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MODELING AND STRESS ANALYSIS OF ALTERNATOR PULLEY FOR LOCOMOTIVES

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ABSTRACT- Computer-aided design and simulation software can greatly enhance productivity, quality assurance and casting yield, their penetration in small and medium foundries and engineering companies has been poor. The aim of this study was to analyse the performance of a V-belt pulley, which is used in the alternator of a locomotive engine. Finite Element Analysis (FEA) was used to simulate pulley deformation. The torque and maximum bearing load being calculated. After FEA solution process, maximum operating stress values were examined. The simulation stress results were obtained with the help of Solid Works Simulation and results were compared with the yield strength of the pulley's material. Hence, the operating condition identified was satisfactory for the expected performance. Even though, there might be a chance of pulley failure due to material and manufacturing fault. As a conclusion, according to the simulation evaluation results, suggestions were made in order to prevent the pulley damage due to fracture.In addition, scope for optimization of the pulley design discussed.

Key words: Solid Works Simulation, Finite Element Analysis.

1. INTRODUCTION

1.1 OUTLINE OF THE WORK

The paper will particularly aim for the integration of the disciplines mechanical engineering and computer science and technology. It will emphasize the importance of current developments; discuss the future trends with valuable results and analysis. Engineers have been interested in analysing failures occurring in different mechanisms for many years. They will use analytical, experimental and numerical, methods in failure analysis.(Montgomery, D. C., 1997)[6].We cannot obtain exact solutions with analytical method for many practical engineering problems. This inability to obtain an exact solution may be attributed to either the complex nature of governing differential equations or the difficulties that arise from dealing with the boundary and initial conditions. Numerical approximations are generally used to deal with such problems.The latest software tools combine heuristic knowledge, geometric reasoning and information management. They assists in designing, modelling, simulating, analyzing and improving cast products over an industry thereby providing a glimpse of the way castings will be designed in future. (Maria. A., 1998)[5]

The aim of this study was to analyze the performance of a V-belt pulley, which is used in the alternator of locomotives. Finite Element Analysis (FEA) was used to simulate pulley deformation. The torque and maximum bearing load calculated by pulley power were 96.77 N-m and 1920 N, respectively at anRPM of the pulley 2500 rpm and power to be developed as 25 KW. After FEA solution process, maximum equivalent stress of 14.92 MPa was determined. The simulation stress results were compared with the yield strength of the pulley's material (80-100 MPa) and found that the maximum stress was well below the yield strength of the material. Hence, the operating condition identified was satisfactory for the expected performance.

2. FINITE ELEMENT METHOD

2.1. FINITE ELEMENT CONCEPT

The finite element method (FEM) is a computer-aided mathematical technique for obtaining approximate numerical solutions to the abstract equations of calculus that predicts the response of physical systems subjected to external influences.

- A problem domain is divided into regions called elements. The collection of elements is called a mesh.
- Governing equations are transformed into approximate algebraic (element) equations.
- Equations are numerically evaluated for each element in the mesh and assembled based on the element connectivity.

- Boundary conditions are imposed that modify the system of equations; values are added to existing terms are shifted from one side of the equations to the other.
- The system of equations are solved.
- Post-processing of the solution provides displays in tabular, graphical or pictorial form.

2.2. HOW DOES FEM WORK ?

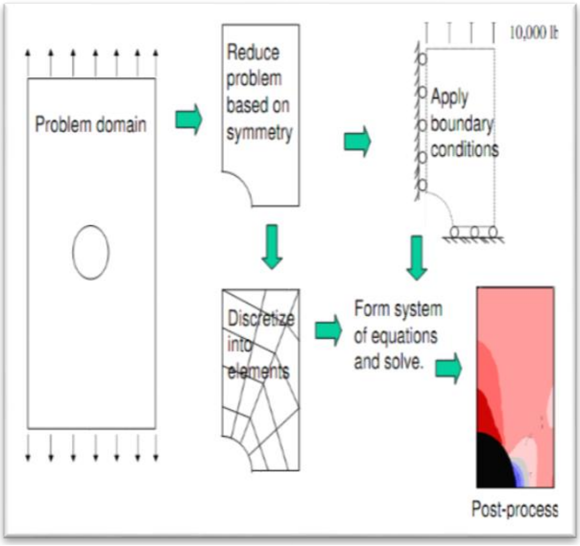

Fig.2.1. Finite Element Procedure

2.3. FEATURES OF V-BELT PULLEY MECHANISM

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.

Table 2.1. Technical Details of the pulley.

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

2.4. THE FINITE ELEMENTS ANALYSIS ON THE PULLEY

Analysis was generated with an approach of linear, static, and isotropic material state. Solid, Standard mesh was used to prepare mesh contraction of pulley model; 39146 total nodes and 24520 total elements were obtained after meshing operation. Assumed properties of material of pulley and accounted forces from the machine parameters were applied to model according to working conditions. Torque and maximum bearing load determined by pulley power were 96.77 N-m and 1920 N, respectively. Material of pulley was assumed as Gray Cast Iron in FEA operation. Mechanical magnitudes of material model were chosen from SOLID WORKS material library. Young modulus, Poisson's ratio and density were assigned as 110 GPa, 0.28 and 7200 kg/m^3, respectively. Maximum Von Misses Stress, determined after FEA solution process, was 14.92 MPa**(Fig 4.2)**.

2.5. SOLID WORKS SIMULATION

Simulation is the imitation of some process used for performance optimisation at testing.Solid Works Simulation offers an easy to use first pass stress analysis tool for Solid Works users. It supports the analysis of a single solid body as well as an assembly. Simulation reduces cost and time-to- market by testing the designs on the computer instead of expensive and time-consuming field tests. The accuracy of result depends on fixtures, loads and material properties. Solid Works simulation includes static, frequency, buckling, thermal, drop test, fatigue, non-linear, linear dynamic and pressure vessel design analysis. It also has flow simulation feature for flow problems. The simulation express has options of assigning material to the part thereby the properties of the material. There is option for fixing the required degree of freedom for constraining the necessary portion of the model. (Maria. A, 1998)[5]

3. MODELING OF THE PULLEY

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 was given to obtain the final model. The pulley model drawingsareas shown in the following **Figure 3.1.**

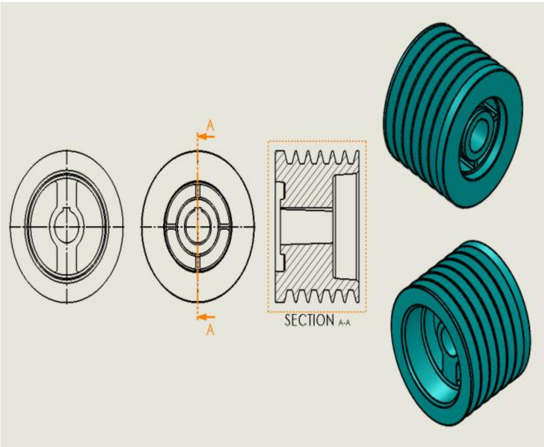

Fig 3.1. Pulley Model Drawings.

4. 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 4.1**:

Table 4.1. Material Properties

Material	Gray Cat 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 as per the details in the following **Table 4.2.**

Table 4.2. Loading Conditions.

Torque	96.77 N-m
Bearing Load	1920 N

The mesh was created using the create mesh option available in the simulation environment as shown in **Figure 4.1.** Moderate meshing was employed and the details of the meshing operation is summarized in **Table 4.3.**Refined mesh was used at areas of high stress concentration to yoield better results.

Table 4.3. Mesh Information

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

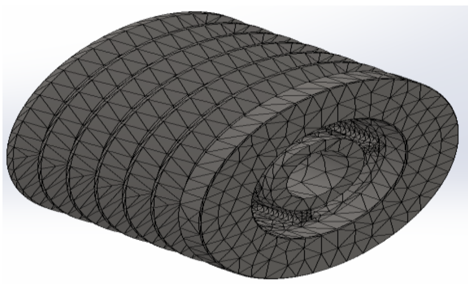

Fig 4.1. Meshed Model

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 **Figure4.2**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 4.4.** 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.

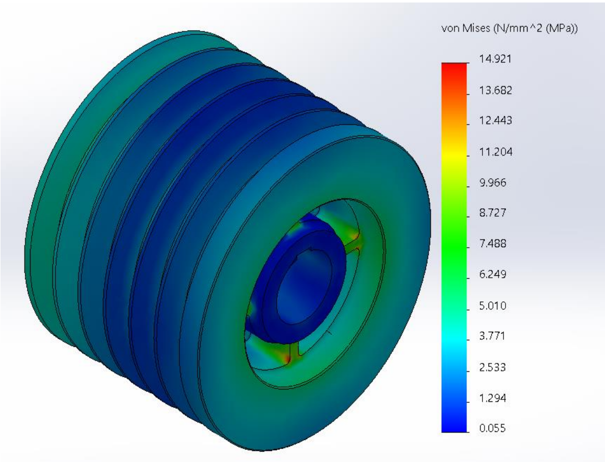

Fig 4.2. Von Mises Stress Plot**.**

Table 4.4. Results of Analysis**.**

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.055 N/mm^2 (MPa) Node: 2057	14.921 N/mm^2 (MPa) Node: 29338
Displacement1	URES: Resultant Displacement	0.000 mm Node: 1348	0.010 mm Node: 1211
Strain1	ESTRN: Equivalent Strain	0.000002 Element: 15279	0.000158 Element: 19034

5. CONCLUSION

The simulationwas carried out to analyse the performance of a V-belt pulley, which is used along with the alternator of a locomotive engine. Finite Element Analysis (FEA) was to simulate pulley deformation. The torque and maximum bearing load calculated by pulley power were 96.77 N-m and 1920 N, respectively assuming RPM of the pulley 2500 rpm and power to be developed as 25 KW. After FEA solution process, maximum equivalent stress of 14.92 MPa was determined. The simulation stress results were compared with the yield strength of the pulley's material (80-100 MPa) and found that the maximum stress was well below the yield strength of the material. Hence, the operating condition identified was satisfactory for the expected performance. Even though, there might be a chance of pulley failure due to the material and manufacturing fault. According to the simulation evaluation results, suggestions were made in order to prevent the pulley damage due to fracture.The recommendation will also be to optimize the pulley design, as the Factor of Safety for the design is around 5.36, which is quite high and can be reduced to around 3, so that the intended design function can be achieved with careful design considerations.

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