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Finite Element Analysis of Safety Pin in Snowplow Equipment

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ABSTRACT

Snow plow equipment is produced with chassis connections suitable for trucks, pickup trucks, tractors, construction machines and pick-ups and mounted in front of the vehicles. In this study, the stress and deflection values of the safety pin used in snow plow equipment will be examined by testing with finite element analysis. In this study, a damaged safety pin was analyzed numerically. The damaged safety pin was modeled with Solidworks package program and stress analysis was performed by ANSYS Workbench package program. In this analysis, the properties of the safety pin made of St37 steel were used. As a result , it was observed that the safety pin was damaged due to the stress distribution.

1. INTRODUCTION

Snow plows are vehicles that clear the roads and open them to transportation in cases where there is heavy snowfall that prevents transportation. It is mounted on dump trucks as front and side snow blades for snow removal. Salt spreader and front snow blade can be installed on the dump truck with a capacity suitable for the needs of the institution. Side snow blades can also be fitted on high-capacity trucks [1]. Shafts; bearing rotating elements such as gear wheels, pulleys, clutches; providing force/moment transmission; are machine elements supported by bearings. The shaft carries the elements attached to it. In addition, the clutch transmits the torque it receives from the gear wheel or pulley to other elements [2]. Shafts are forced by torsional moment during power transmission with rotational speed. As a result, torsional stress occurs in the shaft. In addition, the power transmission elements on the shafts apply force to the shafts. With the effect of these forces, the shafts are also forced to bend. Since normal stresses occur simultaneously in any section of a power-transmitting shaft due to torsional stress and bending, the equivalent stress is taken into account when dimensioning the shaft [3]. Shaft design is the accurate determination of the shaft diameter to provide sufficient strength and rigidity under various operating and loading conditions [4]. Only the bending condition applies to Axles. If it is in torsion then its name will be shaft. Therefore, the axles do not transmit the torque from the engine. They carry the loads on them just like a beam. If the axle is rotating or there is a vibrating load on it, they must be calculated according to the continuous strength, as with the shafts. For this reason, the safety stresses to be used should also be the safety stresses taken according to the continuous strength [5]. Due to the power transmission elements on the shafts, they are forced by shear force, bending moment, torsion moment and axial force. The shaft diameter is calculated by including the physical properties of the shaft material, the positions of the supporting and power transmission elements on the shaft and their effects on the shaft [6-8]. In the light of this information, the designer can determine the diameters required for different regions of the shaft. Adin et al. introduced the mechanical properties of the damaged helical gear to the system and performed the mesh operation by selecting the mesh structure. As a result, they realized that it would be possible to prevent the wrong material selection, which is the biggest damage cause, with the help of numerical analysis [9]. Yavuz et al. in their study; analyzed the damage analysis of a car's disc brake system. In addition, the damaged brake disc was analyzed by the finite element method. As a result, they determined that lamellar graphite cast iron was used as disc material in experimental studies [10]. Yavuz et al. in their study; investigated the fractured surfaces of a machine gear with a spur gear profile that was damaged by fracture. As a result, according to the literature review, they observed that the hardness value was high in the material and ductile fractures were observed due to the ferrite phase formed at the grain boundaries. [11]. Erdogan et al. in their study; performed damage analysis of the gearbox of BMC 935 trucks. As a result, they found that gearbox damage was caused by fatigue [12]. Considering the stress concentrations caused by the cross-sectional differences, the variability of the forces acting on the shaft, the control of the stiffness of the shafts, and the fact that the shaft can be made hollow in the calculation of the diameters, the necessity of using a computer automatically emerges. Snowplow equipment is positioned suspended in the air with the help of pistons when the vehicle is not in use while in motion. A safety system is used to prevent the weight of the snowplow equipment suspended in the air from damaging the pistons. In this study, the damaged safety pin was redesigned and improved by the authors. The values of both safety pins were compared.

2. MATERIAL AND METHOD

The carbon ratio of St 37 steels is around 0.20 maximum. It is the softest of the hot rolled steels. St 37 quality steels are known for their features such as being easy to process, welding and cutting without problems. It is one of the most preferred types of steel construction structures. St 37 (s235) quality class steels come first among the commercial grades of structural steel construction profiles and sheets [13]. The 3D redesign was made for the safety pin by reverse engineering with the help of Solidworks design program as shown in Figure 1. Dimensions were detailed in the technical drawing section.

The physical and chemical properties of the safety pin material were given in Table 1. and Table 2.

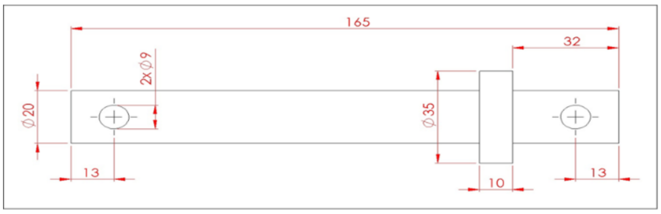

Figure 1. Technical drawing of safety pin

TABLE I.
CHEMICAL PROPERTIES OF SAFETY PIN MATERIAL

Chemical Properties - 1.0037 (S235JR)						
C	Mn	P	S	N	Cu	CEV
0,18-0,2 %	1,4-1,6 %	0,04-0,045 %	0,04-0,045 %	0,009-0,012 %	0,45-0,55 %	0,30-0,38 %

TABLE II.
PHYSICAL PROPERTIES OF SAFETY PIN MATERIAL

Type	1.0037 (S235JR)
Model	Isotropic Linear Elastic Analysis
Failure Criteria	Von Mises
Yield and Tensile Strength	2.35e+8 and 3.6e+8 N/m^2
Elastic Module	2.1e+011 N/m^2
Poisson Ratio	0.28
Mass Density	7800 kg/m^3
Thermal Expansion Coefficient	1.1e-005 /Kelvin

3. RESULT AND DISCUSSION

After using the snowplow equipment for a certain period of time, bending of the safety pin was observed as shown in Figure 2. After this stage, the use of the pin was not considered appropriate.

Figure 2. Bending condition of the safety pin after use

As shown in Figure 3, the safety pin was fixed during the analysis process. While loads are applied to the system as input data, supports are used to fix the system. In a three-dimensional system, each element has 6 degrees of freedom, 3 rotational and 3 translational. Supports are implemented by limiting these degrees of freedom belonging to the element. Boundary conditions must be chosen carefully. Minor errors in boundary conditions can drastically alter the result. The two intersecting surfaces of the safety pin and the other two models used in the snowplow equipment were used as fixed in the analysis phase. All bending analyzes were done with solidworks package program.

Figure 3. Surfaces fixed in bending analyzes

As can be seen in Figure 4 on the snowplow equipment, the load was acted in the middle of the safety pin. The force direction on which the load acts was unidirectional and was acted on a single surface. The force had a value of approximately 25000 N.

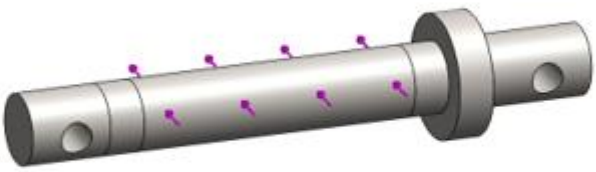

Figure 4. Forces applied in bending analyzes

The mesh view of the safety pin for which bending analyzes were made was given in Figure 5.

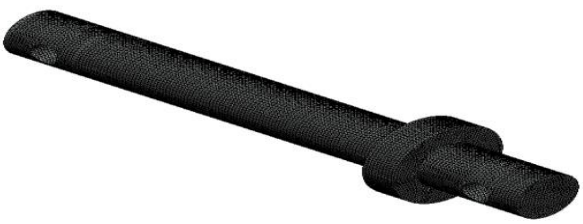

Figure 5. Safety pin mesh view

In the mesh structure given in Figure 5, there were 268365 mesh elements and 51298 nodes. Triangular meshes with good mesh quality with an element size of 1 mm were cast on the safety pin. Due to the fact that the safety pin did not have a complex geometry and the computer used was powerful, the completion time of the mesh was 53 seconds.

The reaction forces of the safety pin after the analysis performed were given in Table 3.

TABLE III.
THE REACTION FORCES OF THE GEAR

	X	Y	Z	Result
Reaction Forces (N)	-0.077755	-0.168421	24999.8	24999.8

As shown in Table 3, the safety pin was fixed during the analysis process. The two intersecting surfaces of the safety pin and the other two models used in the snowplow equipment were used as fixed in the analysis phase.

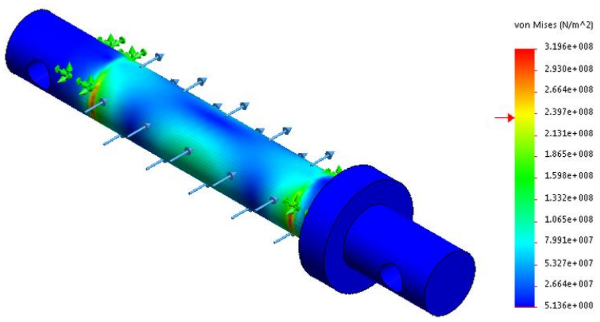

Figure 6. 20mm safety pin diameter - von mises stress value

When the pin diameter shown in Figure 6 was selected as 20 mm, Von Mises Stress values exceed the yield value of the material in the analysis. In the model seen in Figure 6, color changes occurred from blue to red. The colors corresponding to the numerical values on the right side of the graph showed the stresses that occur as a result of the analysis in geometry. Tensile values increased towards red color. The maximum stress value seen in the graph was 319.64 MPa. In geometry, two different support (fixing) locations were selected. The load was applied between the two supports. The maximum stress value occurred in the areas where the support points were. The stress values formed in the support areas exceeded the yield value of the material. The maximum stress value on the contact surface of the force increased up to 133 MPa. The stresses on these surfaces did not exceed the yield value of the material. The minimum stress (close to zero) occurred on the surfaces where the force was not applied and outside the support areas.

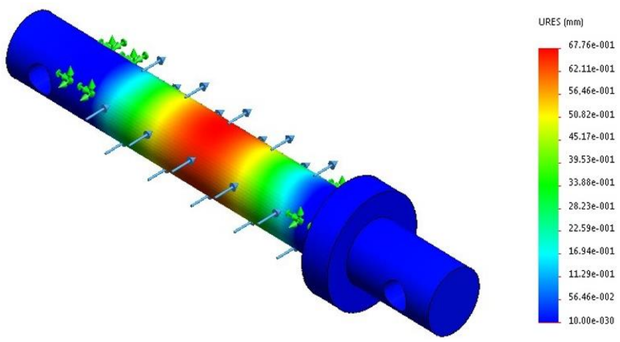

Figure 7. 20mm safety pin diameter - displacement values

When the pin diameter shown in Figure 7 was selected as 20 mm, the deflection values were seen in the analysis. In the model seen in Figure 7, there were changes in deflection values from blue to red. In the graph on the right, the maximum increase in deflection value was seen in red. The maximum deflection value seen in the graph was 6.77 mm. The deflection values at the support points increased up to 3 mm. The maximum deflection value was obtained by increasing the deflection value up to 6.77 mm on the surface where the force contacts. On the surfaces where the force did not come into contact, the deflection value was almost equal to zero.

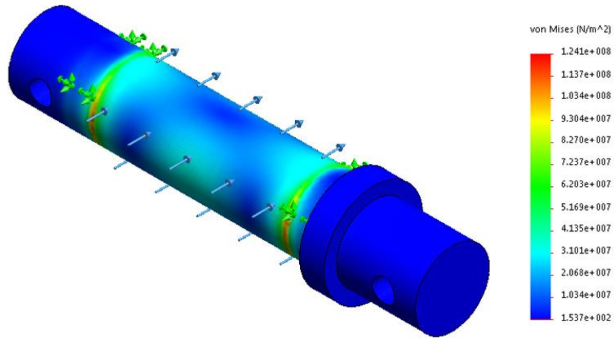

Figure 8. 30mm safety pin diameter - von mises stress value

In the analysis performed when the pin diameter shown in Figure 8 is 30 mm, Von Mises Stress values did not exceed the yield value of the material. In the model seen in Figure 8,

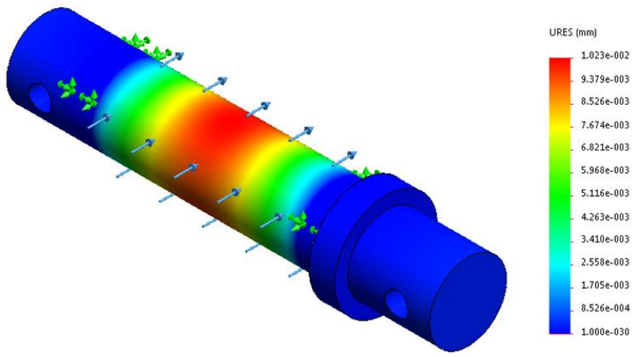

Figure 9. 30mm safety pin diameter - displacement values

When the pin diameter shown in Figure 9 was selected as 30 mm, the deflection values were seen in the analysis. In the model seen in Figure 9, there were changes in deflection values from blue to red. In the graph on the right, the maximum increase in deflection value was seen in red. The maximum deflection value seen in the graph was 0.01 mm. The deflection values at the support points increased up to 0.04 mm. The maximum deflection value was obtained by increasing the deflection value up to 0.01 mm on the surface where the force contacts. The deflection value on the surfaces where the force did not contact and on all surfaces of the geometry in general was almost equal to zero.

4. CONCLUSION

In this study, finite element analysis of the safety pin used in snowplow equipment was made using solidworks simulation program, and stress and deflection values were examined. In the analysis phase, attention was paid to boundary conditions, mesh values and material properties. The analysis was carried out using the pin diameter of 20 mm in Figure 6 and Figure 7, which was seen in the results of the study. The safe yield value of St37 material was 235 MPa. In Figure 6, the maximum stress value was 319.64 MPa. The maximum stress value in the safety pin exceeded the safe yield value in the St37 material. The system was 1.36 times unsafe. In Figure 7, a deflection of 6.77 mm was observed. As the yield value and deflection value increased after the analysis, it was not considered appropriate to reuse the pin after this stage.

The diameter of the safety pin was increased from 20 mm to 30 mm and reanalyzed. The maximum stress value in Figure 8 was 124 MPa. Since the material did not exceed the safe yield value, the system was 1.89 times safe. In Figure 9, the deflection value was observed as 0.01 mm. As a result, the pin diameter increased to 30 mm and the safety pin became more durable. The deflection value also improved, reaching zero.

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BIOGRAPHIES

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