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STRESS ANALYSIS OF GEAR SHIFT FORK WITH MASS OPTIMIZATION

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ABSTRACT

This study focuses on stress analysis and optimization of a gear shift fork. The main function of the gear shift fork is to enable proper engagement and disengagement of the required gear to achieve a specific transmission ratio. The aim of this study is to create a new optimized design of the fork and perform an analysis. Using Autodesk Inventor 2023 software, a 3D model of the fork is created, a finite element mesh is generated, and a static analysis of the old and new model is performed under identical constraints and loads. Using the Shape Generator option within Autodesk Inventor software, optimization which lead to a reduction in the mass of the part by 23% is performed. However, the analysis results show that the maximum Von Mises stress increases in the optimized model.

Keywords: analysis, stress, gear shift fork, optimization, Autodesk Inventor

INTRODUCTION

Today, in industry, saving materials, energy and production time are key factors for increasing the efficiency and profitability of production. That's why optimization has become an indispensable stage in the process of constructing a product. The industry demands that the negative characteristics be minimized and the positive ones maximized in order to optimize the products as much as possible. Due to the rapid development of technology, where nuances are important for market success, optimization is essential. In order to optimize, methods for minimizing mass, cost and the like are often applied. Therefore, there are numerous studies and publications that deal with the optimization and analysis of different structures.

The main function of the fork is to enable the gears to be engaged and disengaged, depending on the desired gear ratio. The main function of the gearbox is to adjust the position of the fork to achieve the engagement between the desired gears and the synchronizer ring. During gear shifting, the fork is exposed to loads, which makes it necessary to check the loads acting on it in order to ensure its long service life.

In order to increase the reliability of the system, the paper (Bo et al., 2015) analyzed the strength and stiffness of the gear shift fork. For this purpose, a 3D model of the fork and a mesh of finite elements were used, which analyzed the effects of force of different values on strength and stiffness. Research results show that the highest stress concentration appears on the lower part of the fork under the action of a force of 1500 N. These results can be applied in practice to improve the performance of automatic mechanical transmission. The publication (Qiangwei, 2017) shows the static analysis of the fork of the truck gearbox, which also shows the presence of the highest stresses under the action of a force of 1500 N. Based on the analysis, the stress distribution and vibrations occurring during operation were obtained. A vibration control scheme was proposed in accordance with the obtained results.

The paper (Joshi, & Sharma, 2018) shows the stress distribution on the old fork model with v block and on the new one without it. The analysis showed that the deformation displacements are the same on both models, but that the stress on the new model without the v block are lower compared to the old one.

The publication (Patel et al., 2015), refers to the accuracy of the manufacturing of the gear shift fork. A new 3D model was designed that reduces production time, increases efficiency, and achieves material saving. Also, in the paper (Jianjun et al., 2016), the method of manufacturing the gear shift fork was discussed in order to achieve the best possible quality of the transmission system. A mathematical model was developed to determine the most favorable parameters of the actuator, which would ensure fast and precise shifting of the gearbox. An actuator based on a pneumatic cylinder was designed. This actuator has been shown to have good performance in terms of gear shifting speed and precision. These results are important for the development of electric vehicles and the development of appropriate technology that would enable efficient gear shifting and thereby improve vehicle performance. Also, these results can be useful in further research concerning the development of gearboxes for electric vehicles.

The relationship between fork stiffness and performance of a five-speed manual transmission is described in (Jaideep et al., 2013). Greater stiffness of the gear shift fork can lead to an improvement in the quality of the transmission. It has been shown that the stiffness of the gear shift fork can be increased in several ways, including increasing the thickness of the fork and using materials with a higher modulus of elasticity. The results of the research show that the influence of the stiffness of the gear shift fork on the quality of the transmission is most pronounced at low speeds and lower loads, while the influence is smaller at higher speeds and higher loads.

This paper presents the results of the static analysis of the transmission fork, the optimization and the static analysis after the optimization, that is, the mass reduction. After the analysis, the area with the highest stress concentration was obtained, then the mass of the part was reduced by 23%, after which the analysis was carried out again.

MATERIAL AND METHOD

The gear shift fork model was created in Autodesk Inventor 2023 software package, as shown in Figure 1 (Autodesk, 2023).

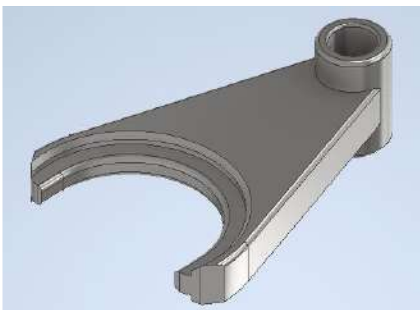

Figure 1. 3D model of the gear shift fork.

The material from which the fork is made is carbon steel. After the fork model was made, a static analysis was performed to determine the place with the highest stress concentration. The Shape Generator option, available in the Autodesk Inventor 2023 software package, was then applied to optimize the model.

RESULTS

After the formation of the 3D model, a simulation was performed that shows the places with the highest stress concentration under the action of a force of 100, 200 and 500 N. The obtained results are shown in Figures 2, 3 and 4.

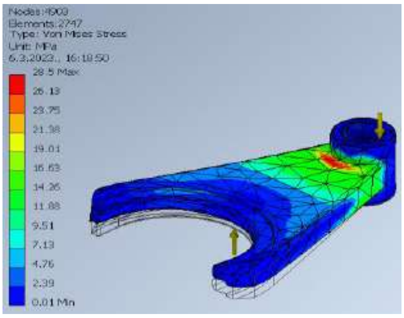

Figure 2. Stress distribution under the force of 100 N.

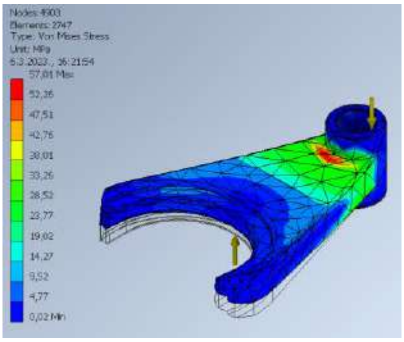

Figure 3. Stress distribution under the force of 200 N.

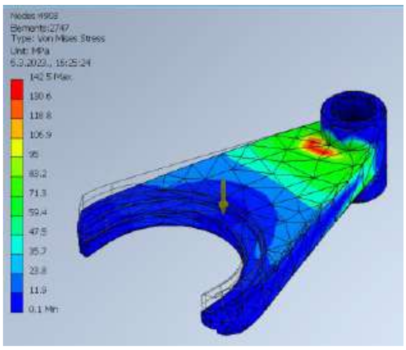

Figure 4. Stress distribution under the force of 500 N.

The results show that the maximum Von Mises stress of 142.5 MPa occurs at a load of 500 N.

The next step is mass optimization, through the Shape Generator option, in which mass is reduced by 23%. By specifying loads and constraints, the program generated an area where the mass of the part will be reduced, as shown in Figure 5.

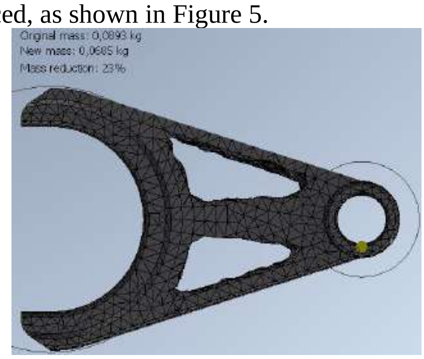

Figure 5. Part optimization.

In order to check the places with maximum stress concentration, a static analysis was performed again on the optimized model. Figure 6 shows the results obtained when the fork was loaded with a force of 500 N.

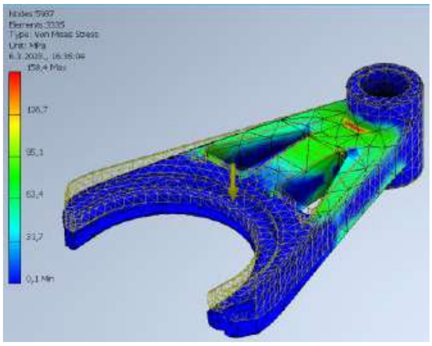

Figure 6. Stress distribution under the force of 500 N on the optimized model without rib.

Then, another modification was made to the model by adding a rib at the location of the highest stress concentration. The results of the static analysis of the optimized fork with the rib are shown in figures 7, 8, and 9.

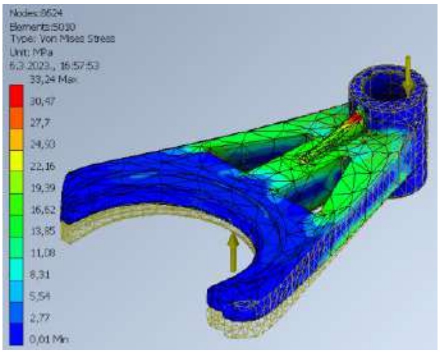

Figure 7. Stress distribution under the force of 100 N on the optimized model.

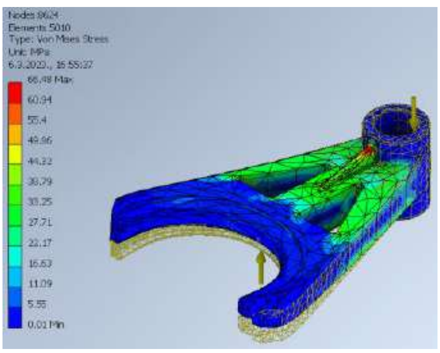

Figure 8. Stress distribution under the force of 200 N on the optimized model.

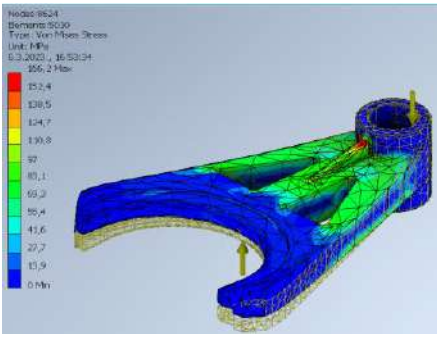

Figure 9. Stress distribution under the force of 500 N on the optimized model.

According to the analysis results, the maximum Von Mises stress occurs at the point of the rib to the cylindrical surface. The maximum stress value of 166.2 MPa occurs under the action of a load of 500 N. Figure 10 shows the results of the analysis before and after optimization with the given tabular values.

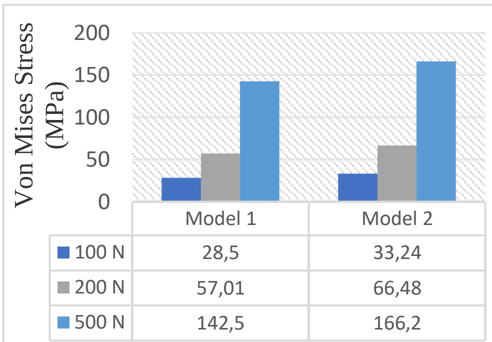

Figure 10. Results before and after optimization.

DISCUSSION

Based on the results, it can be concluded that the Von Mises stress increases in proportion to the increase in load. On the first model, which is not optimized, stress have lower values compared to the new model. After optimization, reinforcement in the form of ribs was added to reduce the maximum stress on the edges of the openings located on the lightened part of the fork. By adding a rib, the maximum stress is transferred to the part between the cylindrical part, which is mounted on the shaft and the rib. In the optimized model, there was an increase in the maximum stress due to the added reliefs in order to reduce the mass.

Compared to the results obtained in (Bo, Wenqing, Yiqiang, & Shanshi, 2015), the same data were obtained that when the force value increases, voltages increase proportionally. Works differ in stress distribution due to different fork construction.

CONCLUSIONS

In order to present the optimization procedure, this paper presents the structural optimization of the gear shift fork, whereby the weight of the part is reduced by 23%. After the conducted research, the conclusion is reached that the optimization supported by 3D modeling software is a simple and quick procedure of analysis and optimization of the part. In this way, it is possible to save materials, extend the working life of the system, shorten the time of production and modification of existing parts. As part of this work, optimization was performed, part reinforcement was added, however, the stresses increased compared to the model before the optimization was performed, so future research directions could be based on how to reduce stresses under the same constraints and loads.

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