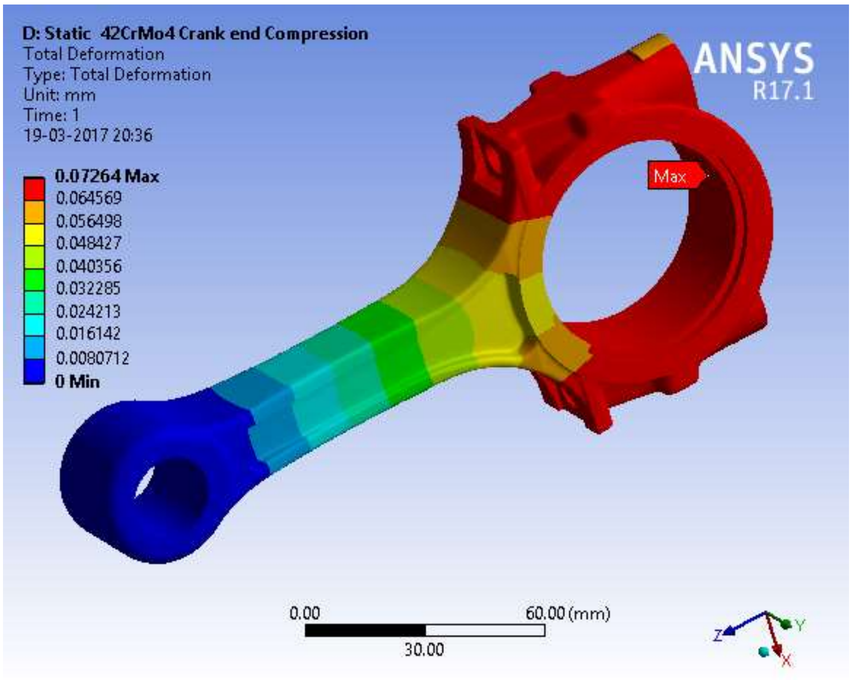
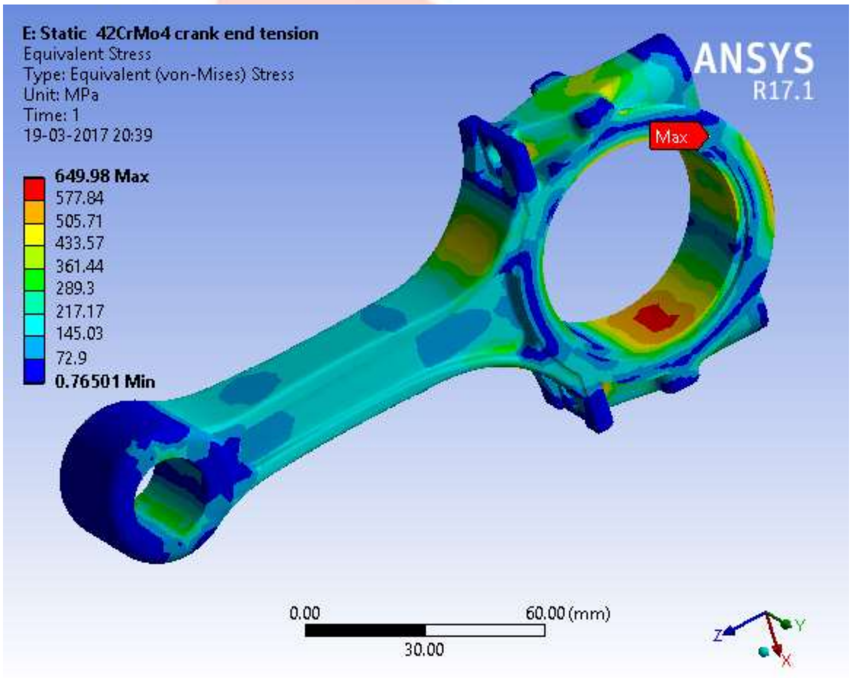


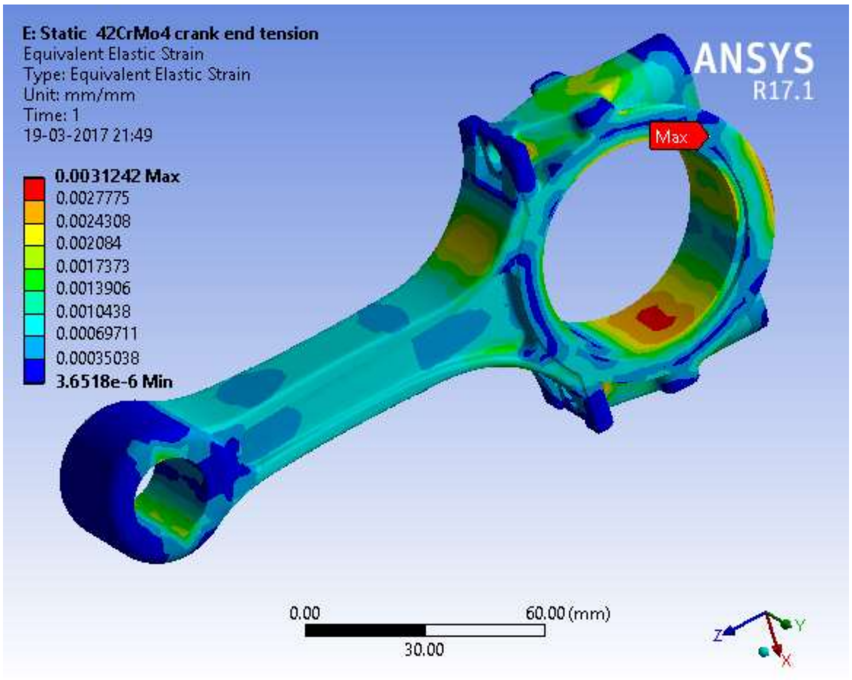
Figure 11: Static analysis result of case 3 for material 42CrMo4

Case 4: Piston End Tension Load

Von-Mises Stress



Von-Mises Strain



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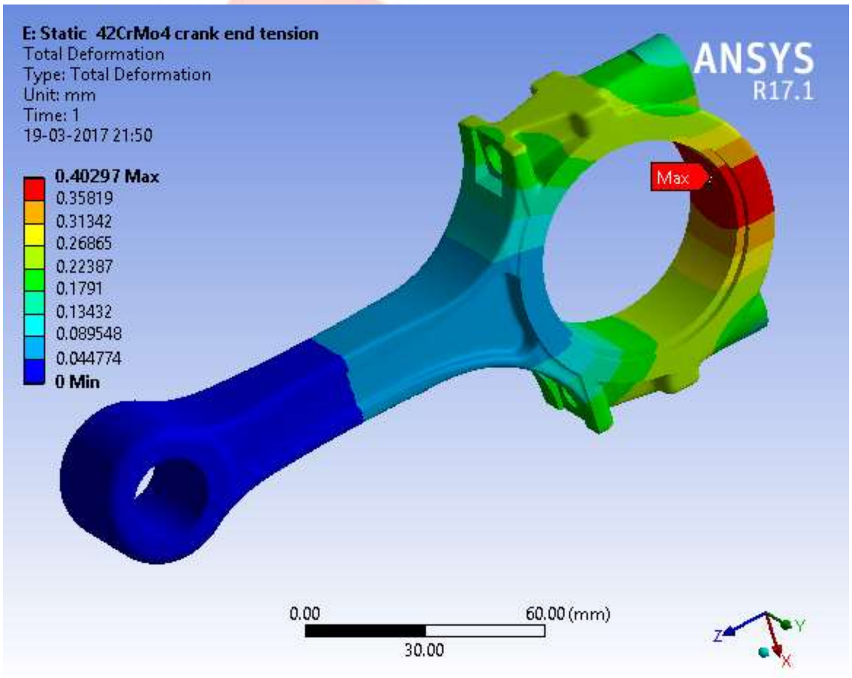
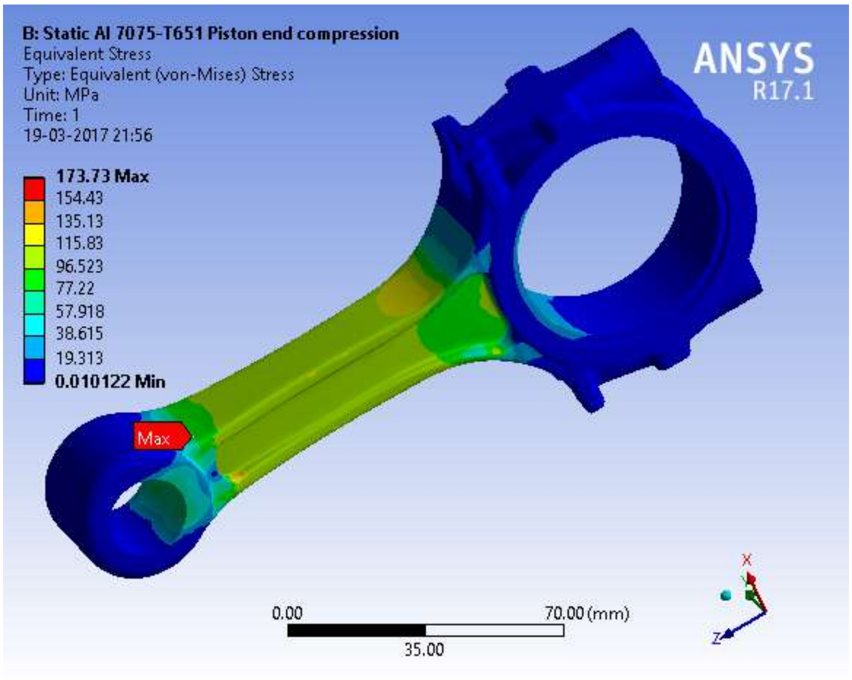


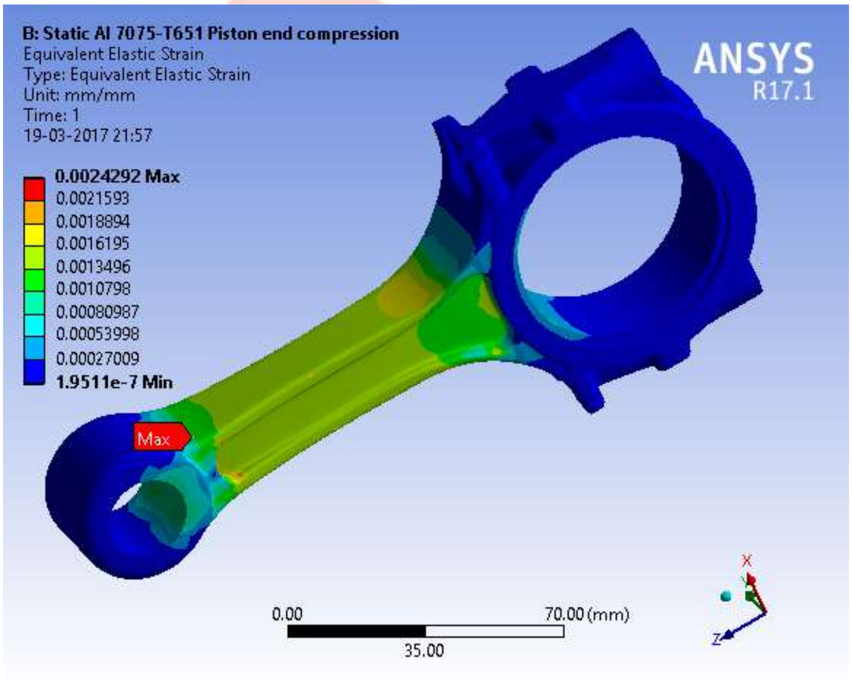
Figure 12: Static analysis result of case 4 for material 42CrMo4

Material 3: Aluminium 7075-t651
Case 1: Piston End Compression

Von-Mises Stress



Von-Mises Strain



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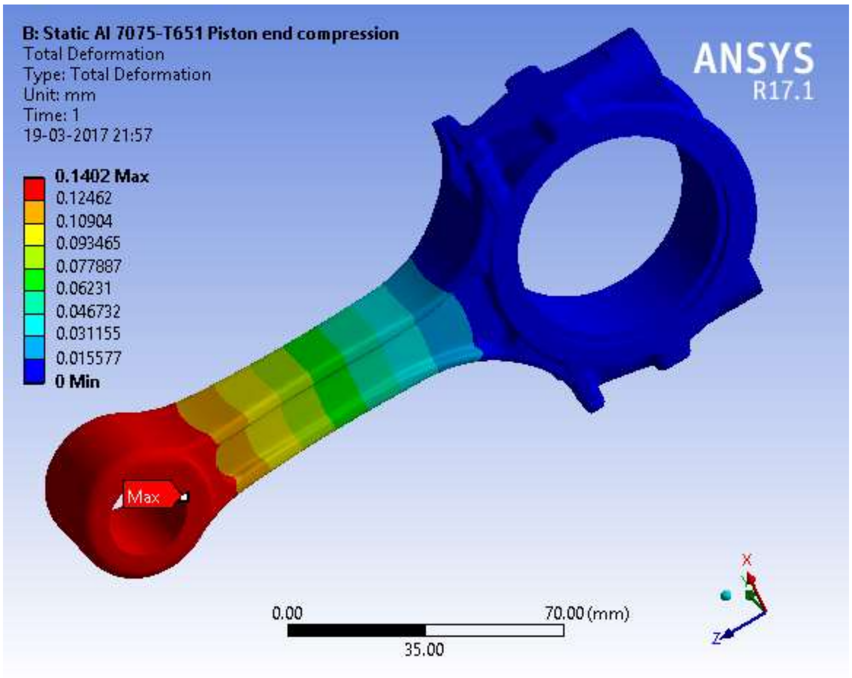
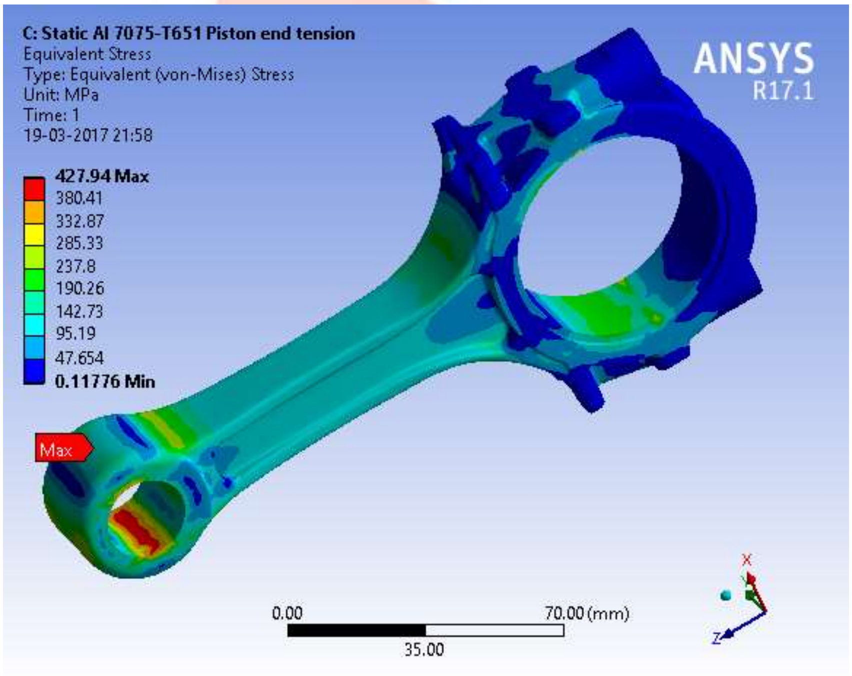


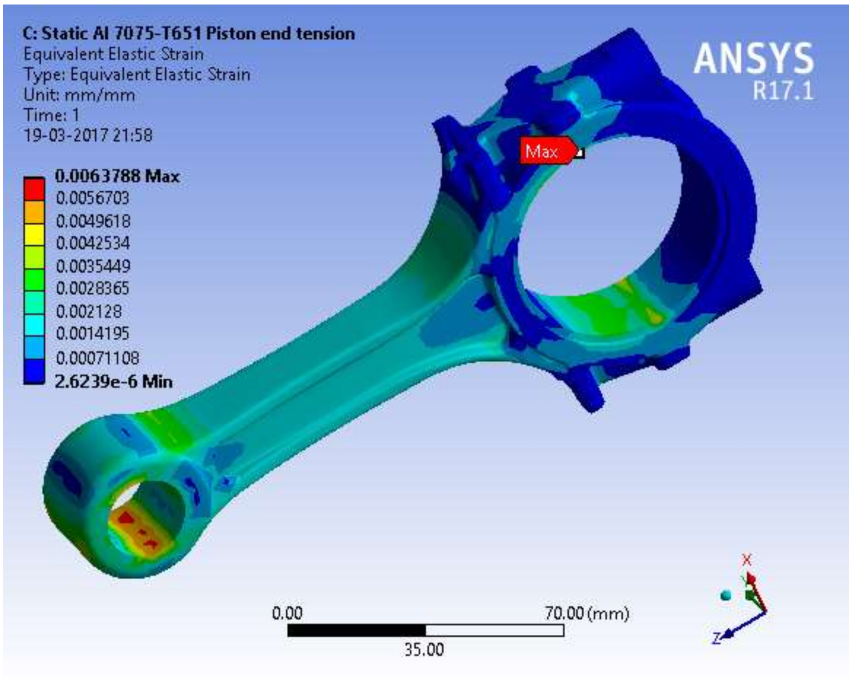
Figure 13: Static analysis result of case 1 for material Al 7075-T651

Case 2: Piston End Tension Load

Von-Mises Stress



Von-Mises Strain



Deformation

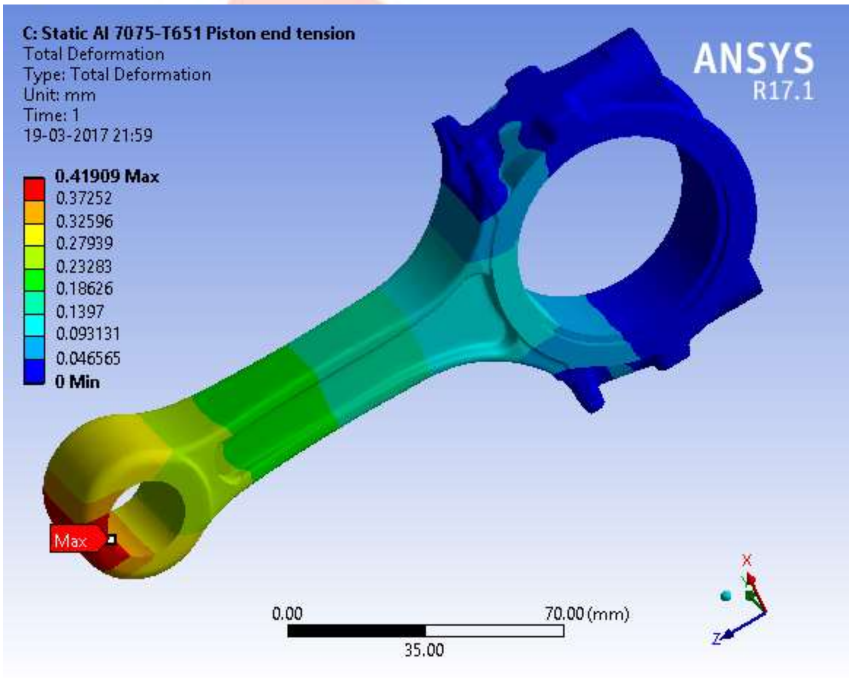
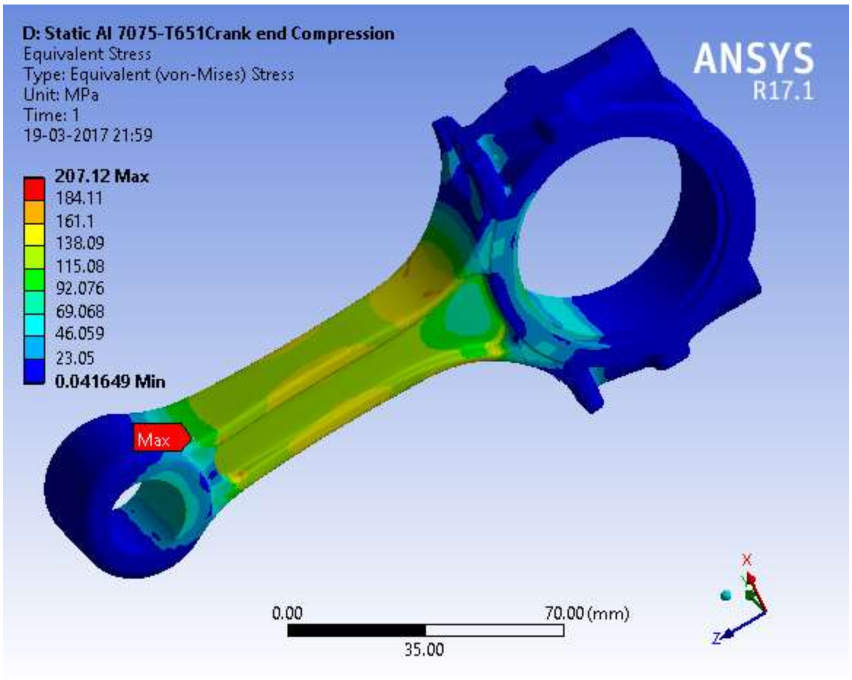


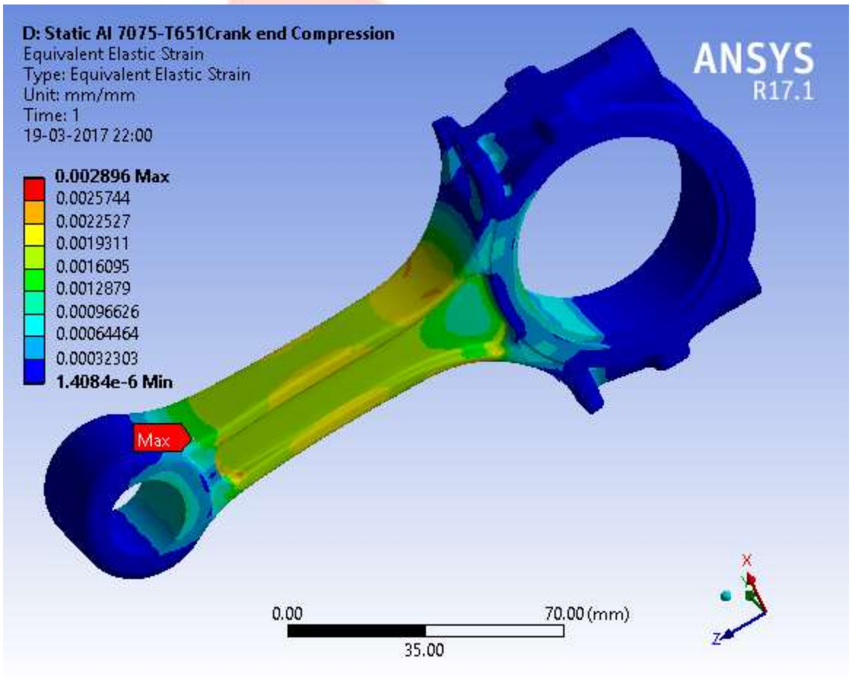
Figure 14: Static analysis result of case 2 for material Al 7075-T651

Case 3: Crank End Compression Load

Von-Mises Stress



Von-Mises Strain



Deformation

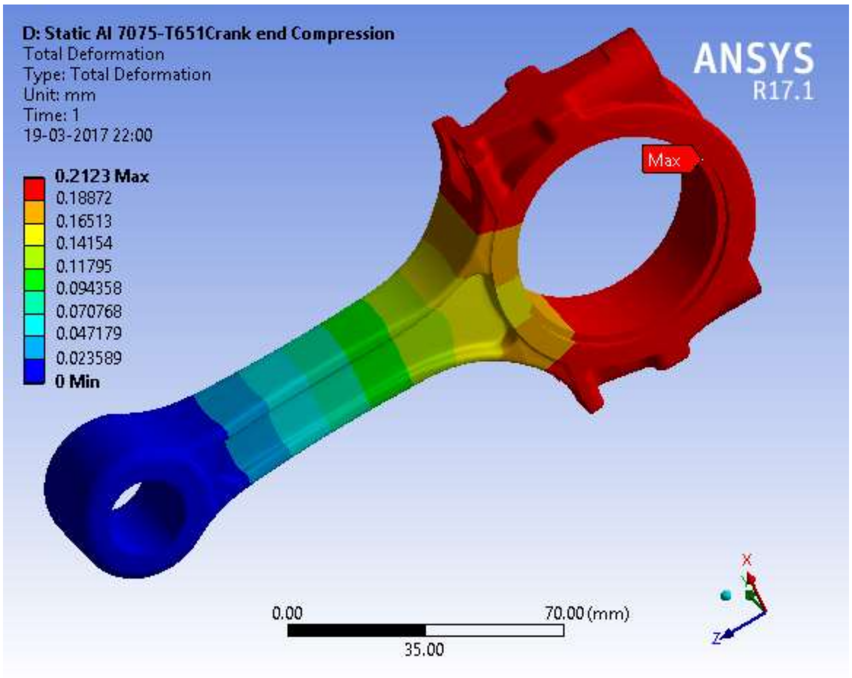
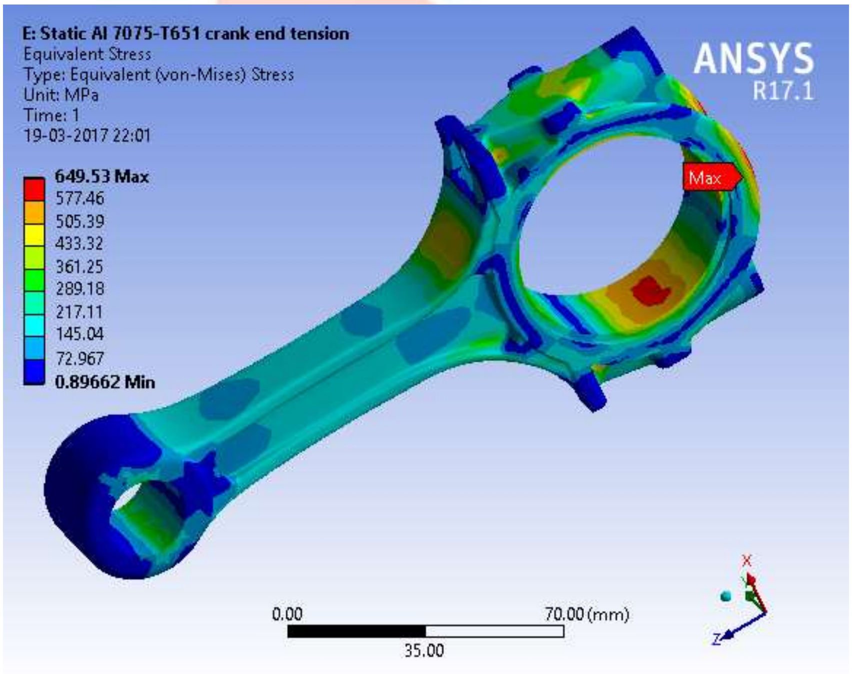


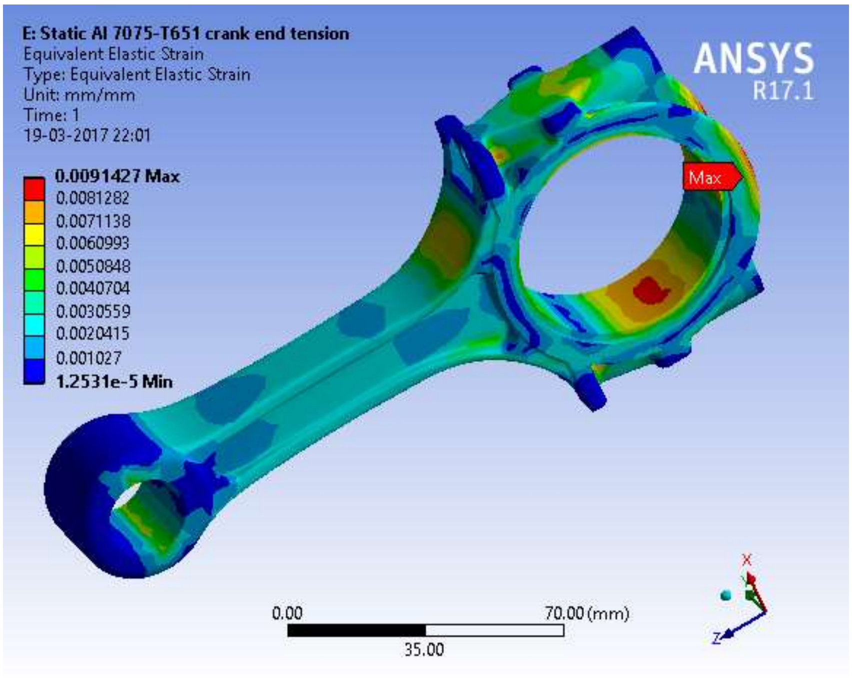
Figure 15: Static analysis result of case 3 for material Al 7075-T651

Case 4: Piston End Tension Load

Von-Mises Stress



Von-Mises Strain



Deformation

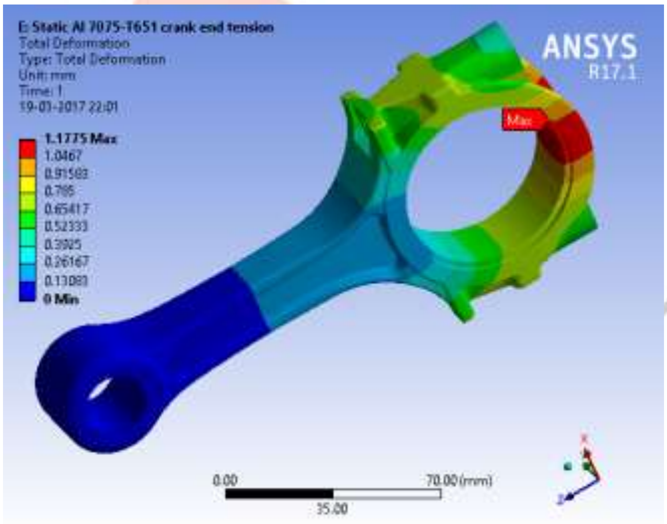


Figure 16: Static analysis result of case 4 for material Al 7075-T651

7. Result Table of static analysis

		Stress (MPa)	Strain	Deformation (mm)	Mass
Case 1	Steel 4340	173.42	8.48E-04	4.91E-02	2.3031 kg
	42CrMo4	173.46	8.28E-04	4.79E-02	2.2972 kg
	Al 7075-T7	173.73	2.43E-03	0.1402	1.920 kg
Case 2	Steel 4340	429.42	2.27E-03	0.1468	2.3031 kg
	42CrMo4	429.05	2.21E-03	0.14326	2.2972 kg
	Al 7075-T7	427.94	6.38E-03	0.41909	1.920 kg

Case 3	Steel 4340	206.94	1.01E-03	7.45E-02	2.3031 kg
	42CrMo4	206.95	9.88E-04	7.26E-02	2.2972 kg
	Al 7075-T7	207.12	2.90E-03	0.2123	1.920 kg
Case 4	Steel 4340	650.03	3.20E-03	0.41309	2.3031 kg
	42CrMo4	649.98	3.12E-03	0.40297	2.2972 kg
	Al 7075-T7	649.53	9.14E-03	1.1775	1.920 kg

8. CONCLUSION:

In automotive industries, to achieve reduced fuel consumption as well as greenhouse gas emission is a current issue of utmost importance. To reduce automobile weight and improve fuel efficiency, the auto industry has dramatically increased the use of aluminium in light vehicles in recent years. Aluminium alloy based metal matrix composites (MMCs) with ceramic particulate reinforcement have shown great promise for such applications.

These materials having a lower density and higher thermal conductivity as compared to the conventionally used. Weight reduction of up to 50 – 60 % in the systems. Moreover, these advanced materials have the potential to perform better under severe service conditions like higher speed, higher load etc.

The objective of the present work is to design and analysis of connecting rod made of Aluminium Alloy. Steel materials are used to design the connecting rod. In this project the material (Forged steel) of connecting rod replaced with Aluminium Alloy. Connecting rod was created in CATIA V5 R20. Model is imported in ANSYS 17.0 for analysis. After analysis a comparison is made between existing steel connecting rod viz., A Aluminium Alloy (Al 7075-T7) in terms of weight, factor of safety, stiffens, deformation and stress. The present work aimed at evaluating alternate material for connecting rod with lesser stresses and lighter weight. This work found alternate material for minimizing stresses in connecting rod. FEA analysis performed using ANSYS 18.1 software for determining stresses & deformation.

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