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DESIGN AND WEIGHT OPTIMIZATION OF PARKING BRAKE LEVER

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ABSTRACT

The parking brake in an automobile is generally used to keep the vehicle stationary. The parking brake lever in cars is generally made of structural steel. The material required for the design of parking brake lever is far superior than its requirement for actual application.The parking brake lever for Maruti 800 car is considered for topology optimization. The existing lever design is over-safe which is to be modified for topology optimization. This paper presents the Stress analysis and optimization of parking brake lever and a proposed work for a change in material considering its safety and application. The current work aims at reducing the weight of the parking brake lever by optimizing its existing design without compromising its safety. In this paper, the Finite element analysis of the existing as well as the optimized design is conducted and the values of stress and deformation are found. Later the material properties are changed from structural steel to aluminum alloy for the optimized model and the results are compared.The equivalent stress plot for the component indicates that the maximum stress for aluminium lever under the load of 100 N is 59.39 which is well below the yield limit of the material.

***Keywords*: ANSYS, Automobile, CATIA, deformation, optimization, parking brake, stress.**

I. INTRODUCTION

In automobiles, especially in cars, the parking brake is a latching brake which is usually used to keep the vehicle at a stationary position. The parking brake lever is generally pulled by the driver of the car when the vehicle has to be parked. Thus, it is also called as the parking brake or emergency brake as sometimes it is applied when the car must be stopped due to an emergency. Also, sometimes when the operator needs both the feet to operate throttle pedals as well as the clutch, the parking brake or hand brake is used to prevent the roll down of the vehicle. The parking brake is although sometimes called as an emergency brake, using it in case of any emergency where the foot brake can still be used is likely to upset badly the braking balance of the vehicle and it can ultimately lead to loss of control over the vehicle. The parking brake operates basically only on the rear wheels whose traction is reduced when the brakes are applied.

The parking brake lever does not have to face heavy loading conditions.The lever has to withstand only the hand pulling force by the driver which is quite less. The existing model of the parking brake lever consists of an over-safety design and can be optimized to reduce its weight without compromising its strength and safety. Most of the research work find out the performance of a mechanical parking brake system for the cars. Also, some of the research include the study of parking brake system and have tried to design a fully automated parking brake system. With the increasing use of the automotive, a development of topology optimization method is necessary

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to optimize the part shape and configuration of the automotive components. Till date, the information available is vast in the literature for finding braking performance for the service brakes, but very less number of studies have been done on the parking brakes. For example, M.R. Mansor et al. [1] reported the concept design of polymer composites for automotive parking brake lever. The Theory of Inventive Problem Solving (TRIZ) was integrated,along with Analytic Hierarchy Process(AHP) methods and morphological. Also, similar to the previous research, a concept design for the polymeric-based composite pedal box system for automotive was presented by Sapuan S.M [2] which describes the concurrent engineering techniques and its importance in designing. In one of the research work, Alexander Kaluza et al. [3] has proposed an approach of concurrent design along with the life cycle engineering for lightweight automotive component development. The paper discusses multi-material design concepts and combination of varied materials on a component lever. Apart from that A H Rozaini et al. [4], tried establishing mathematical model of parking brake and developing reliable parking brake test bench in laboratory in order to determine and evaluate performance of the parking brake (hand brake). Methods for testing the braking system of a load-carrying vehicle are discussed by Vutenis et al [5]. Apart from that, Ali Belhocine et al. [6] attempted to establish parking brake model and its validationfor predicting its torque performance and avoiding roll away phenomenon from the parked condition. H.B. Motra et al [7], meanwhile reported the quantitative comparison of the strain measurement techniques so as to choose the most efficient based on the type of testing. The instability in the hand brake performance for cars and vans was discussed by P.R.J Harding et al[8]. The regulations and safety standards for the federal motor vehicle safety standards have been discussed [9-10].In most of the researches, the performance and other parameters of the parking brake is evaluated but none of them attempted to optimize its mass and design. The objective of this work is to reduce the mass of the parking brake lever by creating modifications in existing design and changing the material properties from structural steel to aluminum alloy.

II. MODELING AND NUMERICAL ANALYSIS OF HAND BRAKE LEVER

The Hand brake lever model from Maruti 800, euro II model is used in this paper which is shown in Fig. 1.

Figure.1-Existing Hand brake lever

Table.1-Material Specification of Hand brake lever [18]

Material Specification	
Structural Steel Grade	S235
Ultimate tensile strength	460 MPa
Modulus of elasticity	200 GPa
Density	7.85e-6 kg/mm^3

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The dimensions and geometry of the hand brake lever are noted from the existing model of the lever.

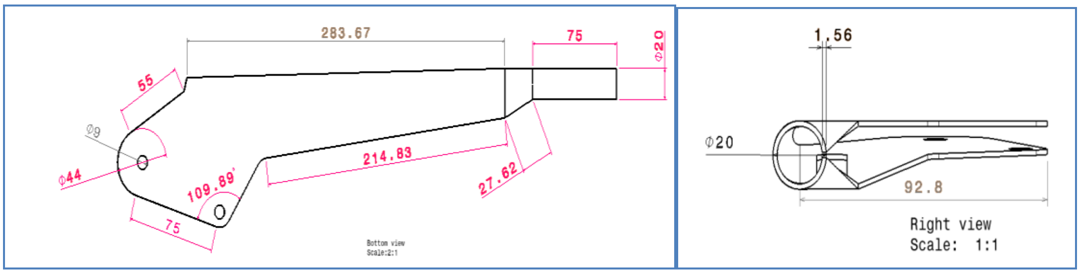

Figure.2- Important dimensions of existing hand brake lever

Accordingly, the design of the lever is made with the help of the dimensions in CATIA V5 software. The basic solid model of the parking brake lever is created and the necessary extrusions are produced.

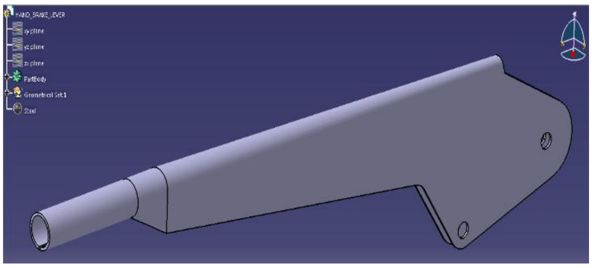

Figure.3- Solid model of existing lever

The solid model design is then imported in ANSYS for analysis. The details of the Finite element discretization of the lever is shown in fig.4.

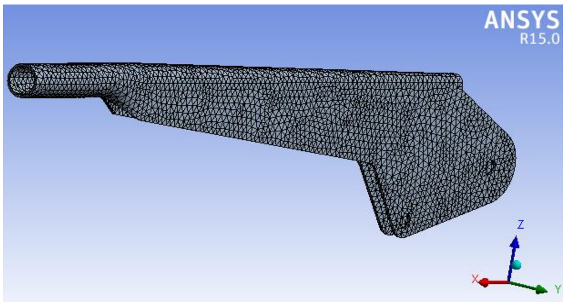

Figure.4-Solid mesh of existing lever

Table.2- Discretization of existing lever

Statistics	
Nodes	37781
Elements	18518

As shown in fig.4, the boundary conditions are given by providing fixed supports at the two holes for mounting the hand brake lever represented by “A”. As we apply the hand brake, an upward pulling force is applied on the Hand grip where the press button is pressed.

The force of 100 N is applied on the hand grip with the constraint at A which is fixed.The load of 100 N is selected according to the FMVSS standards [9] for the safety of automotive vehciles.

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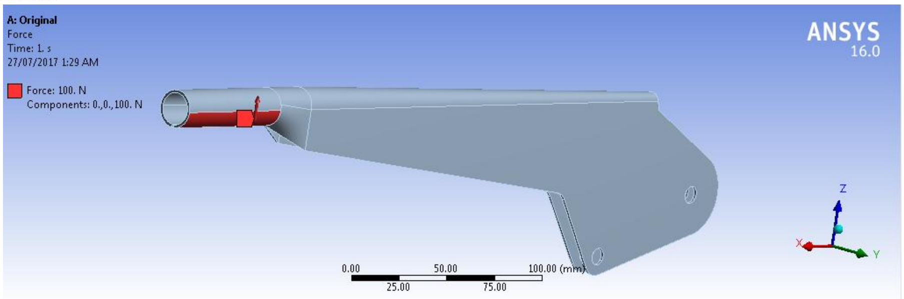

Figure.5-Loading conditions on existing lever

After applying the load of 100 N as mentioned in the boundary condition, the stress and deformation values of the existing hand brake lever is obtained. The figure.6shows the maximum stress and total deformation values of the existing hand brake lever.

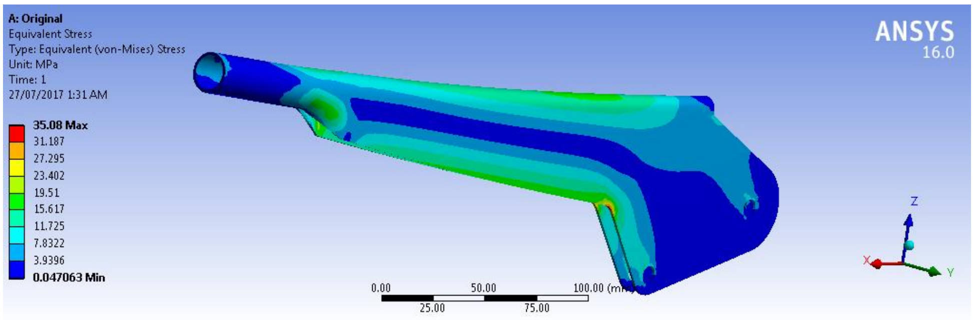

Figure.6-Stress on the existing lever

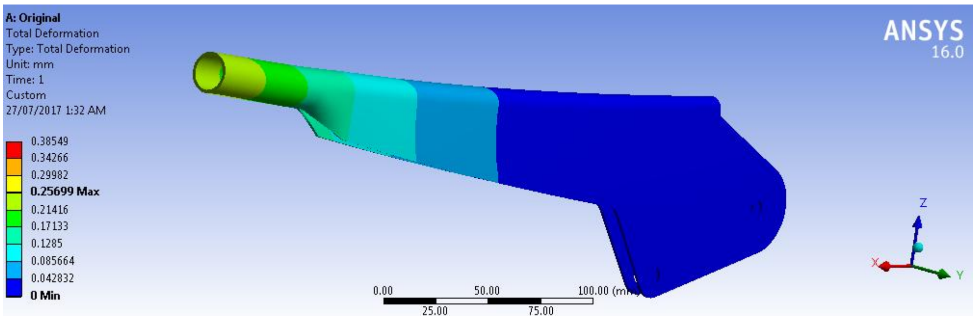

Figure.7-Total deformation on existing lever

Now based on the values obtained from finite element analysis of the existing parking brake lever, it is observed that,some part of the lever is subjectedto very low amount of stress. Based on this, the design is optimized and considering the fact that some of the part from the lever serves as the cover for the ratchet-pawl mechanism and hence cannot be eliminated. Thus, after all considerations the new optimized parking brake lever is designed.

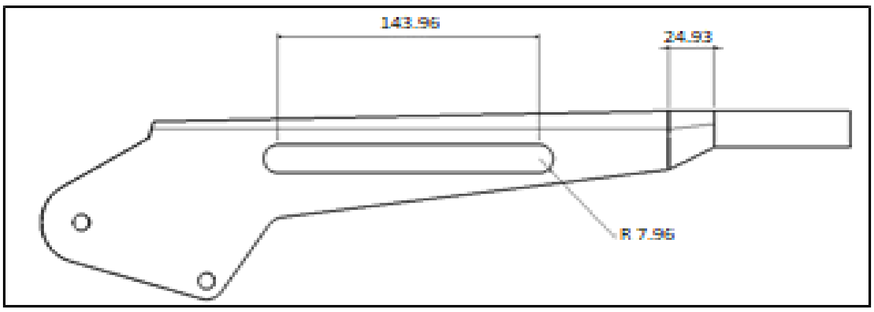

Figure.8-Important dimensions of modified lever

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The design of the modified lever is made with the help of the dimensions in CATIA V5 R20 software. The solid modeling of the modified parking brake lever is made and the necessary extrusions are made.

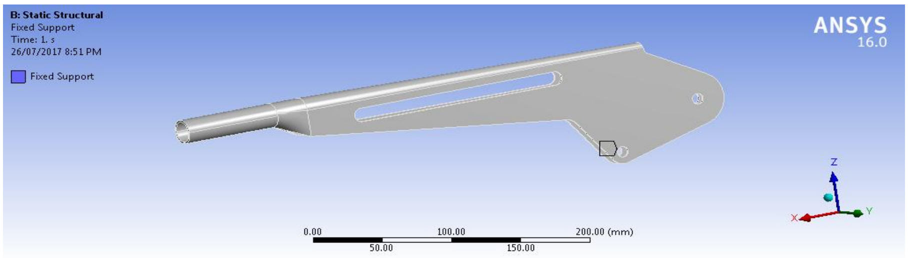

Figure.9-Solid model of modified lever

With the same boundary conditions, the stressand the total deformation values of the modified hand brake lever is calculated for existing material,i.e.; structural steel. Later the material properties are changed from structural steel (S235) to Aluminum alloy (A356) and again stress and deformation values are evaluated.

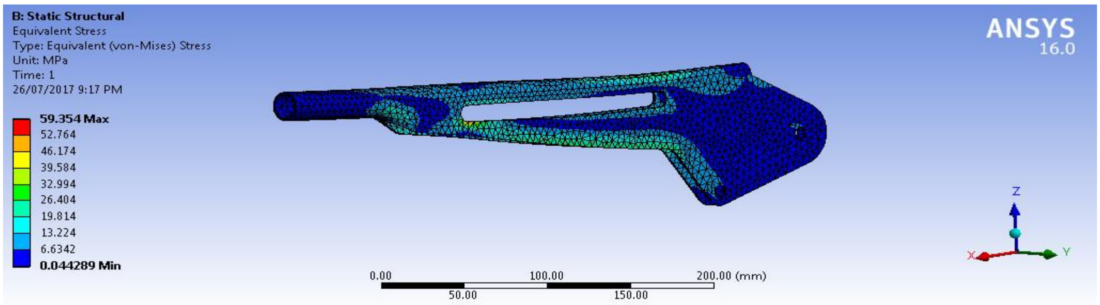

Figure.10-Stress on the modified lever (Structural steel)

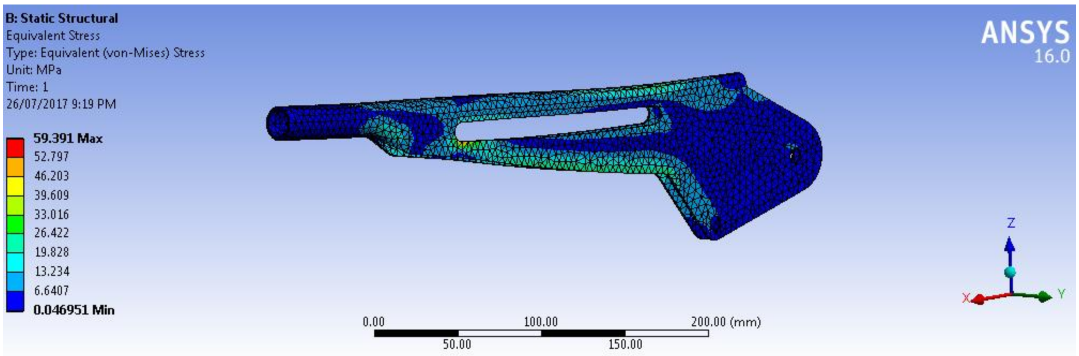

Figure.11-Stress on the modified lever (Aluminum alloy)

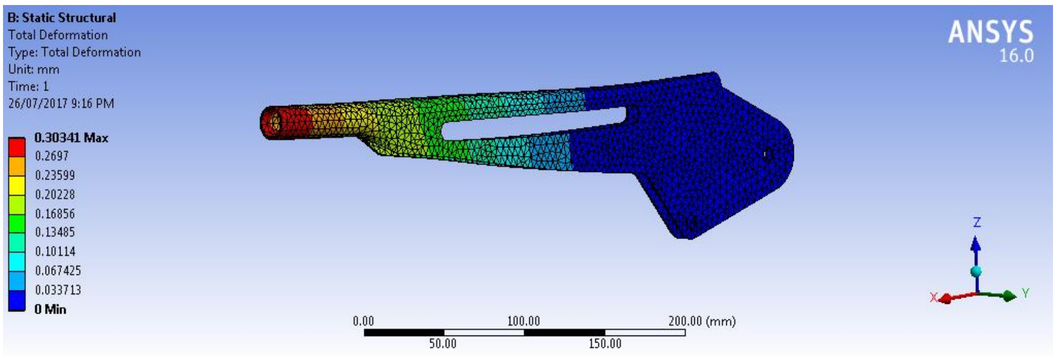

Figure.12-Total deformation on modified lever (Structural steel)

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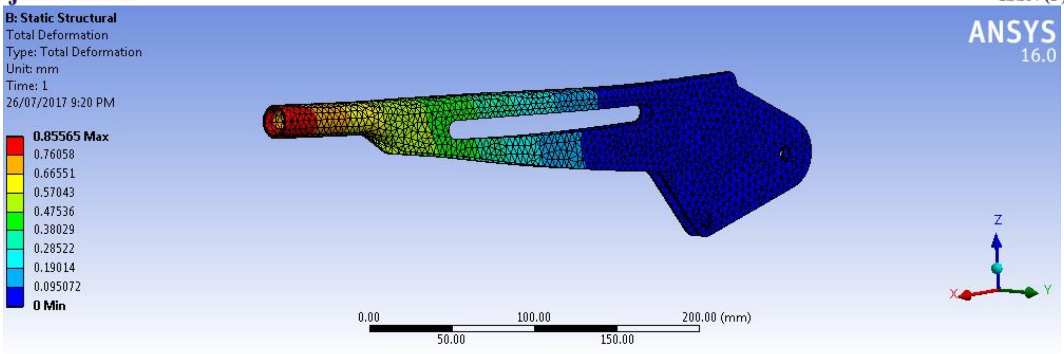

Figure.13-Stress on the modified lever (Aluminum alloy)

Table.3- Material properties

Material properties (Aluminum alloy, A356)	
Density	2.67E-09 tonne/mm^3
Modulus of Elasticity	72.4 GPa
Poisson's ratio	0.33
Ultimate tensile strength	3.1E+08

The stress and deformation values for loading conditions of 20N,40N, 60 N and 80 N were also found using the same finite element analysis for optimized structural steel and aluminum parts.

III. RESULTS AND DISCUSSION

The analysis of the hand brake lever is done with finite element analysis and experimental method. The values of the stress and deformation for the finite element analysis method is shown in table 3.

Table.4- Stress and Deformation values of existing and optimized lever

Load (N)	Max. Stress(MPa) (Existing)	Max. Stress (MPa) (optimized)	Max. Deformation (mm) (existing)	Max. Deformation (mm) (optimized)
100	35.08	59.35	0.256	0.303

Table.5- Stress and Deformation values of optimized lever (FEA)

Load (N)	Max. Stress(MPa) (Structural steel)	Max. Stress (MPa) (Aluminum alloy)	Max. Deformation (mm) (Structural steel)	Max. Deformation (mm) (Aluminum alloy)
20	11.871	11.878	0.0606	0.1711
40	23.741	23.756	0.1213	0.3422
60	35.612	35.634	0.1820	0.5133
80	47.483	47.513	0.2427	0.6845
100	59.354	59.391	0.3034	0.8556

As it is observed that the stress and deformation values obtained from the finite element analysis by modifying the design of the lever has increased a bit but are within the yield limit of the material. The values of the equivalent stress and deformationof the optimized lever are slightly greater than the values of the existing lever, but are within the yield limit of the material. The minimum factor of safety is 7.7 for the optimized hand brake lever made of structural steel and factor of safety 5.2 for aluminum alloy lever. The stress on the optimized hand brake is comparatively quite less than the allowable stress on the material.

The comparison of the stress value obtained from both the material highlights that the aluminum alloy design is safe as that of structural steel design, but the mass of the aluminum is comparatively less than that of steel. The comparison of the mass of the parking brake lever made from both the materials is given in table 5.

Table.6- Comparison of mass of lever

	Existing lever (Unoptimized)	Structural steel (S235) (Optimized)	Aluminum alloy (A356) (Optimized)
Mass	0.535 kg	0.4860 kg	0.1715 kg

From the above reults, it is observed that the mass of the optimized lever made from Aluminum alloy (A356) is less than structural steel (S235) by about 65%. The reduction in weight of the hand brake lever is successfully achieved by design optimization without compromising its strength and safety. Thus, the aluminum alloy hand brake lever is proposed for use in automobiles for mass reduction of parking brake system.

IV. CONCLUSION

In this paper, the stress values of the existing and optimized hand brake lever are evaluated with the help of finite element analysis method and later compared the values of stress by introducing Aluminum alloy. On the basis of results obtained, the following conclusions are drawn:

1. In the modified design of the hand brake lever, the stress is within the yield limit of the material. Hence, the optimized design is safe.
2. There is reduction in the weight of the optimized hand brake lever.
3. The lever made from Aluminum alloy shows a reduction in weight by 65%.
4. The topology optimization in the hand brake lever is executed.

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