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Analysis and Optimization of Bell Crank Lever

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ABSTRACT

A bell crank lever has many applications and they are subjected to great deal of stresses. Therefore, numerical and analytical strategies are utilized to review behavior of stresses and strains in bell crank lever. Virtual model of bell crank lever made ready by gathering information from design data book to carry out investigation. To determine stresses in bell crank lever analytically, formula of lever in bending stresses was employed. The CAD model is prepared using CATIA and numerical analysis of bell crank lever was done in ANSYS where, stress analysis is performed by FEA. Dimensional knowledge is gathered so as to model the particular bell crank lever. Bell crank lever designs are developed by reducing the weight compare to actual bell crank lever with the assistance of topology optimization to get optimal compliant design. For new design, static structural analysis was done using ANSYS nineteen software package. Then the plots of equivalent stress, strain, total deformation and factor of safety were obtained and the design were continuously optimized till a safe design. The experimental testing is carried out on UTM. Then the comparative analysis is applied between the experimental and analysis results and then the result & conclusion are drawn.

Keywords –*ANSYS, Bell crank lever, Topology optimization, UTM.*

1 INTRODUCTION

Bell crank lever is employed to cut back a load by applying of a little effort. It is employed within the machine to elevate a load by the applying of a little effort. For any product which is to be made, taking care of the operating stresses within preplanned specific limit is the most necessary task for design engineer, in order to avoid the failure of a member or component. To enhance the merchandise quality, it's necessary to work out the stresses in varied elements. A bell crank lever is an angled class 1 lever. It is class 1 lever because the fulcrum is between the load and the effort force and it must be used when the effort force be at an angle, usually a right angle, to the load. It is conjointly necessary to grasp the stress and strain distribution so as to predict the failure of part.Development of product now days come up with a huge number of challenges, as the complicated products has to meet extraordinary demands. Methodology for robust design is technique, where at the start of design all the future problems are kept in mind and product is designed accordingly [1]. Wang et al. directed finite element analysis of lever of air disc brake and some basic issues of the switch are discovered. At last, for

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the condition that the switch doesn't meet the quality necessity, geography enhancement is acquainted with improve the state of switch using topology optimization [2].

Zende et al. in their paper, worked on filet advancement is completed for decreasing the most extreme bowing pressure. Improvement is done utilizing simulated annealing process in CATIA product engineering optimizer workbench [7]. The bell crank lever is utilized in numerous industrial applications. To raising a load (W) or to withdraw a force (P), the two arms of the lever are at rectilinear to each other. Levers are arranged into classes using relative locations of the fulcrum, effort and resistance or load. It is usual to calling the input force as the effort and the output force as a load or the resistance [11]. In short, all the researchers in this field used the different optimization techniques with the same objectives like study of various parameters in optimization. Bell crank levers often used in aircraft control systems to connect the pilot's control surfaces for example: on lightweight aircraft, the rudder usually includes a bell crank whose pivot purpose is that the rudder hinge. A cable connects the pilot's rudder pedal to at least one aspect of the bell crank. once the pilot pushes on the rudder pedal, the rudder rotates on its hinge. the other rudder pedal is connected to the opposite finish of the bell crank to rotate the rudder within the other way, in automotive applications like suspensions of pushrod style,as a part of the linkage connecting the throttle pedal to the carburetor, in railway signaling, governor of Hartnell type, etc.

In this paper, designs of bell crank lever is developed by reducing the weight compare to actual bell crank lever with the assistance of topology optimization to get optimal compliant design. For new design, static structural analysis was done using ANSYS nineteen software package. Then the plots of equivalent stress, strain, total deformation and factor of safety were obtained and the design were continuously optimized till a safe design. The experimental testing is done on UTM. Then the comparative analysis is applied between the experimental and analysis results and then the result & conclusion are drawn.

2 MATERIALS AND METHODS

2.1 CAD model

The bell crank lever is designed by using CATIA V5 software for the further optimization of design. Fig. 1 shows the drafting of the bell crank lever. The drafting shows the front view, top view, side view and isometric view also. The dimensions of the model are shown in drafting. CAD software is applied to escalate the capability of the engineers, risen the quality of design, grow communications via documentation, and to kind a database for manufacturing.

2.2 Topology optimization

The material used for bell crank lever is structural steel. Structural steel material is the category of steel which is utilized for making numerous construction materials in number of varied shapes. Before we start analysis, we have to put all data in the workbench such as type of material, Young's modulus, poisson's ratio, etc. Topology optimization is a mathematical application which enhances material style inside a designated region for design, the set of loads and boundary conditions which are designated such that the resulting layout meets a preplanned set of performance targets. The aim of topology optimization in this project is to minimize the weight without affecting the lever stiffness and strength compared to existing design, so the design objective is taken as to minimize the weight.

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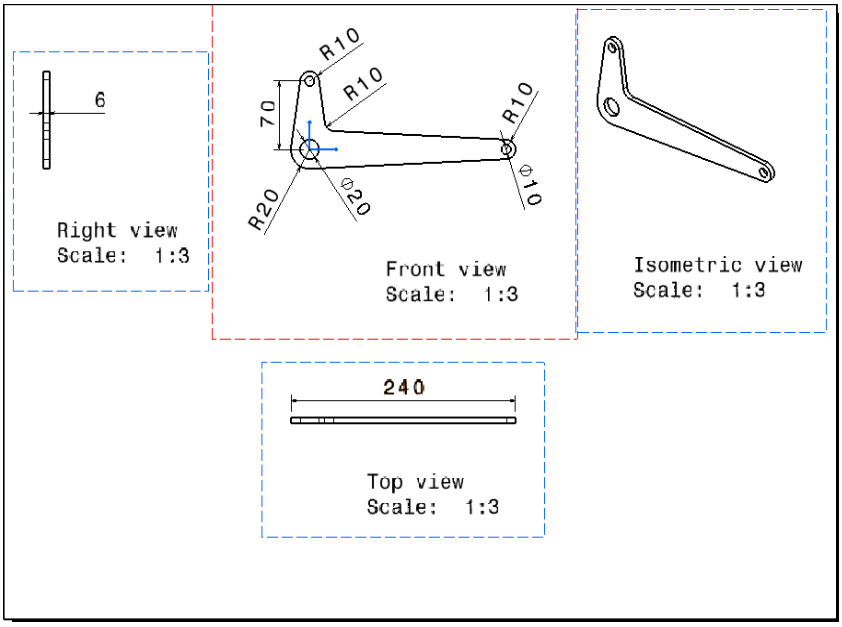


Figure 1: Drafting of bell crank lever

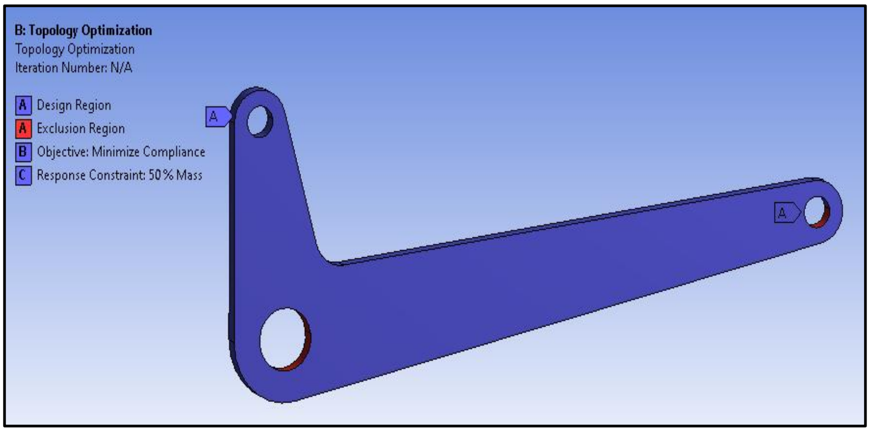
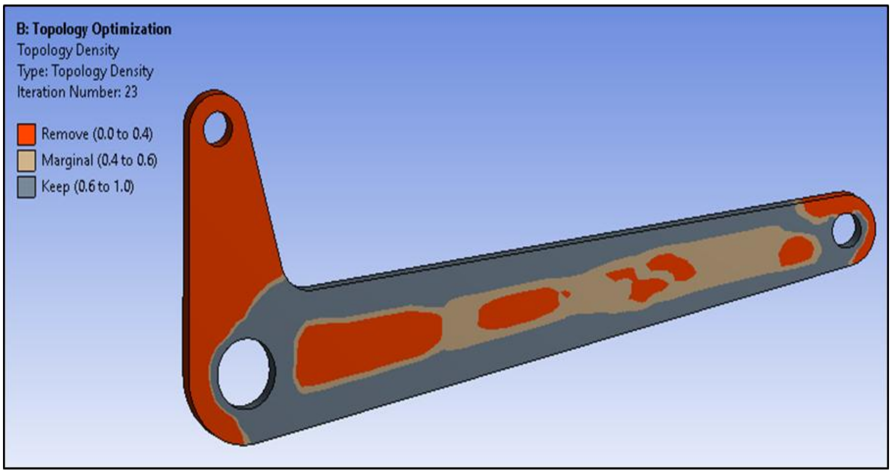
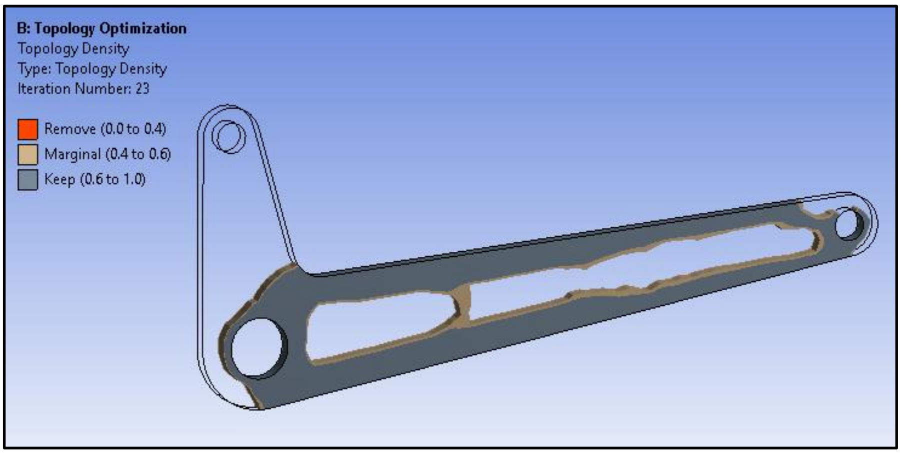


Figure 2: Topology optimization boundary conditions

Topology optimization tool is selected from ANSYS list view and drag and dropped in solution section of static structural so that it takes its all boundary condition, geometry, all details and perform topology optimization on selected component in number of iterations. Fig. 2 shows topology optimization boundary conditions. It took some iteration in the optimization process to get rid of the unutilized material from the designated design space. The process of topology optimization is shown in Fig. 3(a, b).Here, the 50% mass constraint was given. Therefore, after performing topology algorithm on component, selected parts contain red, brown and grey color on it as we see in the figures. So, red region color indicates material removal area along with marginal brown color and grey color indicates to keep the material. So we have to go further and select the specific shape for the component, by doing this again reanalyze the component to observe the sustainability of optimized design over the existing design. The finally new optimized bell crank lever model is shown in Fig. 4. Now, the comparative study of analysis of existing and new bell crank lever is discussed in result section.



(a)



(b)

Figure 3: (a) and (b) Topology optimization process

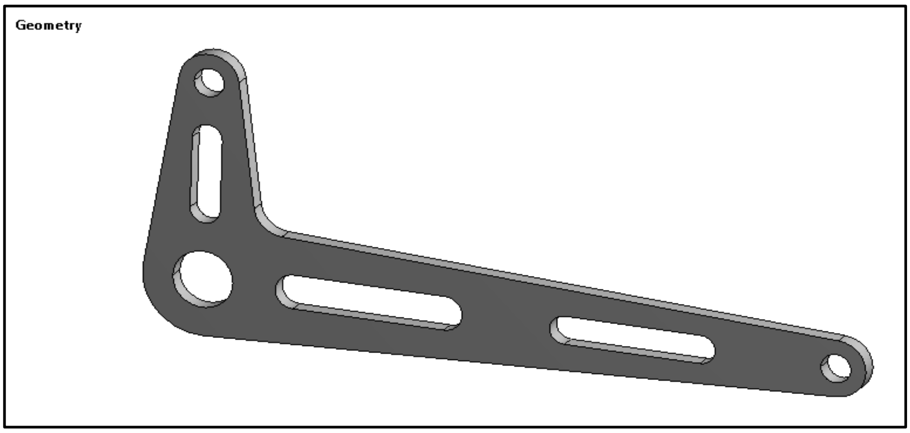


Figure 4: New optimized geometry

2.3 Experimental testing

Table 1: Specifications of UTM

Sr. No.	Parameters	Values
1	Maximum capacity	400 KN
2	Measuring range	0-400 KN
3	Least count	0.04 KN
4	Clearance for tensile test	50-700 mm
5	Clearance for compression test	0-700 mm
6	Clearance between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase, 440 Volts, 50 Hz
9	Overall dimension of machine (L×W×H)	2100×800×2060
10	Weight	2300 Kg

The experimental testing is conducted on universal testing machine of new optimized bell crank lever as shown in Fig. 5 and the results are obtained. Fig. 6 indicating the value of strain obtained after experiment was performed, which is 100 micro strain. A universal testing machine (UTM) is utilized to trial both the tensile and compressive strength of materials.Universal testing machines are named like this because these can carry out numerous trials on an equally multiple range of materials, components, and fabrics.To carry this experiment, a universal testing machine used has an measuring range of 0 KN to 400 KN, with minimum measuring value of 0.04 KN.

Firstly, the load arrow is placed at zero by adjusting the starting setting knob. The dial gauge is fixed and the new optimize bell crank lever for measuring changes of little amounts. Then the new optimize bell crank lever was placed on middle caliper of the machine. Set the automatic graph recording system and start the machine. Once the machine started, it begins to apply an increasing load on bell crank lever. As in this work, the load is of 100 N is applied on the bell crank lever. Table 1 gives the specifications of universal testing machine used for testing of the component.

Figure 5: Testing of optimized bell crank lever on UTM

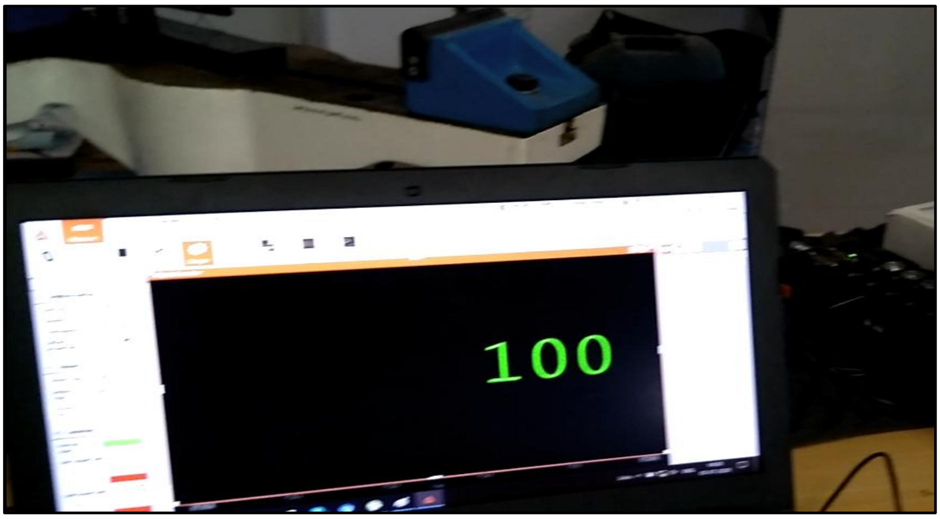


Figure 6: Experimental strain value

3 RESULTS AND DISCUSSION

3.1 Finite element analysis results of existing bell crank lever

The mesh is fundamental part of the computer-aided engineering simulation method. Meshing dominates the correctness, convergence and quickness of the outcome. Fig. 7 shows the model is meshed before further analysis. For this component hexahedral mesh is used, the reason behind that was as the geometry of the component is simple. Also for higher accuracy, hexahedral mesh is mostly preferable. The load applied on lever was 100 N as shown in Fig. 8 boundary conditions. The maximum total deformation of the existing bell crank lever model at given boundary condition is 0.08625 mm as shown in Fig. 9. Equivalent stress is part of the maximum equivalent stress failure theory which is used to predict yielding in a ductile material. Therefore, as shown in Fig. 10, maximum equivalent von-Mises stress of existing bell crank lever at given boundary condition is 17.646 MPa. As seen in the Fig. 10, from the point of fulcrum to the end of the load arm, the central part of arm is low stressed region, which is also same for the effort arm. Therefore, the concept of evolutionary structural optimization (ESO) also implemented in this research work, in which we remove the material from low stressed region of the component.

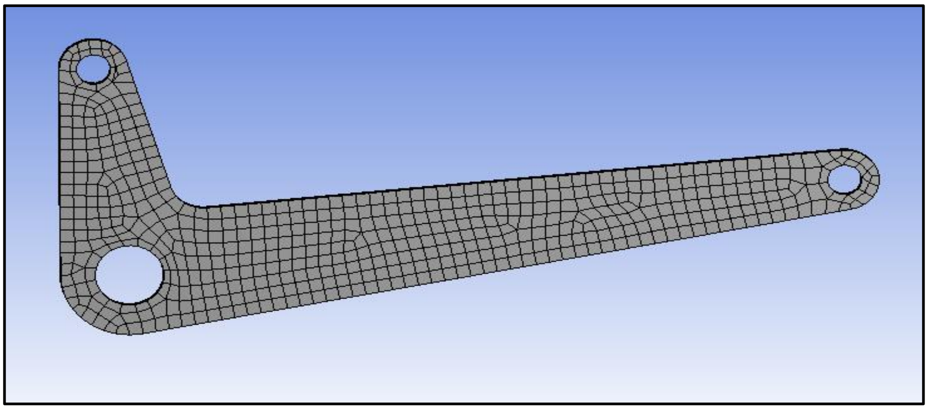


Figure 7: Meshing of existing bell crank lever

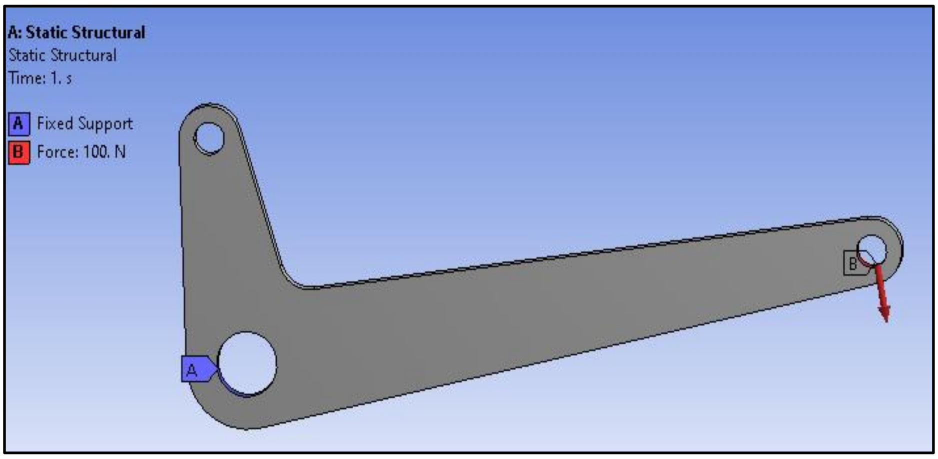


Figure 8: Boundary condition applied

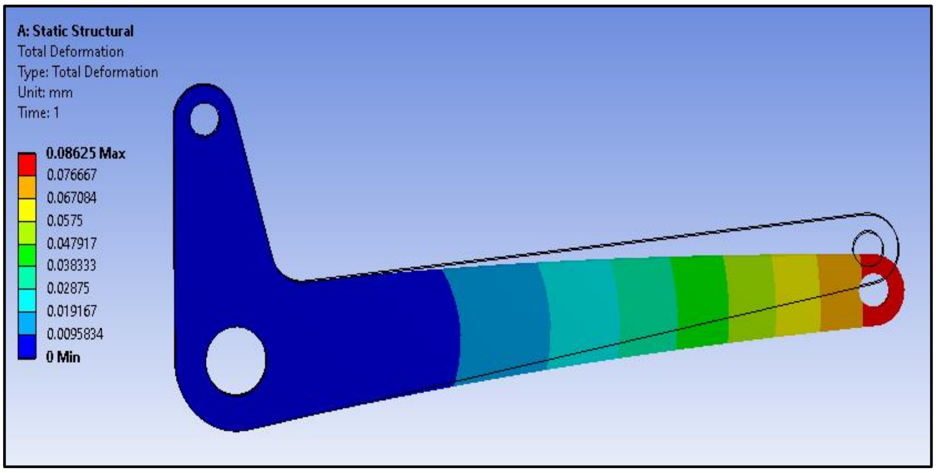


Figure 9: Total deformation of existing bell crank lever

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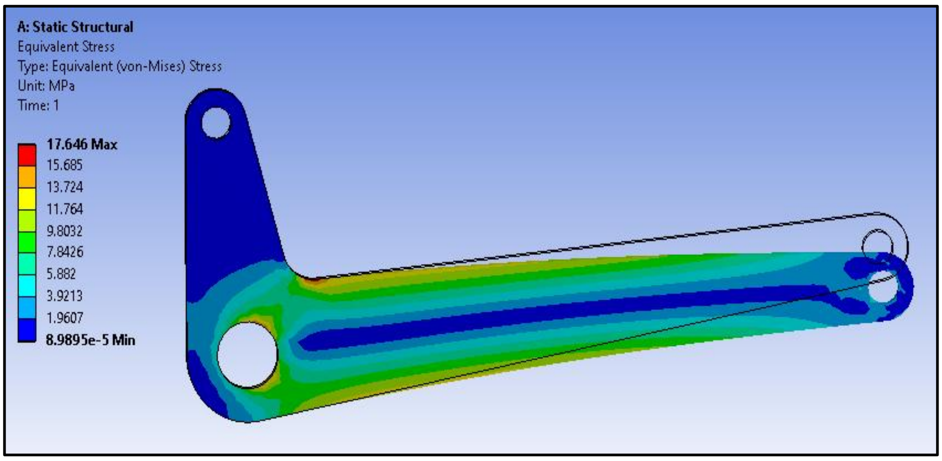

Figure 10: Equivalent (von-Mises) stress for existing bell crank lever

3.2 Finite element analysis results of optimized bell crank lever

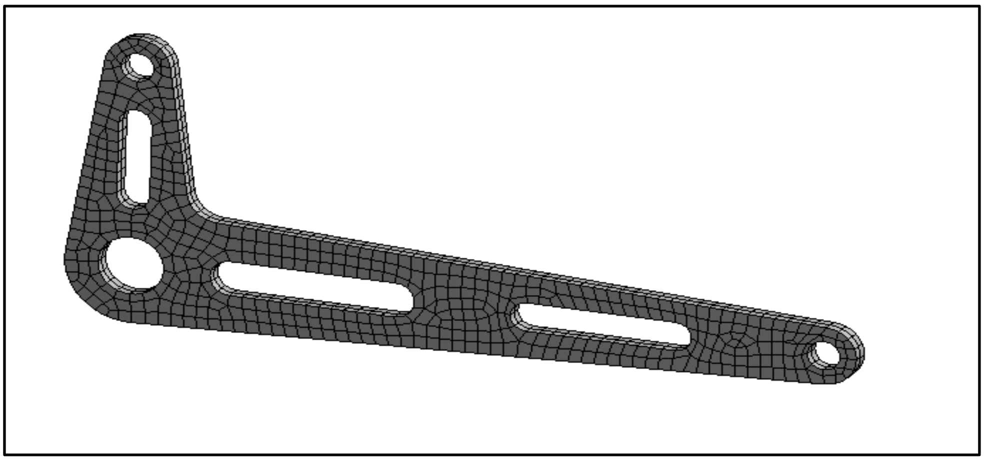

Figure 11: Meshing of optimized bell crank lever

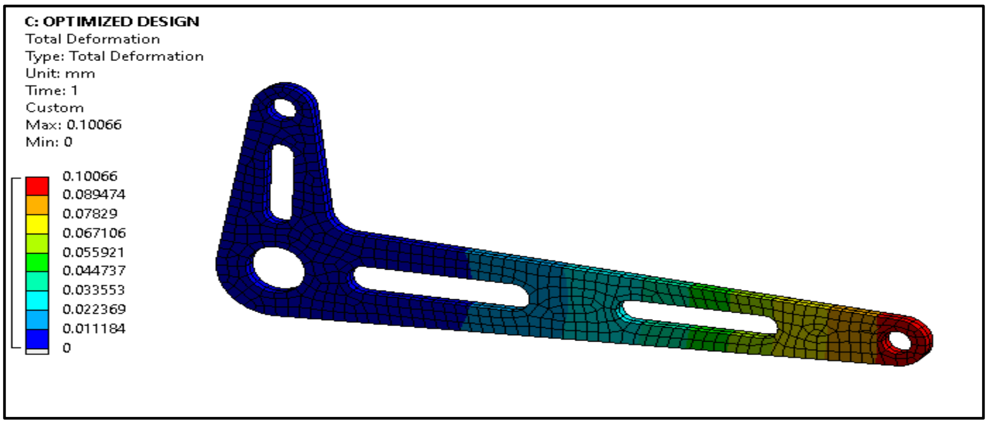

Figure 12: Total deformation of optimized bell crank lever

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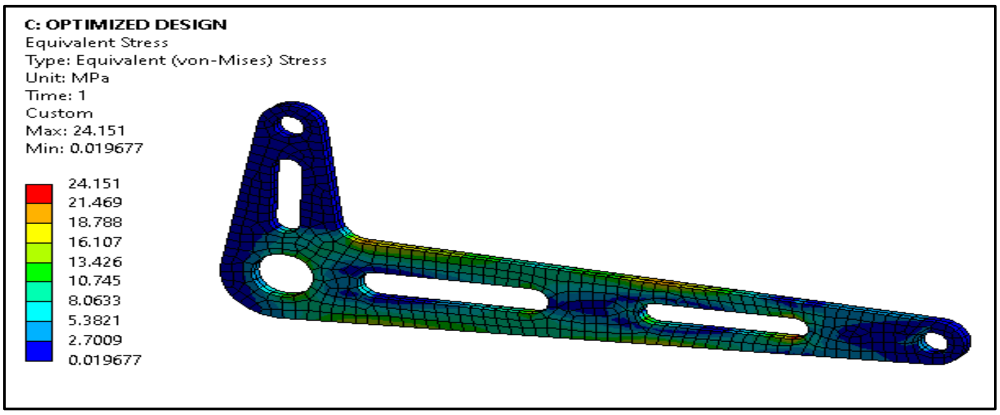

Figure 13: Equivalent (von-Mises) stress of optimized bell crank lever

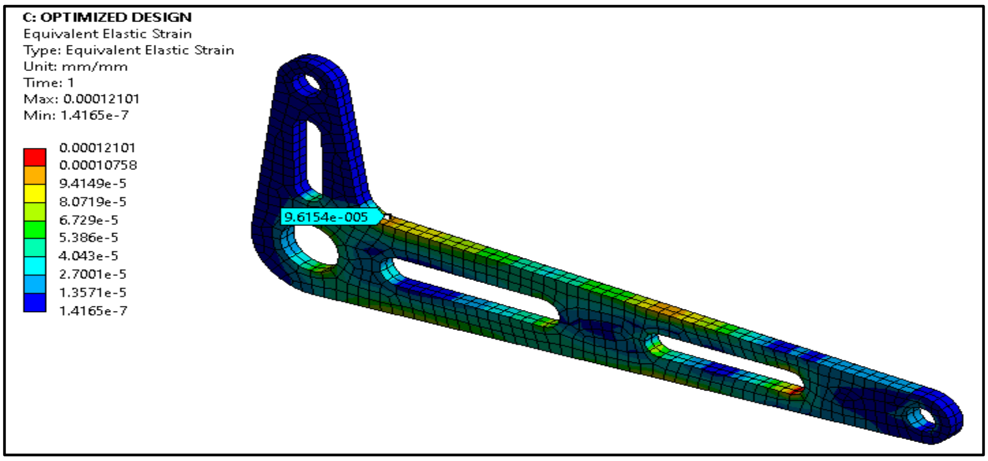

Figure 14: Equivalent elastic strain of optimized bell crank lever

Fig. 11 shows meshing of optimized model. Maximum deformation under static condition of new optimize bell crank lever as shown in Fig. 12 is 0.100 mm. The deformation was maximum at the point of loading i.e. at the end of load arm. The red color region indicates the maximum deformation. Fig. 13 shows equivalent (von-Mises) stress, maximum equivalent stress under static condition of new optimized bell crank lever is 24.151 MPa. The equivalent elastic strain of the optimized bell crank lever was also obtained as shown in Figure 14. FEA equivalent strain observed is around 96 micro strain.

3.3 Comparison of result data for initial and optimized lever

Table 2: Stresses and deformation results

Parameters	Initial	Optimized	Percentage
Mass	0.38838	0.31442	19.04%
Von-Mises stress (MPa)	17.646	24.151	-37.24%
Deformation	0.0862	0.100	-16.009%

3.4 Experimental and FEA result comparison

Table 3: Equivalent elastic strain

Design	Equivalent elastic strain
FEA strain of optimized bell crank lever	96 Micro strain
UTM strain of optimized bell crank lever	100 Micro strain

Table 2 shows the results of the stresses and deformation. The von-Mises stress for the existing bell crank lever is 17.646 MPa, whereas for optimized bell crank lever it is 24.151 MPa. This is due to the material is removed from the component. However, this stress is within the permissible limit. The deformation of the existing component is 0.0862 mm and for optimized component,it is 0.100 mm. Deformation also slightly increased but, as the deformation must be less than 2 mm, we can say it is within permissible limit. Now coming to the mass of the component, for initial it is 0.38838 and for optimized it is 0.31442 so, there is 19.04% of the reduction in the mass, which is our main aim in this research work. Therefore, the aim of weight optimization achieved through topology optimization. The Table 3 shows the equivalent elastic strain of the component. For FEA, strain of optimized bell crank lever is 96, and UTM strain of optimized bell crank lever is 100. From this, both values ofstrain are nearly equal. Therefore, the result was validated.

In finite element analysis of bell crank lever while meshing, for the existing model there are 6932 nodes and 1124 elements. On the other hand, for optimized model there are 6299 nodes and 952 elements, that is less than the existing model of bell crank lever. This is because of the topology optimization process. Meshing for existing bell crank lever was shown in Fig. 6. Similarly, after topology optimization again for analysis of optimized bell crank lever it meshed as shown in Fig. 10. From the overall results it is clearly observed that all the values of new and existing bell crank lever model are approximately and nearly equal, whilst weight of optimized lever is reduced as it is observed from the geometry of bell crank lever. It seems that, increase in the radius of the fillet or optimizing it is always not work, the reason is that if we increase radius mass of the component increases and decreasing it causes that region weak [6]. Therefore, we must make balance between these parameters while optimizing the component.

4 CONCLUSIONS

Bell crank levers are used to elevate load by applying little amount of effort. Where load and force acts at right angles. Many researches carried out and used various techniques of optimization for mechanical linkages like numerical analysis, analytical methods and studied the stress patterns. However, various researches are done on this particular topic there is still need to do some research on Weight based optimization considering space limitations, weight reduction. Therefore, in present study, static analysis of existing bell crank lever was performed, to determine stresses and deformation. For reduction of weight, topology optimization method is used.

In topology optimization, red region indicate the material removal area in which specific shape areas are to be cut and reanalysis is to be performed to understand the effect of existing boundary condition.

The mass of the existing bell crank lever was 0.38838 kg and after optimization it was 0.31442. So there was 19.04% of reduction in the mass of the material. Therefore, main aim of this study that is to optimize weight is achieved and this method is feasible.

From FEA results it is to be concluded that maximum deformation and von-Mises stress in optimized bell crank lever is 0.100 mm and 24.151 MPa. From experimental and FEA results of strains induced in optimized bell crank lever are almost same so, the validation of the result is done.

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