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Fatigue Analysis and Life Predictions of Forged Steel and Powder Metal Connecting Rods

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***Abstract*- The report investigates and compares fatigue behavior of forged steel and powder metal connecting rods. At the same time comparing cost analysis of both the materials like forged steel and powder material are compared. They must be capable of transmitting axial tension and compression loads. For applying tension and compression loads we are using latest solver technology called Altair Hyper works software. In which we have Altair Hyper mesh for preprocessing, Altair Radios for solving tension and compression analysis at the same time fatigue analysis for checking the life of two different materials based on tension and compression condition are solved. Final conclusion is based on the result of which material is having more life. Based on cost of the two different materials, which will be low cost so that which material connecting rod can be more applicable.**

1 INTRODUCTION

The function of connecting rod is to translate the transverse motion to rotational motion. It is a part of the engine, which is subjected to millions of repetitive cyclic loadings. It should be strong enough to remain rigid under loading, and also be light enough to reduce the inertia forces which are produced when the rod and piston stop, change directions and start again at the end of each stroke. The connecting rod should be designed with high reliability. It must be capable of transmitting axial tension, axial compression, and bending stresses.

The two most competitive high volume manufacturing processes of connecting rods are forged steel and powder metal processes. There has been a significant increase in the production of powder metal connecting rods in the last decade. The main driving force for this trend has been cost effectiveness of powder metal connecting rods resulting from near net shape manufacturing. The cost of the powder metal connecting rod is lower than that forged steel. But, forged steel

The below table describes about the dimensions of forged steel and powder metal connecting rod dimensions, which units are in mm. same dimensions are used to design connecting rod in CATIA V5R19 software using sketcher and part design module in CATIA. The above parameters of four cylinder engines are considered of analysis of connecting rod,

2 MODELING USING CATIA V5 R19

Connecting rod is designed using CATIA V5 R19 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models. As per literature review based on 2d drawing we designed connecting rod. Applications of CATIA Version 5 like part design, assembly design, drafting.

The same CATIA V5 R19 3d model is shown below for reference. Dimensions are taken from oliverconnetingrods.com. The design of 3d model is done in catia v5r19 software, and then testing is conducted using below mentioned software's.

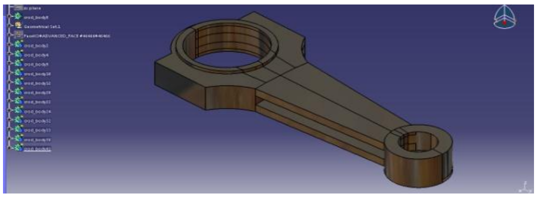


Figure 2.1: Catia 3D model of connecting rod

Above figure 2.1 shows H-beamconnecting rod. The design of 3d model is done in CATIA V5R19 software using sketcher, part design, and assembly drawing module in CATIA. [1]

ENGINE PARAMETERS	DIMENSIONS
Connecting rod length	157.00 mm
Crankshaft radius	52.00 mm
Crank to C.G distance	42.50 mm
Engine speed	4000-8000 rpm
Maximum firing pressure	53.70 ATM
Maximum compression pressure	10.00 ATM
Piston diameter	87.5 mm
Piston assembly mass	585.00 g
Forged steel connecting rod weight	430.00 g
Powder metal connecting rod weight	490.00 g

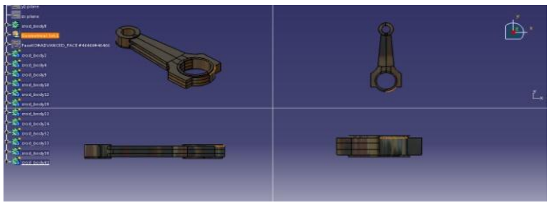


Figure 2.2: Connecting rod views

Above figure 2.2 shows H-beam connecting rod in different views for easy identification after assembly drawing.

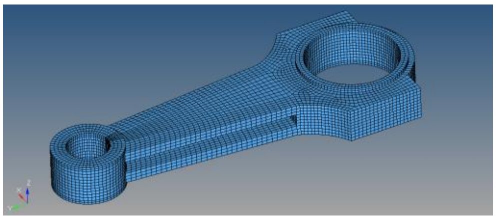


Figure 2.3: Manual options for doing 3d mesh using hyper mesh

Modeling incorporated three-dimensional geometry, tension and compression loading, symmetry conditions and other aspects of designing. A 3-D model is designed in CATIA V5 and then imported in to Altair hyper mesh, after completing preprocessing we solved using ALTAIR RADIOSS. Dimensions of the connecting rod were taken as the average of three different connecting rods to generate the model. Due to symmetry of the geometry, the component was first half modeled, and then the entire geometry was created by reflecting (mirror imaging) the half geometry.

3 TYPE OF ANALYSIS

Tension and compression loads were applied as pressure on the bearing surfaces of the connecting rod. Under actual service condition, pin end experiences tension by the piston pin causing distribution of pressure along the upper half of the inner diameter, which is approximated by the cosine function. In compression, the piston pin compresses the bearings against the pin end inner diameter, causing uniform distribution of pressure. The same phenomenon of pressure distribution caused by the

As tensile test and compressive test values are mentioned , using same values tensile and compressive loads are mentioned in hyper mesh interface.

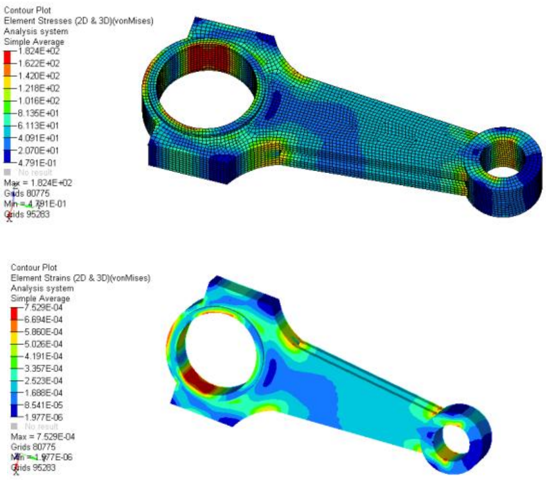
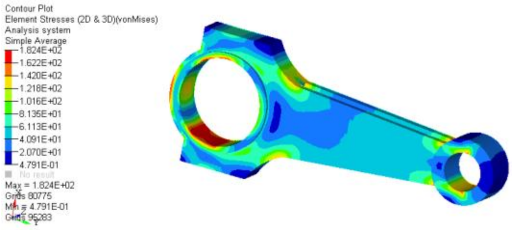
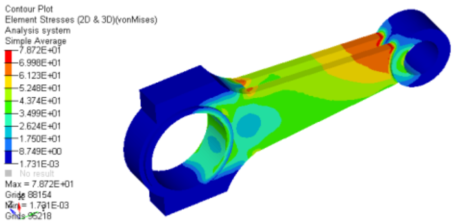


Figure 3.1: Von mises stress locations used for mesh size sensitivity analysis (Loading at crank and constraint at pin end).

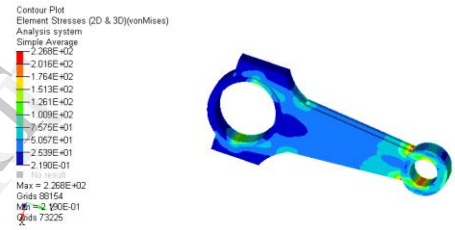
Above figure shows results for mesh sensitivity analysis for 1.27mm mesh size. This is suitable for accurate results.



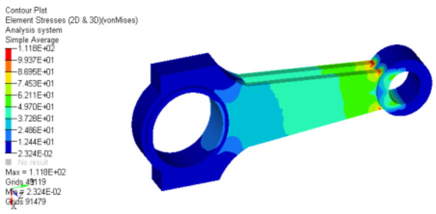
(a) Tension at the crank end, (stress = 182 MPa)



(b) Compression at the crank end, (stress = 78 MPa)



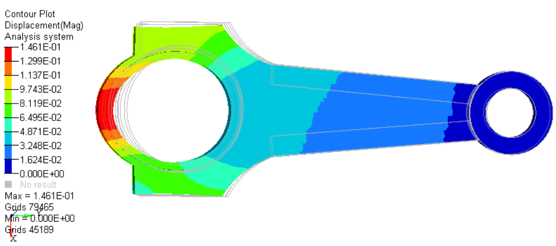
(c) Tension at the pin end, (stress = 226MPa)



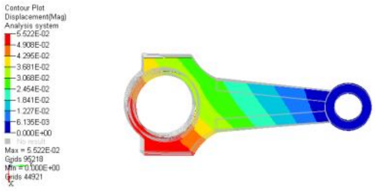
(d) Compression at the pin end, (Stress = 111MPa)

Figure 3.2: Von mises stress (Mpa) contours of forged steel connecting rod at applied press load. (a) Tension at the crank end, (b) Compression at the crank end, (c) Tension at the pin end, and (d) Compression at the pin end.

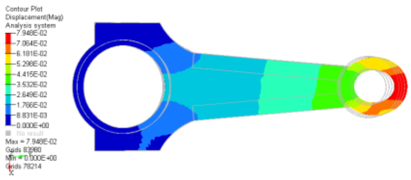
As per above figure4.4 it is showing voin mises stress by which we know that connecting rod is safe or fail.



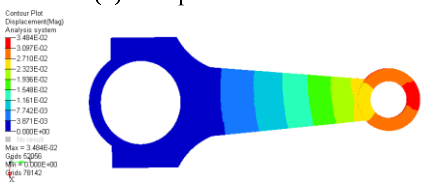
(a) Displacement = 0.146m



(b) Displacement = 0.0522mm



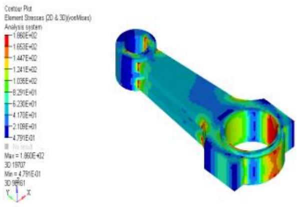
(c) Displacement = 0.079mm



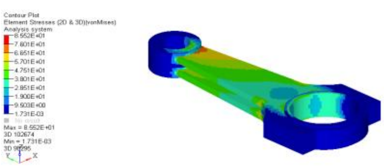
(d) Displacement = 0.0348mm

Figure 3.3: Displacement contours in Y-direction for forged steel (a) Tension at the crank end (b) Compression at the crank end, (c) Tension at the pin end, and (d) Compression at the pin end

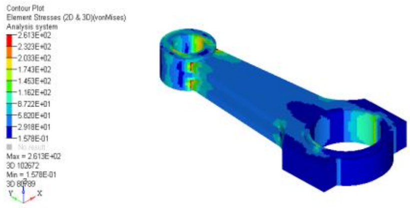
As per above displacement values for tensile and compressive test there is no difference in it. The values are very near to both of the materials. When compared with virtual analysis results there will be few variation because finite element method and finite element analysis belongs to numerical methodology.



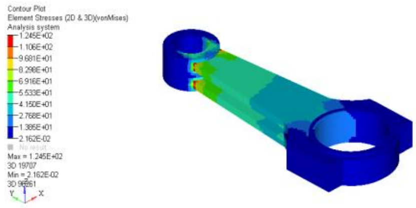
(a) Tension at crank end (stress= 186 MPa)



(b) Compression at crank end (stress=85 MPa)

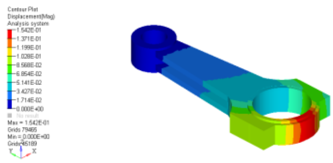


(c) Tension at pin end (stress = 261 MPa)

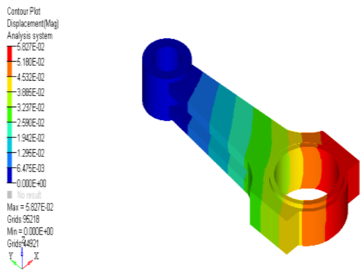


(d) Compression at pin end (124 MPa**)**

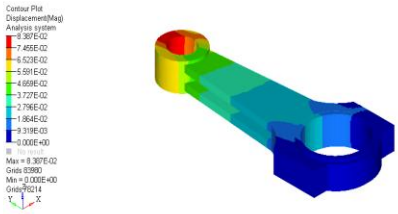
Figure 3.4: Von mises stress contours of powder metal connecting rod at applied pressure load, (a) Tension at crank end, (b) Compression at crank end, (c) Tension at pin end, (d) Compression at pin end.



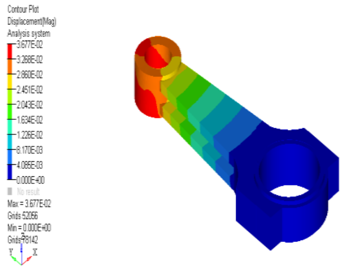
(a)Displacement = 0.154mm



(b)Displacement = 0.058mm

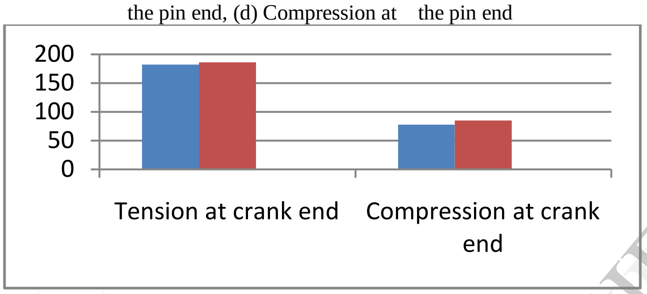


(c) Displacement = 0.083mm



(d) Displacement = 0.0348mm

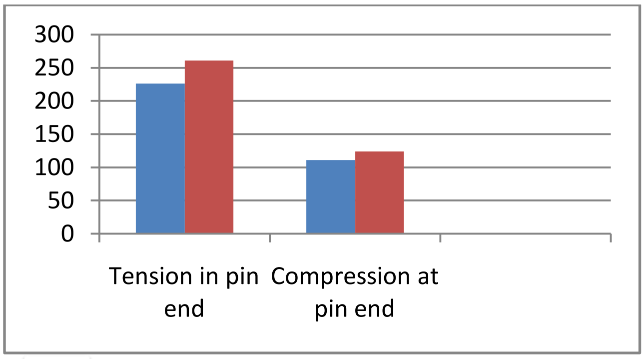
Figure 3.5: Displacement contours at Y-direction for powder metal. (a) Tension at the crank end (b) Compression at the crank end, (c) Tension at the pin end, (d) Compression at the pin end



Forged steel

Powder metal Figure 3.6: Powder material stress Vs forged steel stress at crank end

As per above figure, the stress values powder metal and forged steel at stress values contains variation. Therefore, both the materials can be applied to connecting rod.

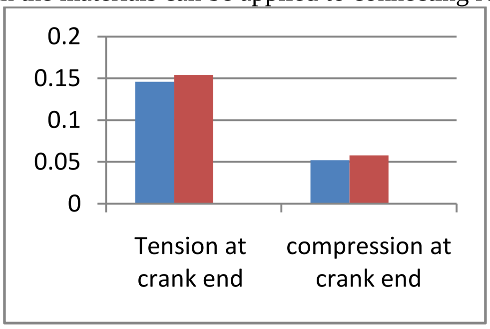


Forged steel

Powder metal

Figure 3.7: Powder material stress Vs forged steel stress at pin end.

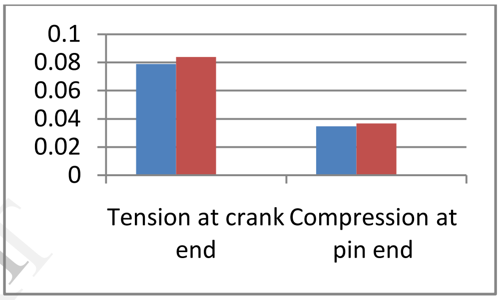
As per above figure, the stress values powder metal and forged steel at stress values contains variation. Therefore, both the materials can be applied to connecting rod.



Forged steel

Powder metal

Figure 3.8: Displacement of forged steel & powder material at crank end



Forged steel

Powder metal

Figure 3.9: Displacement of forged steel & powder material at pin end.

From the above figures 3.8 and 3.9 it is showing that there is variation in displacement of both materials and it is clear that forged steel and powder material can be used for connecting rods.

4 FATIGUE ANALYSIS METHODOLOGY USING RADIOSS

Fatigue life of connecting rod is calculated by S-N approach using Radios. The S-N approach is suitable for high cyclic fatigue, where the material is subject to cyclical stresses that are predominantly within the elastic range. Structures under such stress ranges should typically survive more than 1000 cycles.

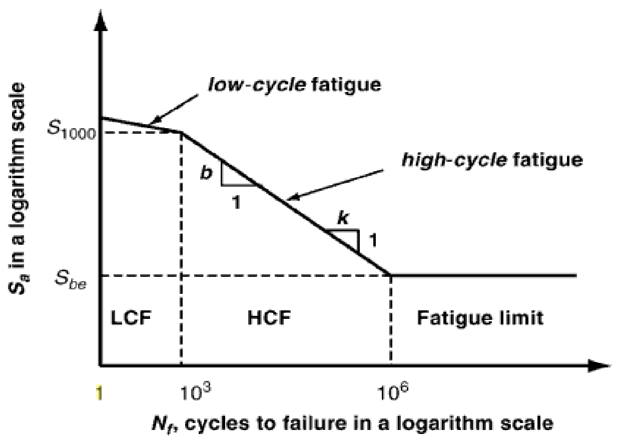
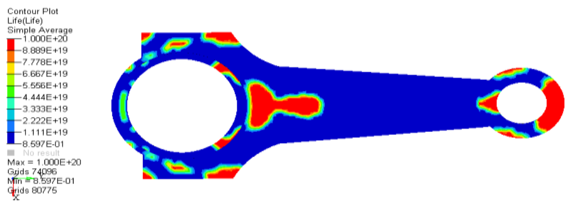
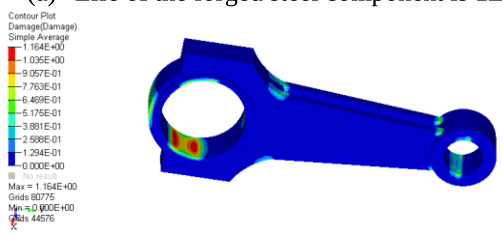


Figure 4.1: Low cycle and high cycle regions on the S-N curve



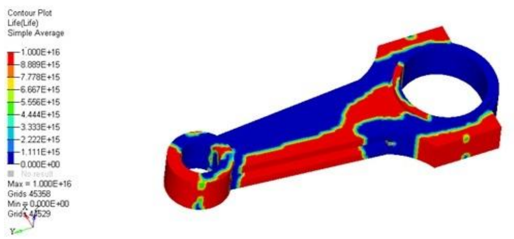
(a) Life of the forged steel component is 1E20 cycles.



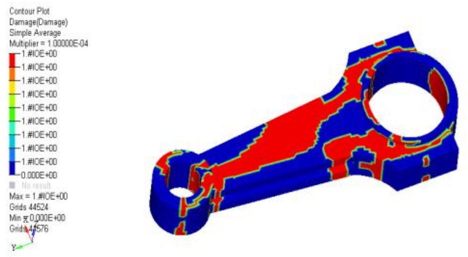
(b) Forged steel damages will happen at red color Contour area as shown in above

Figure 4.2 : Fatigue test for forged steel Connecting Rod

The above figure 4.2 shows results for forged steel material, image (a) describes that forged steel life which will work for 1e20 cycles. Same (b) images shows us damages which will happen in future when it is very near to get cracks to connecting rod.



(a) Life of the forged steel component is 1E16 cycles.



(b) Powder metal connecting rod get damages will happen at red color contour area as shown in above image

Figure 4.3: Fatigue test for powder metal connecting Rod

The above figure 4.3 shows results for powder metal, image (a) describes that powder metal life which will work for 1e16 cycles. Same (b) images shows us damages which will happen in future when it is very near to get cracks to connecting rod.

Figure 4.2 & 4.3 shows good variation of fatigue behavior for forged steel and powder metal. The given life cycles are mentioned above, for forged steel life is a 1e20 cycle and for powder metal life is a 1e16 cycle. So by this it is proved that forged steel life is more compared to powder metal. Based on industrial requirements forged steel material will be selected. For knowing which material is having high or lower cost, cost analysis is performed for both materials.

5 CONCLUSIONS AND FUTURE SCOPE OF WORK

5.1 CONCLUSIONS

In this study, first a literature review on several aspects of connecting rods in the areas of load and stress analysis and cost analysis. Forged steel and powder metal connecting rods were then used to obtain and compare the fatigue properties and behaviors. Experimental results and observations, and analysis performed, the following conclusions can be drawn:

1. Results of tensile and compressive test of connecting rod, which shows clearly that forged steel has 20% more life then the powder metal connecting rod.
2. As per fatigue test for both powder material and forged steel, forged steel life shows 1E20 cycles and for powder metal connecting life is 1E16 cycles. There is different of 20% compare to forged steel. By this it has been proved that forged steel is better replacement on powder metal.
3. A major reason for the increased use of powder metal connecting rods has been its cost effectiveness. Some automotive manufacturers are starting to switch back from powder metal to forged steel connecting rods, due to their higher fatigue life which ranges 1E20 cycles and reasonable manufacturing process cost of rupees 290.51
4. From tensile tests and monotonic curves it is concluded that forged steel is considerably stronger than the powder metal. Yield strength of forged steel is 16% higher than that for the powder metal. Ultimate tensile strength of forged steel is 8% higher than that of the powder metal.

5.2 FUTURE SCOPE OF WORK

- Recent developments of C-70 and micro alloyed steels have eliminated the machining process associated with fracture surfaces and thus reducing production cost. Fatigue analysis and life predictions can be conducted for the C-70 and micro alloyed steel connecting rods using tensile, compressive and fatigue test are to be conducted.

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