Design Optimization of Alternator Pulley for Locomotives

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Abstract – *Computer Aided Design, Simulation & Optimization Study can greatly enhance productivity of designs. In this study, the Design of an Alternator Pulley for Locomotives has been analyzed using the Design Optimization Tool in SolidWorks Software to optimize the model for lesser design stress and higher strength to weight ratio, thereby reducing the pulley weight considerably to serve the purpose of the application and to save a considerable amount of material. This weight reduction was achieved by optimizing a key dimension of the design after performing several trials on the design to meet the design constraints and set goals. Accordingly, a strength to weight ratio increase of 45.95% was achieved with a weight reduction of 35.74%.*

***Key Words*: Alternator Pulley Design, Computer Aided Design, Simulation, Optimization etc.**

1. INTRODUCTION

Design Optimization Study involves setting up key design variables of the design accommodating different values of the set variables. Then the design stress constraints are set up based on the parent study design stress and a maximum design stress limit assigned. The most important aspect is to set up the goal of the study indicating a lower mass of the design without compromising the strength to weight ratio.

1.1 Features of V-belt Pulley

The V-belt alternator pulley used in this study was required to transmit 25 KW power generated from the wheels of the locomotive, which is fixed with an axle pulley, which serves as the input pulley. Both the pulleys were connected by V-belts. The alternator pulley is the output pulley which is keyed to a shaft. At the other end of the shaft is the rotor of the alternator which rotates inside a stator having field windings, which will be exited initially. The rotor will cut the magnetic field produced by the stator producing A.C. current which can be rectified to D.C and stored in the battery. This power generation serves for lighting and air-conditioning purposes of the locomotive coaches thus deriving their own power helping in energy conservation. The technical features of the V-belt pulley are summarized in Table-1.

Table-1: Technical Details of the pulley[1].

Technical Features	Unit (mm)
Pulley outer diameter (mm)	235.4
Pulley inner diameter (mm)	50.4
Pulley width (mm)	175
Depth of V-Groove	20

1.1 Pulley Design

The basic feature of the model was created using the revolve tool which requires a sketch to be rotated about an axis at 360^0 .The next step was to create the four ribs on the right side of the pulley which serves the purpose of clipping of the pulley for handling it. The final step was to create the two ribs on the left side of the pulley, which was also done by the extruded cut tool for a depth of cut of 28 mm to obtain the final model[1]. The pulley design is as shown in Figure 1.

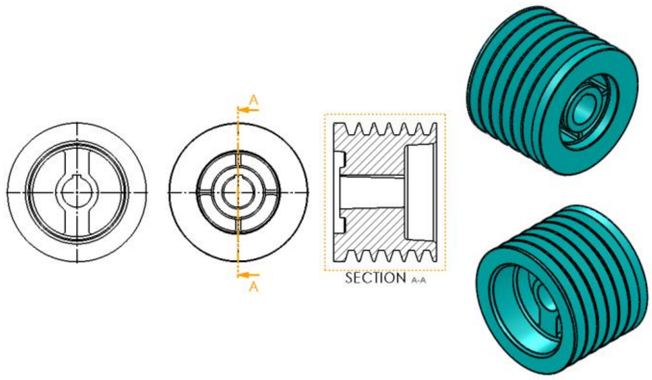

Fig-1. Pulley Design.

1.2 Simulation

The simulation was carried out with the help of Solid Works Simulation. Linear, Static and Isotropic analysis being performed on the pulley, which includes Material selection, Fixing Degrees of Freedom, applying loads, meshing, running the analysis and post processing.

The material was assigned to the pulley model from the material library of Solid Works Simulation using the apply material option of the Solid Works Simulation. The pulley material was Grey Cast Iron having the following material properties as in the Table-2.

Table-2: Material Properties[2]

Material	Gray Cast Iron
Elastic Modulus	110 GPa
Yield Strength of Material	80 – 100 GPa
Poisson's Ratio	0.28
Density	7200 kg/m^3

Details of the loading conditions are summarized in the following Table-3.

Table-3: Loading Conditions

Torque	96.77 N-m
Bearing Load	1920 N

Moderate meshing was employed, and the details of the meshing operation is summarized in Table-4. Refined mesh was used at areas of high stress concentration to yield better results. The meshed model is realized as showing in Figure 2.

Table-4: Mesh Information

Mesh Type	Solid Mesh
Mesher Used:	Standard Mesh
Number of elements:	24520
Number of nodes:	39146

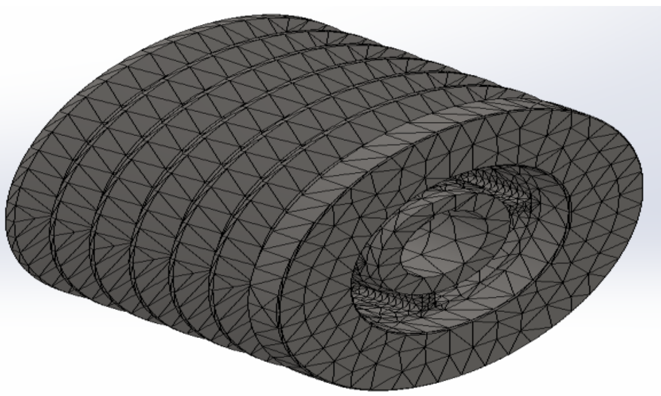

Fig-2. Meshed Model

The post processor includes plotting of the Von Mises Stress plot (Equivalent Stress plot) and the deformed shape. The Von Mises Stress plot as shown in Figure 3 indicates that the maximum Von Mises stress of 14.921 MPa was below the yield strength of the material (80-100 MPa) which proves the design to be within safe limits. The details of the results of the analysis are summarized in Table-5. The analysis can be re-run using much finer meshes to obtain closer approximations. The element sizes, aspect ratios can also be controlled to obtain more approximate solutions.

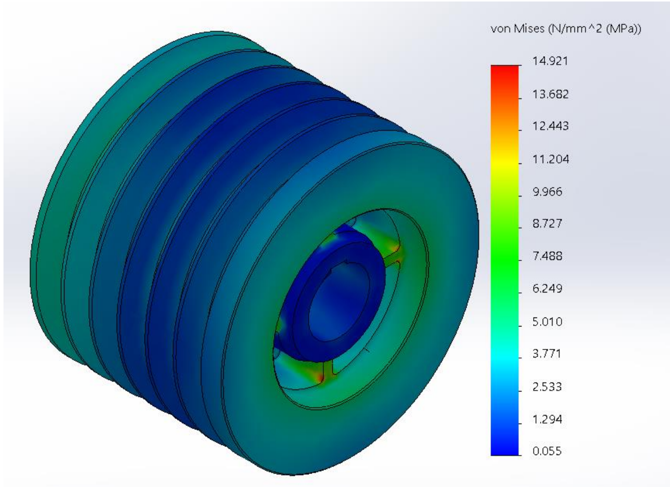

Fig-3. Von Mises Stress Plot.

Table-5: Results of Simulation

Name	Type	Min	Max
Stress	VON Mises Stress	0.055 N/mm^2 (MPa) Node: 2057	14.921 N/mm^2 (MPa) Node: 29338
Displacement	Resultant Displacement	0.000 mm Node: 1348	0.010 mm Node: 1211
Strain	Equivalent Strain	0.000002 Element: 15279	0.000158 Element: 19034

2. DESIGN OPTIMIZATION

The major part of the study was to optimize the pulley design based on the initial simulation study results used as input for the design study. The optimization study was set as per the details in Table-6. Accordingly, 39 scenarios were run based on the variable set, constraints induced leading to a fixed goal of mass reduction and enhanced strength to weight ratio for the pulley design. The optimized model design was simulated separately to obtain the Von Mises Stress plot.

Table-6: Properties of Optimization Study

Properties	Details
Study Name	Design Study
Analysis Type	Design Study (Optimization)

Design Study Quality	High Quality (Slower)
Design Variable	Pulley Outer Diameter (Range 200 to 235.4 with step of 1mm)
Design Constraint	Von Mises Stress (Less than 80 MPa)
Design Study Goal	Minimize Mass

2.1 Results of the Design Optimization Study

The results of the Design Optimization Study have been summarized in Table-7. 39 scenarios were run to perform the study and some of the scenarios have been tabulated. Most importantly the optimized result has been achieved successfully.

Table-7: Results of Optimization Study

Scenario	Pulley Diameter (mm)	Von Mises Stress (MPa)	Mass (g)
Initial	235.4	14.921	4102.7
Optimal	200	14.164	2636.2
Scenario 2	201	14.02	2674.3
Scenario 3	202	14.523	2712.7
Scenario 16	215	13.2	3228.5
Scenario 26	225	16.39	3647.2

The optimal results indicated a strength to weight ratio increase of 45.95% from the initial study along with a design weight reduction of 35.74% without any distortion in the pulley design. The optimization results were used to run the design simulation on the optimized model and the Von Mises Stress Plot is as shown in Figure 4.

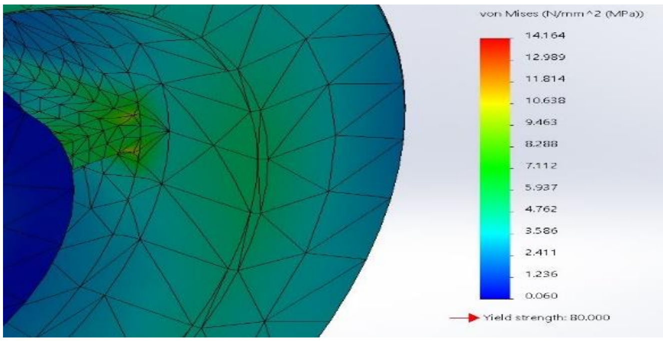

Fig-4. Von Mises Stress Plot of the Optimized Model.

3. CONCLUSION

Design Optimization Study is a very important aspect of the design process. This study can yield very good results in the design phase with respect to the enhanced strength to weight ratio along with weight reduction of the model leading to material saving and cost reduction. The Design Optimization Study can be used further to analyze with different materials of the model and yield even better results and can lead to an important decision of Material Selection for Design and Manufacturing.

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