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Static Structural Analysis and Optimization of Pneumatic Compressor Connecting Rod

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Abstract: ***The reciprocating engine mechanism is widely used as a suitable mechanism for pumps and compressors. In this study, finite element analysis is carried out for the connecting rod using ANSYS under static load condition. Connecting rod is a main component which connects piston and crankshaft. This all together forms a driving mechanism. The Power Transmission of this mechanism is in push & pulls form. Basically, connecting rods are designed to sustain higher bending stress. These stresses are due to loading at TDC. This paper contains the static analysis and optimization of pneumatic compressor connecting rod. The existing connecting rod having weight 272.79 gm. Design of existing connecting rod done by using CAD package CATIA V5. FEA done using ANSYS package. FEA help in identifying strain and stress occurs in connecting rod. Optimization is done using manual removal. According to FEA result, machining is done. After optimization, connecting rod weight is 256.51 gm. The surface preparation is done before installing strain gauge on component. The Experimentation is done on optimized connecting rod by testing on UTM by compressive force at Piston End.***

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

1. Introduction

In the two-stage air compressor, a compressor consists of two cylinders. An air compressor is a device that increases the amount of air in a confined space. From this, confined air creates pressure and power for industrial, domestic, commercial and personal applications. In this study, one component of two stage air compressor in particular, the connecting rod, analyzed and optimized. The function of connecting rod is transmission. This happens by converting the rotary motion of crankshaft into the motion of the piston in reciprocating form. This mechanism used and applied in the all I.C. Engines and Compressors. The cross section of the connecting rod is made as and I –section to provide the maximum rigidity with minimum weight. The construction of connecting rod consist a long shank, a small end and a big end. The shank cross-section is in circular, rectangular, I-section or H-section form. For low speed engines circular section is preferred and I-section is for high speed engines. These all connecting rods are manufactured by casting, forging and powdered metallurgy. Connecting rod is subject to inertia force. Also, Gas forces result in axial and bending stresses on the connecting rod. This stresses due to when connecting rod subjected to a state of loading. Because of this connecting rod must be capable of transmitting bending stresses, axial compression and axial tension in the mechanism.

2. Literature Review

D. Gopinath et al. [2015] Studied, after carried out static structural analysis of the connecting rod the stresses in each loading conditions were studied and then area where excess material can be removed were decided. Optimization was performed to reduce weight of forged steel. The shank region of the connecting rod offered the greatest potential for weight reduction [1].

J. D. Ramani et al. [2014] Performed & studied a detailed load analysis. This study has done on the connecting rod for load and stress analysis and then optimization for weight reduction of same connecting rod. In the study, loads acting on the connecting rod studied. The results were also used to determine the variation of Tensile and Compressive loading the component was optimized for weight reduction subject to space constraints and manufacturability [2].

Kuldeep B et al. [2013] Studied, The Connecting rods are manufactured by using carbon steel and in recent days aluminum alloys are finding its application in the connecting rod. In this work, connecting rod is replaced and used of an aluminum based material which reinforced with silicon carbide and fly ash. And it also describes the modeling and analysis of connecting rod. Finite element analysis was carried out by considering two materials [3].

Leela Krishna Vegi et al. [2013] Studied & Performed, Connecting rod is modeled by CATIA V5 R19 software and analysis is carried out by ANSYS 13.0 Software. Finite element analysis of connecting rod is done by using the material as Forged steel. The result parameters, Von misses stress and strain, Factor of safety, Deformation and weight reduction were done by using ANSYS software [4].

M. S. Shaari, et al. [2010] Studied & Performed, The topology optimization was of connecting rod of an Internal Combustion Engine. The aim of this study was to develop structural model, finite element analysis of it and the optimization of the connecting rod. The topology optimization technique was used to achieve the objectives of optimization which was to reduce the weight of the connecting rod. After optimization, the connecting rod is 11.7% light and low maximum stress compares to existing design [5].

Pravardhan S. Shenoy et al. [2005] Study was done to achieve weight and cost reduction for a forged steel connecting rod. This has been done by performing a detailed load analysis on connecting rod. This work has done for dynamic load and optimization for weight and cost. The loads acting on the connecting rod as a function of time were obtained. Static FEA and the load analysis results, the load for the optimization study were selected [6].

Rafael Augusto de Lima et al. [2009] Designed & studied a connecting rod for a light weight spark-ignition four-stroke I.C.Engines by applying topology optimization. Topology optimization methodology combines FE analysis with a powerful optimization algorithm to find the optimum mass distribution inside the defined design volume concerning the loads and boundary conditions and considering a specified optimization objective function [7].

Satish Wable et al. [2016] Study used the CATIA software for the modeling and ANSYS software for analysis. These can be used for designing any connecting rod in Automobile. Connecting rod designed for weight and cost reduction also increased the life time of connecting rod. Up to some level of extent the weight of the connecting rod was lighter and having more strength as compared to the existing design [8].

3. Research Methodology

First create model and select the design of connecting rod by using CAD package CATIA V5 .Then use and apply load and boundary conditions to connecting rod. Find the optimization solution for the same connecting rod. Then, the Von-Misses stress, Minimum Principal Elastic Strain & Total Deformation is achieved from the ANSYS software. This data is checked with actual experimentation result after optimization. The methodology is shown in figure 1.

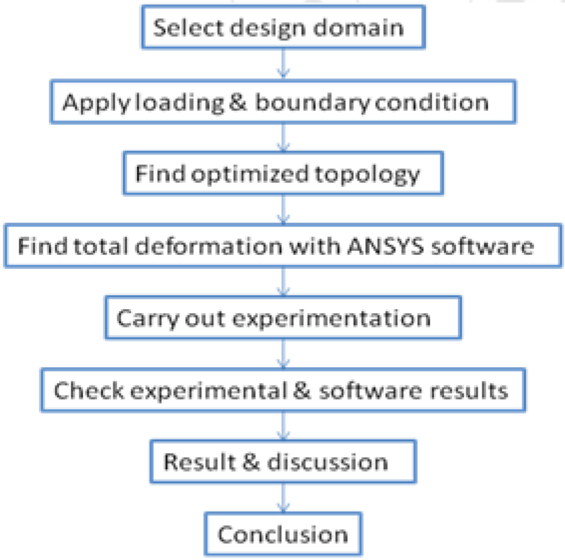

Figure 1: Research Methodology

4. Problem Statement

Currently, connecting rods of compressors contains excess material, leads to increase in weight. It directly affects the manufacturing cost, material cost, performance and efficiency. Hence, Connecting rod (shank area) of Pneumatic Compressor can be optimized where higher stresses acts due to loading at TDC which form basis.

5. Objective

The main objective of the study is static analysis of Pneumatic Compressor connecting rod under loading conditions. Another objective is to propose an optimized model of connecting rod with same material which will have better performance.

6. Static Analysis

The various forces acting on the connecting rod are:
1) Forces on the piston due to gas pressure and inertia of the reciprocating parts.
2) Forces due to inertia of the connecting rod or inertia bending forces.
3) Forces due to friction of the piston rings on the piston.
4) Forces due to friction of the piston pin bearings and crankpin bearings.

From above Forces, The Force on the piston due to gas pressure calculated with the following parameters;

Connecting Rod Configuration:
Connecting rod length = 204 mm
Piston Pin diameter = 30 mm
Crank diameter = 50 mm
Stroke length =102 mm

Material Properties
Material = Aluminium Alloy
Material density, $\delta = 2770$ kg/m^3
Poisson's ratio, $\mu = 0.33$
Young's Modulus, E =71000 Mpa
Yield strength, S_y =280 Mpa
Ultimate tensile strength, S_u =310 Mpa

Force on the piston due to gas pressure Calculation:
Compressor Maximum Gas Pressure = 1.26 Mpa
Area of piston on which Force is to be applied is rectangular in cross-section.
So, Area= $l \times b$; Area = 38×32
Area = 1216 mm^2

Force due effect of gas pressure on Piston:
Pressure=Force/Area
Force= Pressure× Area;
F = (Maximum Gas Pressure) × (C/s Area of Piston)
F =1.26×1216
F=1532.16 N
This force is Compressive force at Piston End and Crank End is fixed.

7. Finite Element Analysis

Design of Existing Connecting Rod is done by using CAD package CATIA V5 as shown in figure 2.

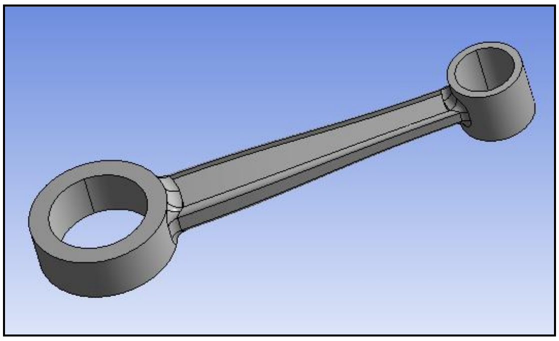

Figure 2: CAD model of Existing Connecting Rod

Details of Meshing:
Element Type: Second order Tetrahedron
Elements Count: 60456
Nodes Count: 92034

Boundary Condition to Existing Connecting Rod is Compressive force at Piston End and Crank End is fixed. Compressive force is 1532.2 N applied at Piston End.

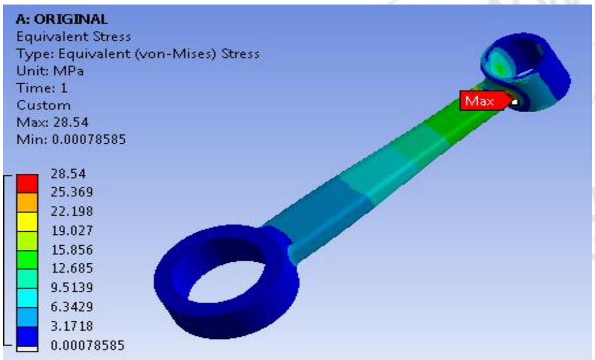

Figure 3: Von-Misses Stress of Existing Connecting Rod

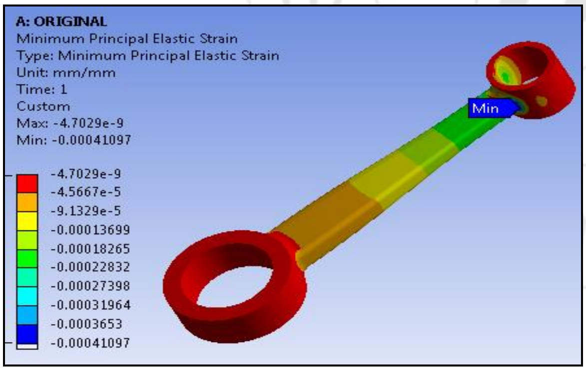

Figure 4: Minimum Principal Elastic Strain of Existing Connecting Rod

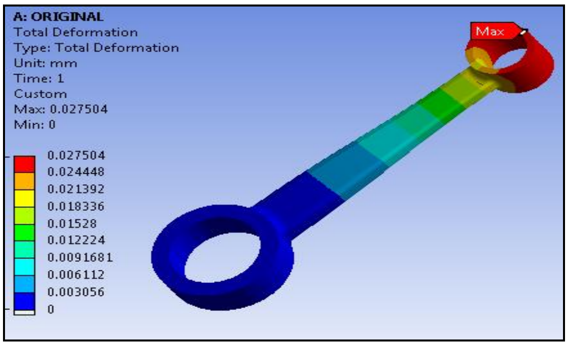

Figure 5: Deformation of Existing Connecting Rod

8. Optimization

Optimization is a process of determining the best design from a given design and material by applying loads and boundary conditions to it after which resulting design achieving a set of performance.

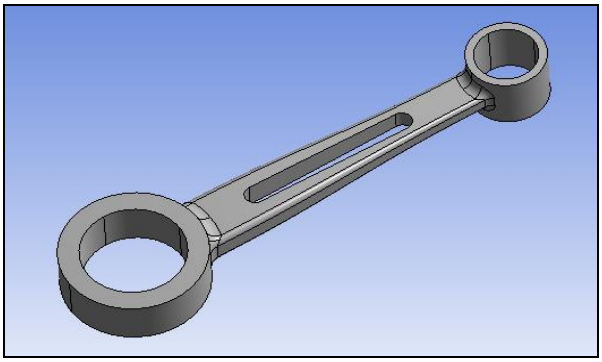

Figure 6: CAD model of Optimized Connecting Rod

From Figure 5, The Von-Misses stress plot the blue colored region shows stresses which are very low. So there is a scope for optimization by removing the material. The material is removed by manually and the model is checked on UTM to withstand the load.
Details of Meshing:
Element Type: Second order Tetrahedron
Elements Count: 66501
Nodes Count: 99698

Boundary Condition to Optimized Connecting Rod is Compressive force at Piston End and Crank End is fixed. Compressive force is 1532.2 N applied at Piston End.

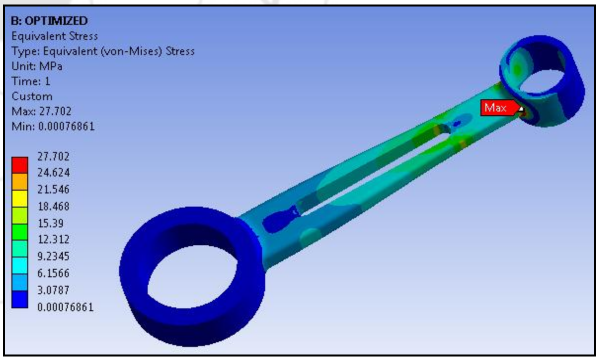

Figure 7: Von-Misses Stress of Optimized Connecting Rod

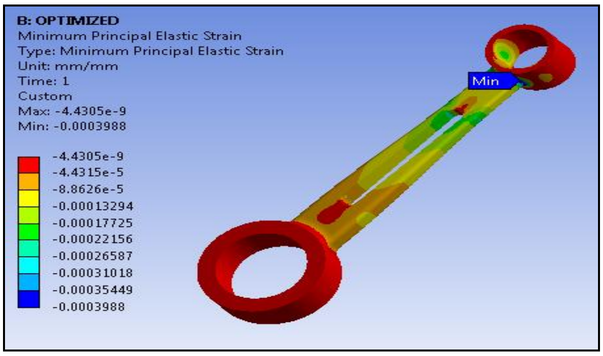

Figure 8: Minimum Principal Elastic Strain of Optimized Connecting Rod

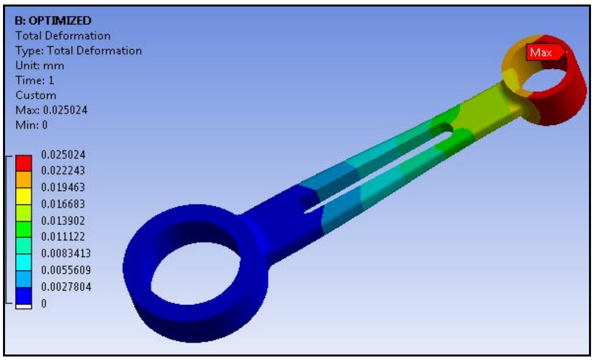

Figure 9: Deformation of Optimized Connecting Rod

Weight of Existing Connecting Rod =272.79 gm.
Weight of Optimized Connecting Rod= 256.51 gm.
Total Weight Reduction=16.28 gm.
% Weight Reduced = [(272.79-256.51) / (272.79)] x100
= 5.96 %

9. Results

Results obtained are as Follows,

Table 1: Finite Element Analysis Result of Connecting Rod

Sr. No.	Connecting Rod	Existing	Optimized
1.	Von-Misses Stress	28.54 Mpa	27.70 Mpa
2.	Minimum Principal Elastic Strain	410.97 με	398.8 με

Table 2: Weight Reduction of Connecting Rod

Connecting Rod	Existing	Optimized	Weight reduction
Weight	272.79 gm.	256.51 gm.	16.28 gm.

10. Conclusion

The shank portion of the existing connecting rod had the potential for optimization and weight reduction. The optimized connecting rod is 5.96% lighter than the existing connecting rod. Both design produced stresses are within the yield limit 280 Mpa of the material.

References

[1] D. Gopinath, Ch. V. Sushma, "Design and Optimization of Four Wheeler Connecting Rod using FEA." , 4th International Conference on Materials Processing and Characterization, www.sciencedirect.com, Proceedings 2 (2015) 2291-2299, July 2015.
[2] J. D. Ramani, Sunil Shukla, Pushpendra Kumar Sharma, "FE-Analysis of Connecting Rod of I.C.Engines by Using Ansys for Material Optimization" Int. Journal of Engineering Research and Applications www.ijera.com ISSN: 2248-9622, Vol. 4, Issue 3(Version 1), March 2014, pp.216-220.
[3] Kuldeep B, Arun L. R, Mohammed Faheem, "Analysis and Optimization of Connecting Rod using Alfasic Composites", International Journal of Innovative Research in Science, Engineering and Technology, Vol-2, Issue-6, June 2013.
[4] Leela Krishna Vegi, Venu Gopal Vegi, "Design and Analysis of Connecting Rod using Forged Steel," International Journal of Scientific & Engineering Research, Volume 4, Issue 6, June-2013 ISSN 2229-5518.
[5] M. S. Shaari, M. M. Rahman, M. M. Noor, "Design of Connecting Rod of Internal Combustion Engine: A Topology Optimization Approach" National Conference in Mechanical Engineering Research and Postgraduate Studies, pp. 155-166, December 2010.
[6] Pravardhan S. Shenoy, Ali Fatemi (2005) "Connecting Rod Optimization for Weight and Cost Reduction." SAE International Journal, 2005-01-0987.
[7] Rafael Augusto de Lima, Robson Ferreira da Cruz, "Design of a Connecting Rod For Internal Combustion Engine by applying Topology Optimization", 20th International Congress of Mechanical Engineering, November 2009.
[8] Satish Wable, Dattatray S. Galhe, Raj Kumar L. Mankar, "A Review on Design and Optimization of Connecting Rod" IJARIIE-ISSN (O)-2395-4396 Vol-2 Issue-1 2016.
[9] Vikram A. Shedge, Prof. K. H. Munde, " Optimization of Connecting Rod on the basis of Static & Fatigue Analysis", IPASJ International Journal of Mechanical Engineering (IIJME), ISSN 2321-6441, May 2015.

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