Design & Optimization of Screw Compressor Housing Thickness

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Abstract - *Gas compressors are mechanical devices used for raising the pressure of gas or vapour either by lowering its volume (as in the case of positive displacement machines) or by imparting to it a high kinetic energy which is converted into pressure in a diffuser (as in the case of centrifugal machines).*

In this Project we are going to analyze effect of internal and External Pressure on Thick walled cylinder, how radial stress & hoop Stress will vary with change of radius. Contact pressure in shrink Fit and its effect on hoop stress and radial stress in analyzed. Analysis of the original design has given us output as maximum deformation observed is 0.17 mm and principal stress observed is 104.3 MPa which are well within the acceptance criteria for the Grey cast iron which is 120 MPa Optimized modules suggest different weights and areas from where the material can be reduced from which 5 % is observed to be the maximum weight that can be reduced by complying with the all the constraints as well as design purpose of the model. Final optimized model is created by following the optimized shape suggested by the optimization module and is observed that weight is reduced from the 24.6 kg to 23.8 kg.

Key Words: Screw Compressor, Analysis, Optimization, Weight Reduction

1. INTRODUCTION

This design guideline covered the selection and sizing method of compressor used in the typical processing industries. The guideline helps engineers to understand basic design of the difference types of compressor, and gain knowledge in selection and sizing. Compressors are widely used in industries to transport fluids. It is a mechanical device that compresses a gas. There are many types of compressors, thus a proper selection is needed to fulfil the typical necessity of each industry. Generally, the compression of gases may be accomplished in device with rotating blades or in cylinders with reciprocating too high, while the reciprocating compressors are required for high pressures. Besides volumetric flow rate, there are also many parameters to be considered, includes the valid standards to be used.

1.1. CLASSIFICATION OF COMPRESSORS

The detailed classification of compressors is shown in Figure 1. The dynamic principle is utilized in the multi blade dynamic compressors. These are further sub divided into centrifugal and axial flow types.

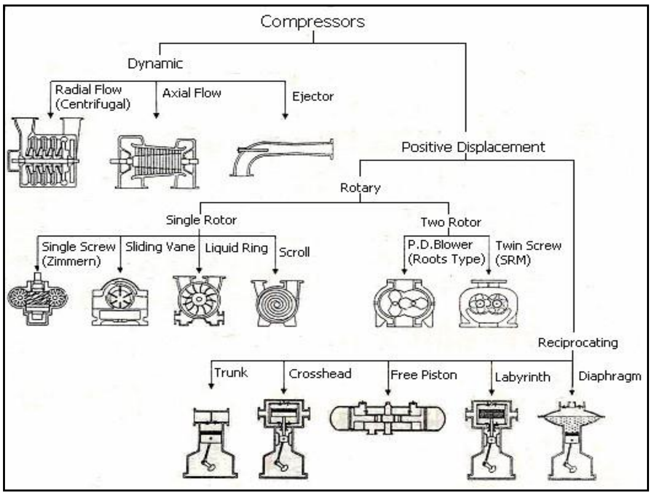


Fig -1: Classification of compressors

2. LITERATURE REVIEW

The research "Finite Elements Strength Analysis of a Compressor Consisting of Four Helical Rotors," was presented by Aleksander Nieoczym, Karol Szklarek. This article reports the results of tests of a compressor consisting of four helical rotors.[1] Ermin Husak, Ahmed Kovacevic, Sham Rane presented research on "Numerical Analysis of Screw Compressor Rotor and Casing Deformations." In this research the authors have said that, Performance and reliability of screw compressors is highly dependent on their operational clearances. [2] M. Selvaraji submitted paper on "Finite Element Analysis of Screw Compressor." In this paper the author has concluded that there is a growing demand for all types of screw compressors in the industry due to user requirements. Design and construction of screw compressors are demanding tasks that require advanced calculations and theoretical knowledge.[3]

3. PROJECT OUTLINE

3.1. PROBLEM STATEMENT

Thick walled cylinders are widely used in chemical, petroleum, military industries as well as in nuclear power plants. They are usually subjected to high pressure & temperatures which may be constant or cycling. Industrial problems often witness ductile fracture of materials due to some discontinuity in geometry or material characteristics. The conventional elastic analysis of thick walled cylinders to final radial & hoop stresses is applicable for the internal pressure up to yield strength of material. General application of Thick- Walled cylinders include, high pressure reactor vessels used in metallurgical operations, process plants, air compressor units, pneumatic reservoirs, hydraulic tanks, storage for gases like butane LPG etc. In this Project we are going to analyse effect of internal and External Pressure on Thick walled cylinder, how radial stress & hoop Stress will vary with change of radius. Contact pressure in shrink Fit and its effect on hoop stress and radial stress in analysed.

3.2. OBJECTIVES

CAD Design a Screw Compressor using AUTODESK INVENTOR for solid modelling. To perform optimization of the screw compressor housing using FEA

4. FINITE ELEMENT ANALYSIS

FEA analysis on the screw compressor is performed with below boundary conditions.

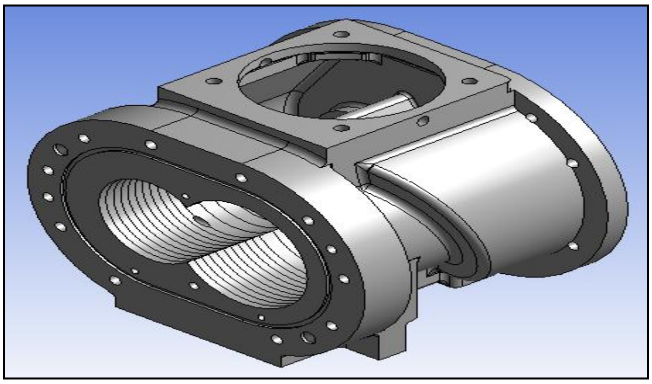


Fig -2: Geometry of the Designed Component 10 mm shell

Meshing is performed on the screw compressor housing below are the details on the meshing. 4mm mesh size is used for the meshing of the screw compressor casing. Solid elements in the shape of tetrahedrons are used. Total of 68000 nodes are used for meshing of the casing and 462000 elements are used for the meshing of the component.

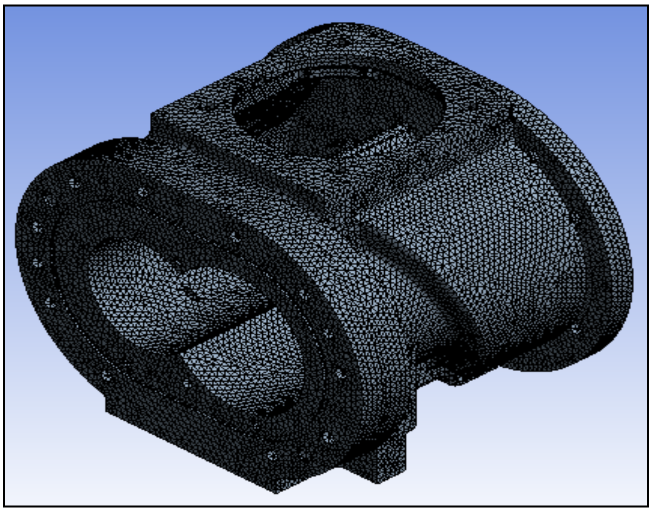


Fig -3: Meshing of the Casing

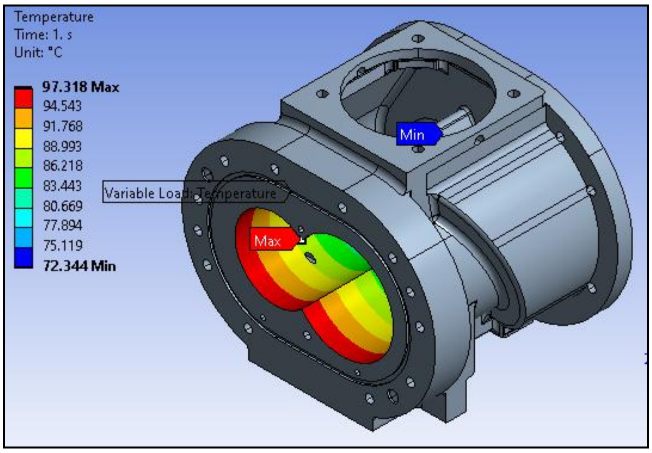


Fig -4: Temperature Boundary Condition

Thermal boundary condition is applied with varying temperature between 97 and 72 on the screw compressor inner body face of compression area. 35 degrees centigrade temperature is applied to rest of the internal faces of compressor casing.

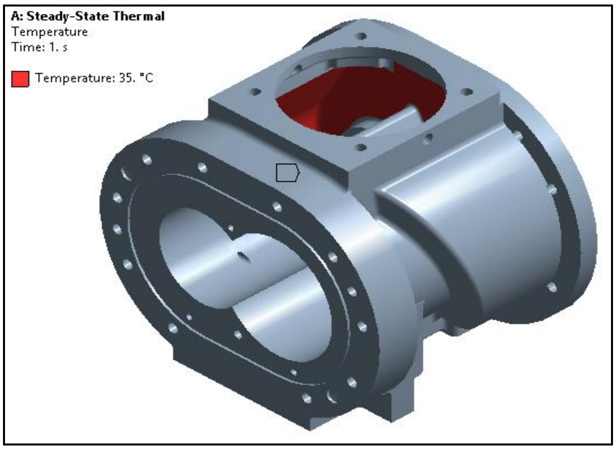


Fig -5: Temperature Boundary Condition

With given boundary conditions the static thermal analysis is ran to understand the pattern of the temperature distribution throughout. Thermal analysis results and other structural boundary conditions are used as a loading conditions in the static structural analysis on the screw compressor casing to understand the structural impact on the system due to temperatures and pressure.

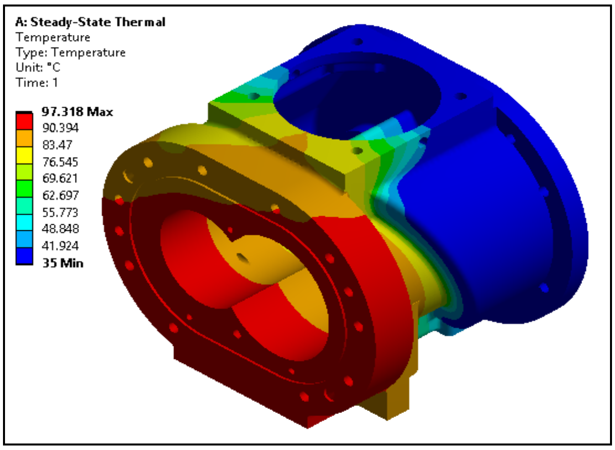


Fig -6: Temperature Plot for Screw Compressor Casing

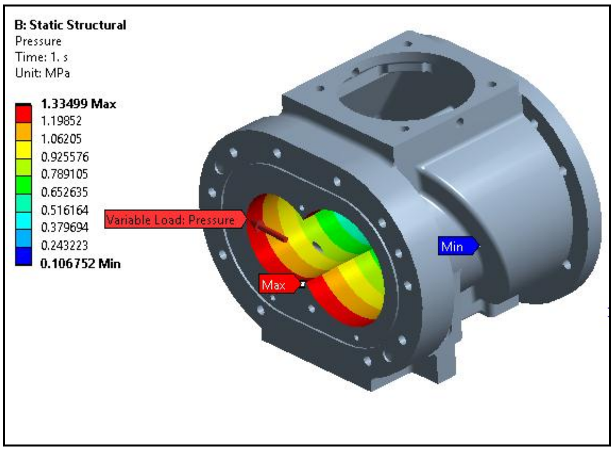


Fig -7: Pressure boundary condition

Equation is used to apply continuously variable pressure from inlet to outlet side of the compressor.

$$P = (((z-14.4) \times 0.0078883890736032)) + 0.125$$

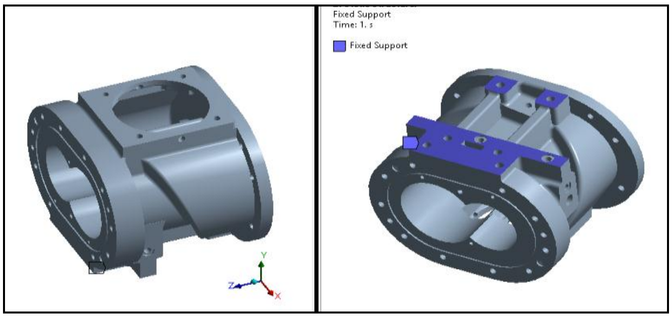


Fig -8: Fixed boundary condition

Fixing boundary condition is applied on the mounting area of the screw compressor body where is attaches itself with the rest of the mechanism. Temperatures from the thermal analysis are imported in this analysis to understand the impact of thermal temperature loadings on the structure of the screw compressor body combined with other structural forces.

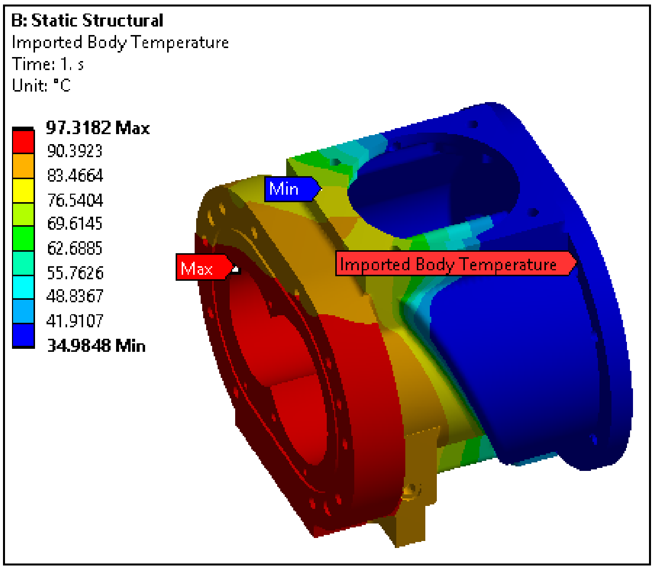


Fig -9: Imported body temperatures from the thermal analysis

Gray Cast Iron

Density	7.2e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.1e+05 MPa
Poisson's Ratio	0.28
Bulk Modulus	83333 MPa
Shear Modulus	42969 MPa
Isotropic Secant Coefficient of Thermal Expansion	1.1e-05 1/°C
Compressive Ultimate Strength	820 MPa
Compressive Yield Strength	0 MPa
Tensile Ultimate Strength	240 MPa
Tensile Yield Strength	0 MPa
Thermal	
Isotropic Thermal Conductivity	0.052 W/mm·°C
Specific Heat Constant Pressure	4.47e+05 mJ/kg·°C
Electric	
Isotropic Resistivity	9.6e-05 ohm·mm
Magnetic	
Isotropic Relative Permeability	10000

Fig -10: Imported body temperatures from the thermal analysis

Structural Analysis is performed on the compressor casing with the above boundary conditions and results are presented below from the same.

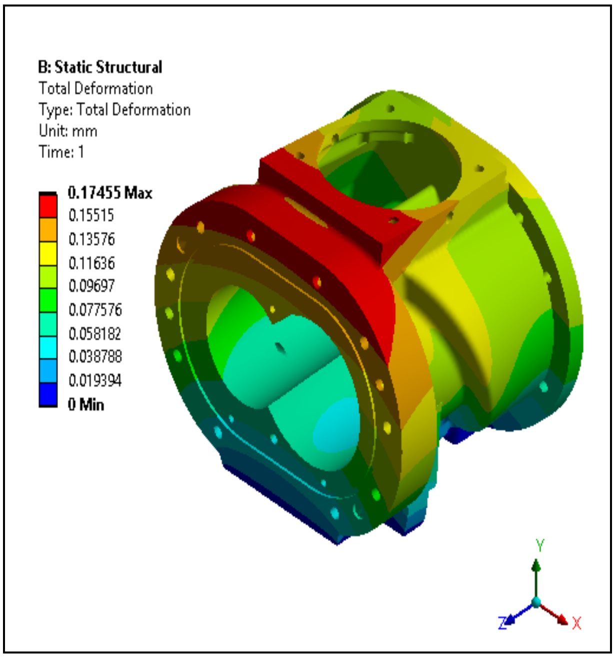
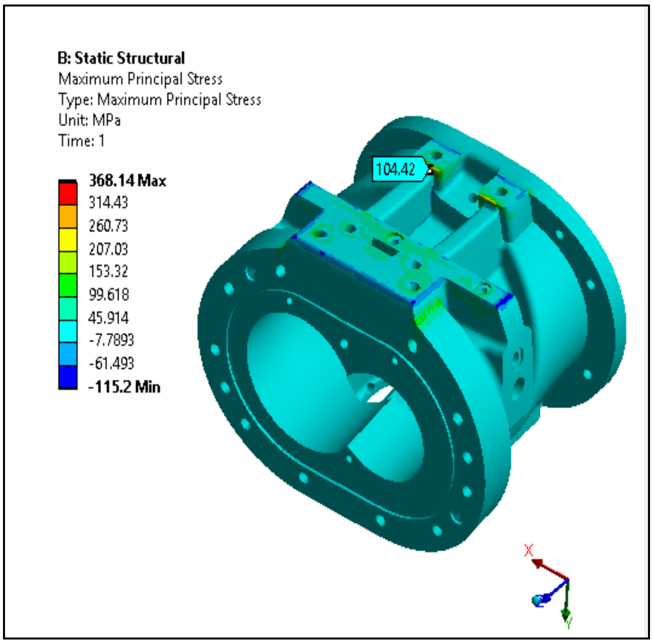


Fig -11: Imported body temperatures from the thermal analysis

Grey cast iron is the material used for the casing of the screw compressor so the stress we have to consider for the failure criteria is principal stress as per the failure theory guidelines.



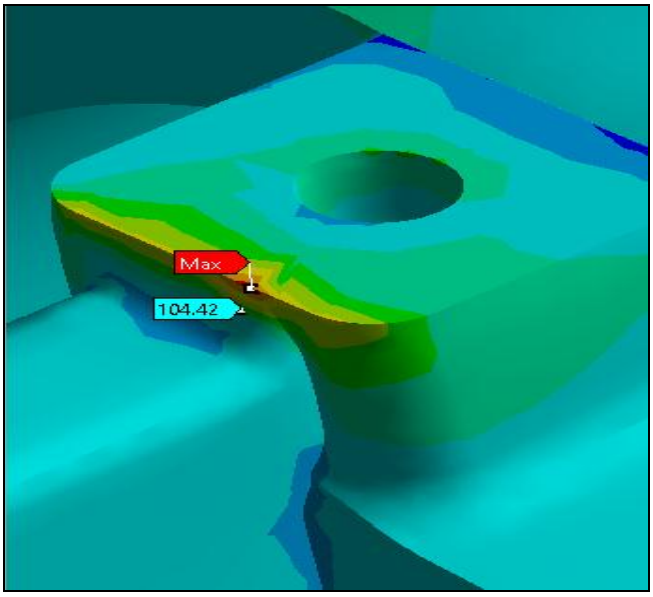
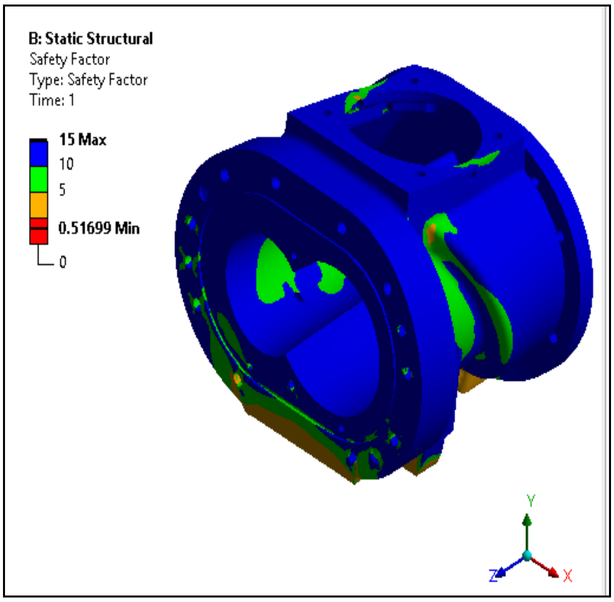


Fig -12: Maximum Principal Stress Plot

Maximum principal stress plot shows the reportable maximum stress of 104.4 MPa as indicated by the probe in the plot above. Value of the maximum shown in the plot is 368 MPa but it is due to fixing area singularity edge as it can be clearly seen in the plots. So couple elements away from the maximum stress observed is 104.4 MPa which is well within the acceptance criteria of the stress.



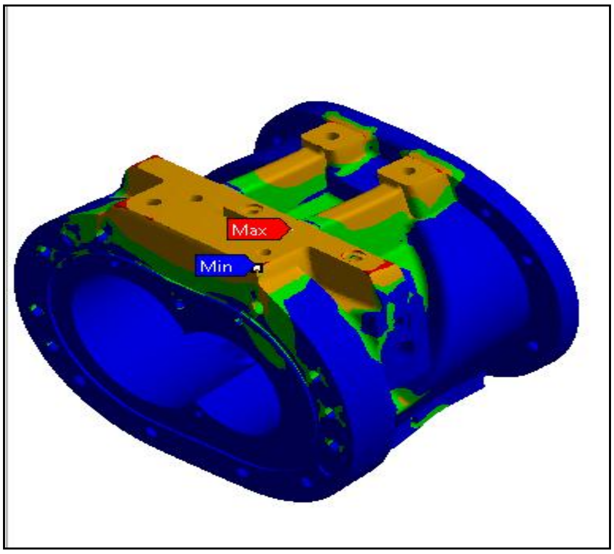


Fig -13: Safety factor plot at static structural analysis

Topology optimization is performed using topology optimization module of the ANSYS workbench in which the complete analysis set up results are imported and following inputs were provided for the analysis.

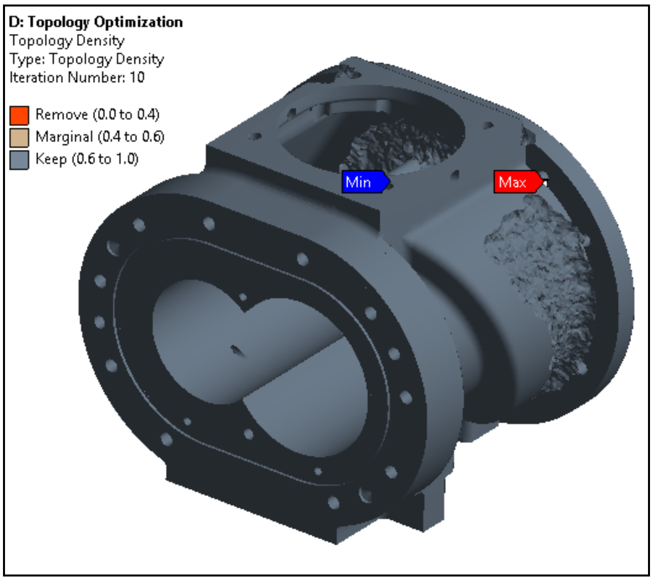


Fig -14: Optimization with 7 % weight reduction volume removed

7 mm deep cut of the highlighted area is performed on the areas highlighted by green from both sides of the screw compressor casing design. It has resulted in to 800 grams reduction of the overall weight of the casing which is approximately 3.3 % of the actual weight of the design. Weight of the new design is observed to be 23.8 kg.

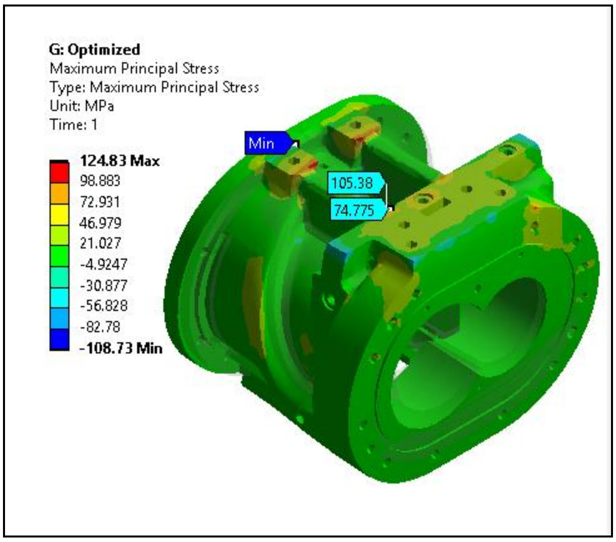


Fig -15: Maximum Principal Stress Plot optimized model

Maximum principal stress plot shows maximum value of the stress as 105 MPa which is well within acceptance limit in the grey cast iron stress limits.

Results are observed and following observations are made as shown in the table

Table Weight reduction per optimization module

Table -1: Weight reduction per optimization module

Sr No	Iteration	Weight (kg)
1	Original Design	24.6
2	3% Reduction	23.6
3	5 % Reduction	23.3
4	7 % Reduction	22.9

From optimization modules it is observed that 5 % reduction is the maximum possible reduction without harming the purpose of the designed entity.

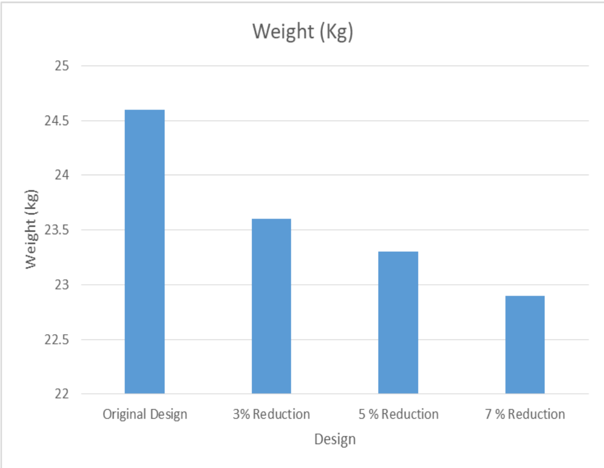


Chart -1: Weight vs Design Iteration

Table 3: Comparison of results

Sr.No	Design	Weight (Kg)	Max. Tem. (°C)	Total deform (mm)	Maximum Principal Stress (MPa)
1	Original Design	24.6	97.3	0.17	104.4
2	Optimized Design	23.8	97.3	0.17	105.4

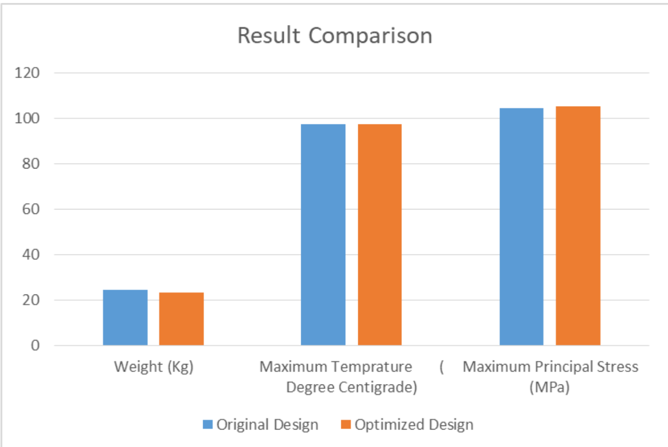


Chart -2: Graph of Results from Original and optimized design

5. CONCLUSIONS

Overall study of the screw compressor design and work done on the optimization of the model till now is studied and implemented in the current project successfully. Different dimension of the design and parameters with shape of the screw compressor housing is finalized using design formulae and the years of engineering expertise from the Kirloskar engineering division. Acceptance criteria for the design stresses are 120 MPa from the grey cast iron material properties considering 2 factor of safety on the tensile strength. Analysis of the original design has given us output as maximum deformation observed is 0.17 mm and principal stress observed is 104.3 MPa which are well within the acceptance criteria for the Grey cast iron which is 120 MPa. Optimized modules suggest different weights and areas from where the material can be reduced from which 5 % is observed to be the maximum weight that can be reduced by complying with the all the constraints as well as design purpose of the model. Final optimized model is created by following the optimized shape suggested by the optimization module and is observed that weight is reduced from the 24.6 kg to 23.8 kg. Stresses and deformations in the optimized module are within the acceptance criteria and design is safe according to principal stress failure theory.

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