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MODELING AND TOPOLOGICAL OPTIMIZATION OF EXISTING AUTOMOBILE BRAKE PEDAL

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ABSTRACT

From the past decade, Automobile industries are putting a lot of efforts to produce lower weight vehicles to increase the productivity and the efficiency. So, there is an importance of vehicles to design with lower weight by eliminating considerable amount of material from its components. In this connection a brake pedal which is very important component is chosen with existing design used for retarding or stopping a vehicle. In this work a new design is proposed for an existing automobile brake pedal which is optimized based on topological optimization approach by considering mass as a parameter. The material type selected as a structural steel which is unaltered. The modeling of the brake pedal is done with the aid of Computer Aided Design (CAD) software i.e. ANSYS Space Claim Direct Modeler (SCDM) which is very user friendly in editing the geometry while performing topology optimization. Simulation is done by using ANSYS 2020R1. At last a low weight brake pedal with new design is suggested without change in its shape and performance requirements of an existing brake pedal.

Keywords: Brake Pedal, Computer Aided Design, Finite Element Analysis, Topological Optimization.

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1. INTRODUCTION

Many works have been carried out to optimize the design of various brake pedals of automobiles and in many ways it's design can be optimized with the methods like Topology optimization, Shape optimization, Direct optimization etc. [1] Design and optimization done for the two components as Bell crank lever and brake pedal performed topology optimization to reduce the weight of it. [2] Suggested that the precise dimensions of an brake pedal will be known by making the study of design of experiments, shape optimization, and topology approach is used for decrease the weight of it. [3] Performed static structural analysis on brake pedal with two different materials and compared the results before and after topology optimization based on factor of safety and suggested the best one of them.[4] Proposed the new design of brake pedal with light in weight without sacrificing it's performance requirements. [5] a new design of brake pedal is suggested which is 22 percent low weight than the existing brake pedal without forefiting performance characteristics like strength and stiffness.

In this work, a digital model of the brake pedal is generated by referring the above mentioned literature for dimensions and topological optimization is carried out to remove the material from inner part of the component by keeping its shape unchanged. The scope of this work is to introduce the new design standards of the existing component can be replaced by the optimized component with reduced mass and without compromising the performance. ANSYS' Topological optimization is performed to reduce the weight of the component. Topology take cares about the low stress geometric regions with in the permissible limits. As we know that the removal of material from the component, the stress and deformation may increase slightly, but this increase is allowed if they are within the permissible limits.

2. METHODOLOGY

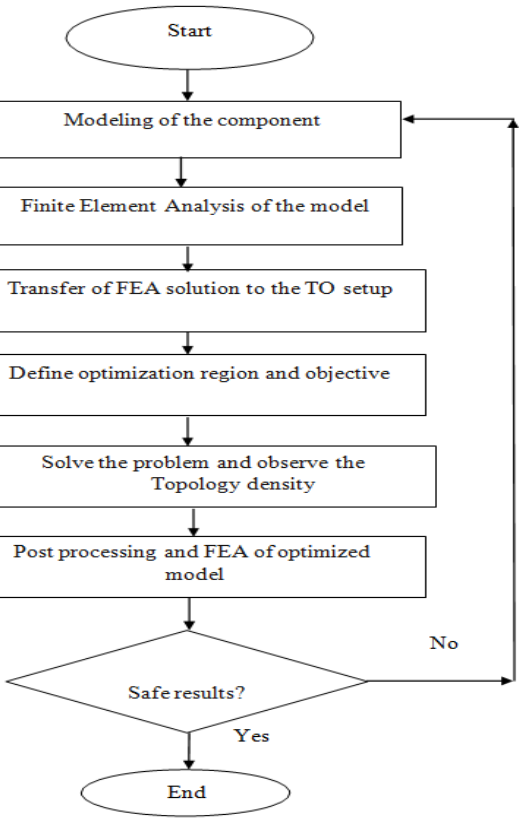


Figure 1. Flowchart of material optimization procedure

3. DRAFTING OF A COMPONENT

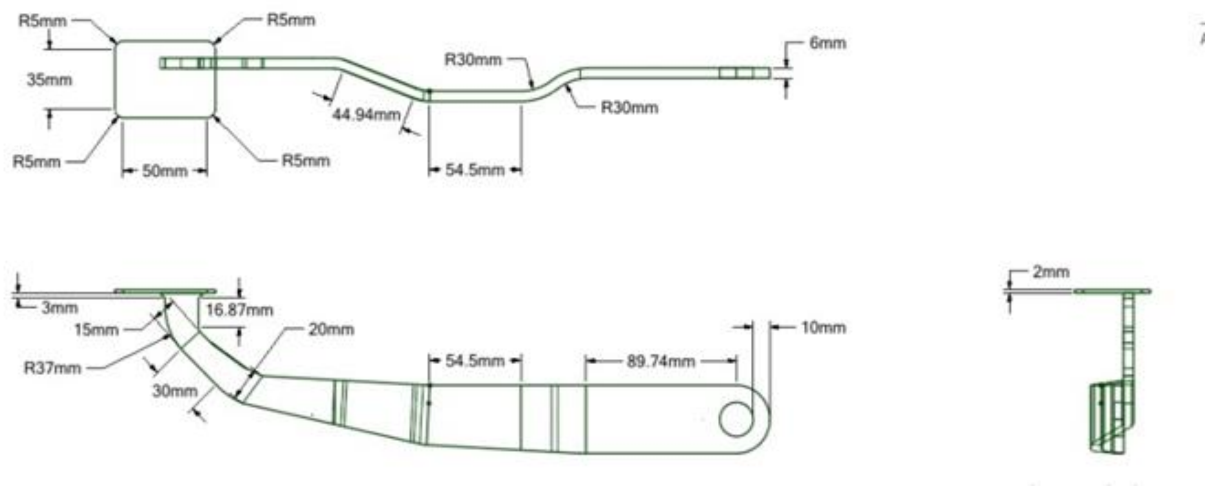
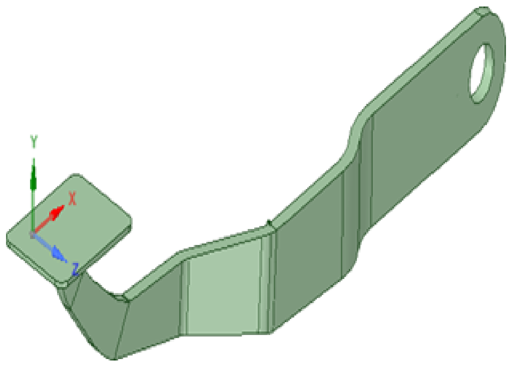


Figure 2. Drafting model of the initial brake pedal

4. MODELING OF THE COMPONENT



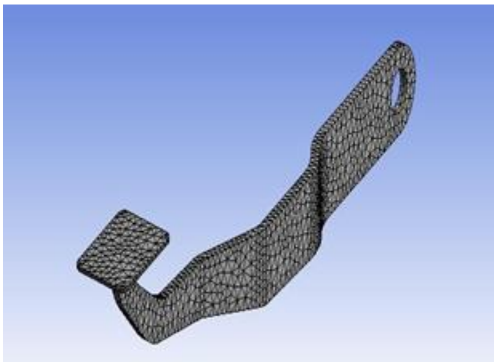


Figure 3. 3D SCDM Model of brake pedal

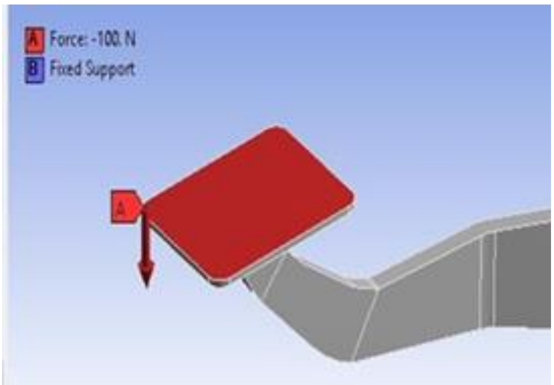
Figure 4. 3D SCDM Model of brake pedal

5. FINITE ELEMENT ANALYSIS

S.NO	MATERIAL PROPERTIES	MESHING
1	Material : Structural steel	Element : Tetrahedron
2	Young's modulus : 200GPa	Elements count : 5712
3	Poisson's Ratio : 0.3	Nodes count : 11192
4	Density : 7850 kg/m3	

5.1. BOUNADRY CONDITIONS

A fixed support is applied on the surface 'B' as shown in the Figure4, 100 N force is applied vertically downwards on the pedal surface 'A' as shown in the Figure5.



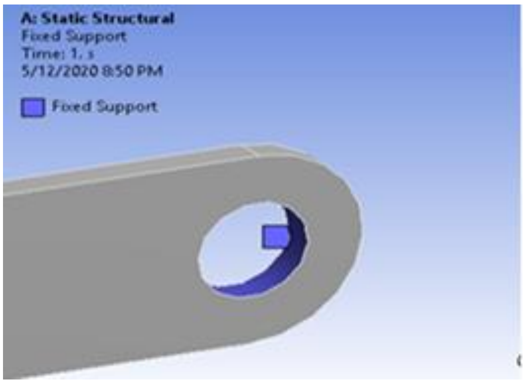
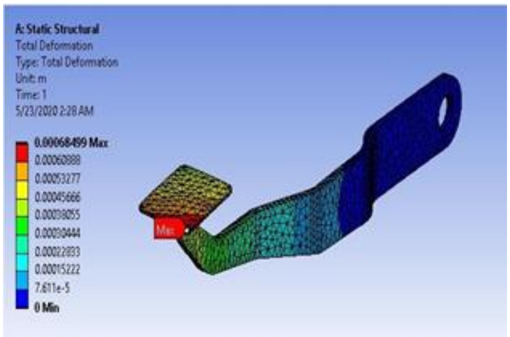


Figure 5. Fixed support at mounting point. **Figure 6.** Load of 100N applied on pedal surface.

6. STATIC STRUCTURAL SIMULATION RESULTS



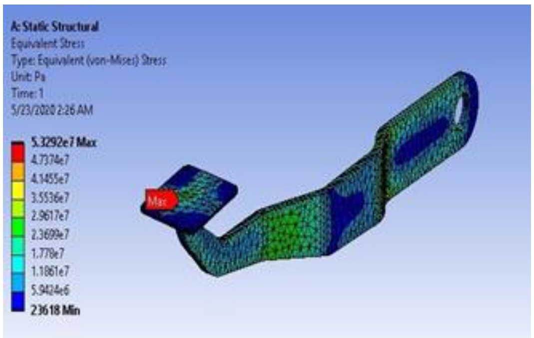


Figure 7. Deformation of existing model **Figure 8.** Load of 100N applied on pedal surface.

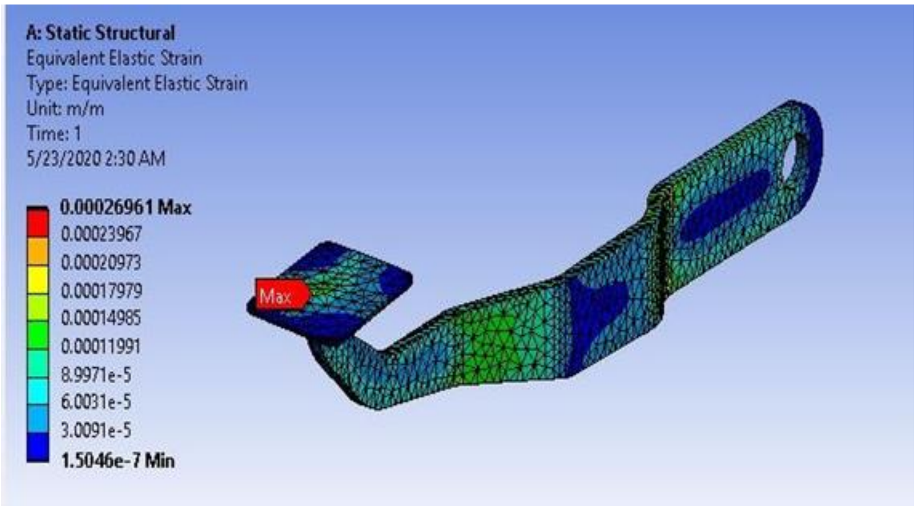


Figure 9. Equi-Elastic strain of the existing brake pedal

1. Maximum stress developed is 53.292 MPa and the minimum stress developed is 0.023618 MPa.
2. Maximum deformation is 0.00068499m and minimum deformation is 0m.
3. Maximum strain is 0.00026961 and minimum strain is 1.5046e-7.

Here developed stress is much lower than permissible limits i.e yield stress. So, the material should be able to proceeds further to perform topological optimization. If it is not meeting yield stress criteria geometry has to be changed.

7. TOPOLOGY OPTIMIZATION

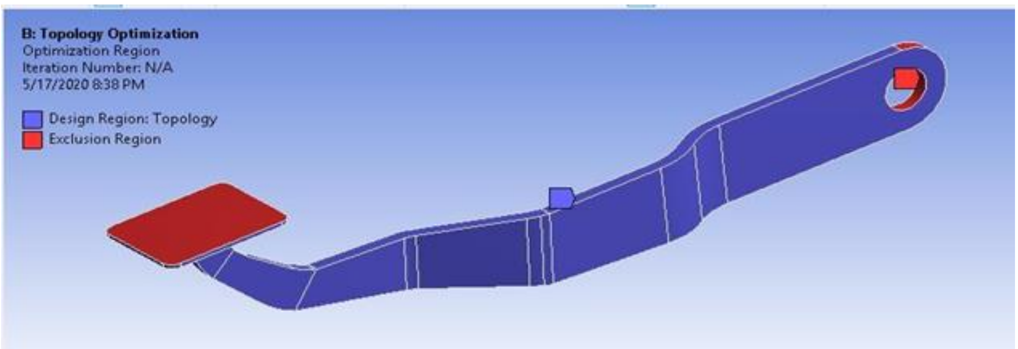
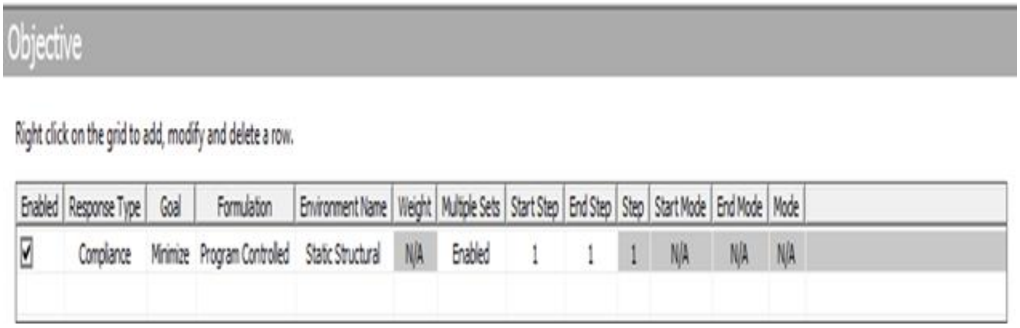


Figure 10 Design and Exclusion Region

Topology optimization identifies the space in the component that needs to be optimized in which the space will have low stress values called design space. As well as the Topology optimization solver will leave some of the regions while taking out the nearbymaterial to find the best topology for a component. The Design region and Exclusion region for the brake pedal is shown in the Figure10.

8. OBJECTIVE

In this work, the objective for topological optimization of brake pedal is minimizing the compliance. In mechanics, "compliance" roughly stands for the inverse of "stiffness". To improve the structural integrity, strains developed in the structure should be minimized. It means that minimizing the compliance or maximizing the stiffness. For some other applications, such as in designing morphing structures, compliance shouldbe increased at certain regions. Therefore compliance is minimized or maximized depending on the aim. The objective table in ANSYS Topological optimization is shown in the Figure 11.



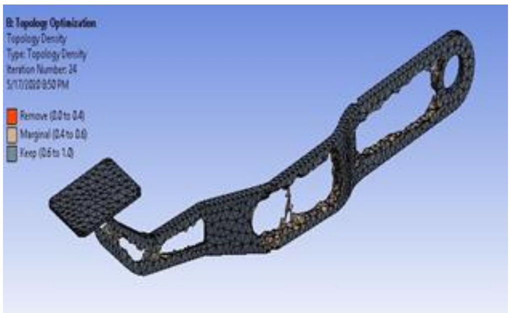
Objective

Right click on the grid to add, modify and delete a row.

Enabled	Response Type	Goal	Formulation	Environment Name	Weight	Multiple Sets	Start Step	End Step	Step	Start Mode	End Mode	Mode
☑	Compliance	Minimize	Program Controlled	Static Structural	N/A	Enabled	1	1	1	N/A	N/A	N/A

Figure 13 Objective table of Topological optimization of the brake pedal

9. TOPOLOGY DENSITY RESULTS



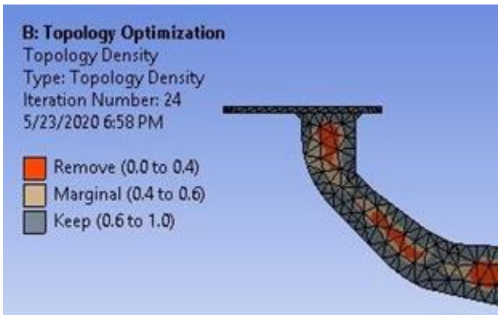


Figure 14. Different regions in the optimized geometry **Figure 15.**Optimized Brake pedal

The results shown in the figure14 and figure15 are not preferable for manufacturing. In this connection SPACE CLAIM direct modeler will be used to create the regular geometries on where the irregularities are present.

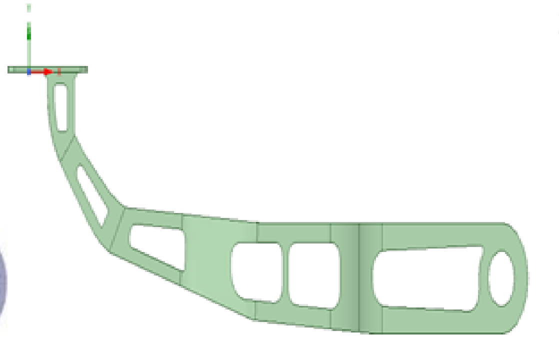


Figure 16. Modified geometry in Space Claim **Figure 17.** Modified geometry in Space Claim

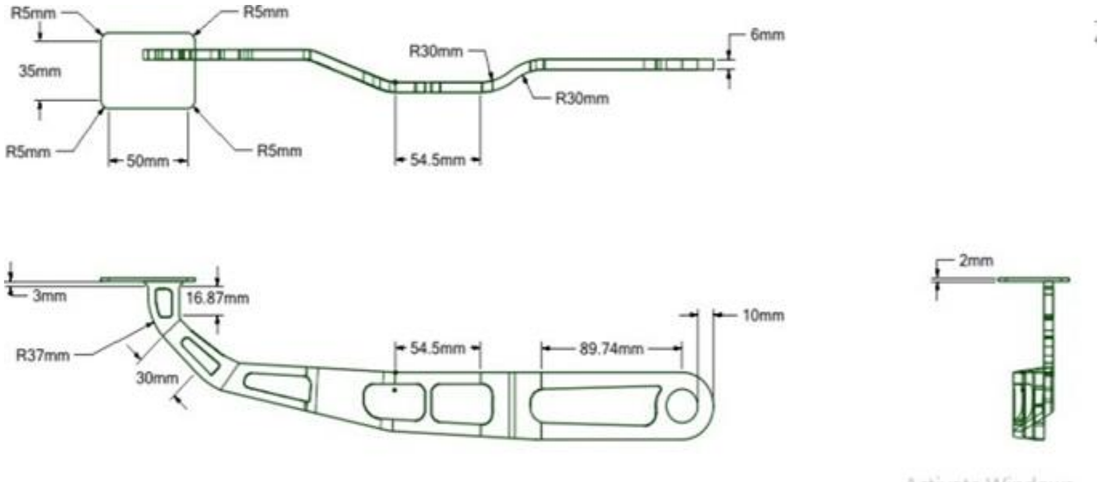


Figure 19. Drafting model of modified design

10. STATIC STRUCTURAL ANALYSIS OF OPTIMIZED MODEL

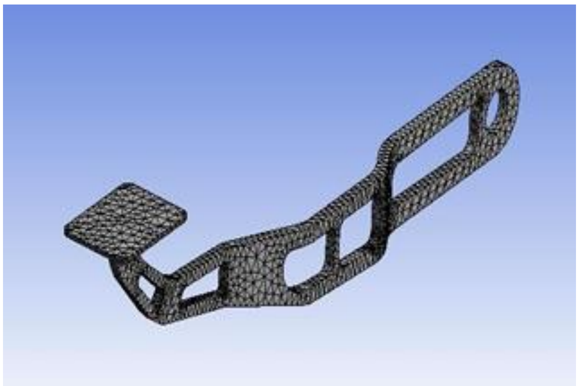


Figure 19. Discretized model of optimized brake pedal

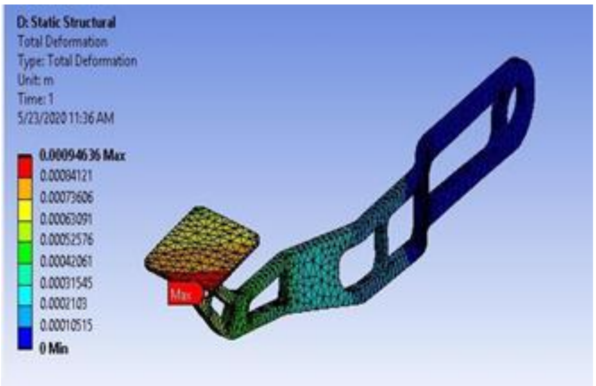


Figure 20. Total deformation of optimum model

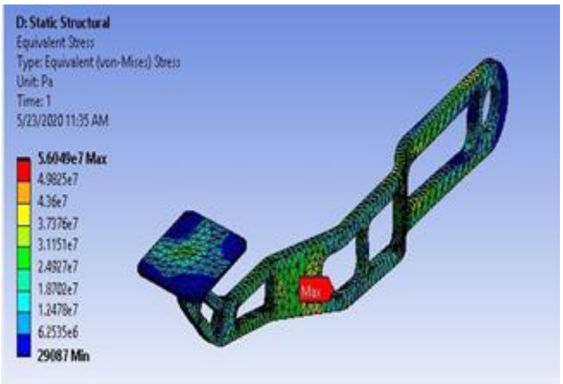


Figure 21. Equivalent stress of optimum model

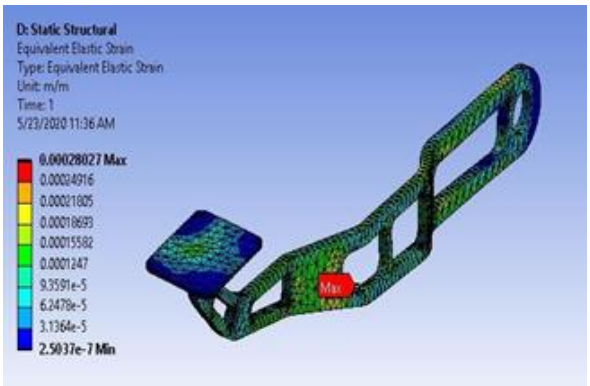


Figure 22. Equivalent strain of optimized brake pedal

1. Maximum stress developed is 56.049 MPa and the minimum stress developed is 0.029087 MPa.
2. Maximum deformation is 0.00094636m and minimum deformation is 0m.
3. Maximum strain is 0.00028027 and minimum strain is 2.5037e-7.

11. RESULTS AND DISCUSSIONS

Table1. Reduced mass and volume results of brake pedal.

Initial Model		Optimized Model		Reduction in mass and volume
Mass (kg)	Volume (m^3)	Mass (kg)	Volume (m^3)	43%
0.59891	7.629e-005	0.3405	4.338e-005	

Table 1 shows the optimum results of mass and volume of an initial model and optimized model.

From the above table, it is clear that the mass of model before optimization is 0.59891 Kg and after optimization is 0.34055 Kg, thereby reducing 0.25836 Kg. The volume of initial model is 7.6294e-005 m^3 and that of optimized model is 4.3382e-005 m^3, thereby reducing 3.2912e-005 m^3. As the mass and volume are directly proportional properties, the percentage reduction in mass and volume is 43.

Table 2. Deformation, Von-mises stress results of initial, Optimized Component

S. No	Load (N)	Initial Model		Optimized Model	
		Equivalent stress (MPa)	Deformation (mm)	Equivalent stress (MPa)	Deformation (mm)
1	90	47.96	0.616	50.44	0.851
2	100	53.29	0.684	56.04	0.946
3	115	61.28	0.787	64.45	1.088
4	125	66.61	0.856	70.06	1.183
5	140	74.60	0.958	78.46	1.324
6	150	79.93	1.027	84.07	1.419

Table2 shows the variance, von-mises values in the application of the various forces on the original and well-designed brake pedal model receiving maximum stress of the prepared model as 84.07MPa at 150N is considered within the permissible limit of 250 MPa. Therefore, the prepared model is allowed in view of the stress distribution situation. It is possible to increase the loads until the yield stress (250 MPa) values of the selected item can get failure.

12. CONCLUSION

This work mainly concentrated on minimizing the weight of the existing brake pedal and suggests the new design standards which are not suggested from the literature. Weight has been reduced to 258.3 grams which is a 43% lower weight of the existing model.

1. The maximum stress produced in which the model before optimization and after optimization is much less than yield stress 250 MPa and the change in deformation is negligible.
2. Material removal is done from low stress locations only. So it does not affect the strength of the model.
3. Proposed design which will be called as optimized model given good results in mass and volume point of view with 43% reduction.
4. Unlike in the referred literature, the material has been removed from the innerregions of the brake pedal by keeping the shape of the component unchanged.

REFERENCES

[1] Tanmay Nandanwar, Keyour Waghela, Eshaan Gupta, Narendiranath Babu T "Topology optimization of the bell crank & brake pedal, International Conference on Design, Automation, and Control (ICDAC 2020). IOP Conf.Series: Materials Science and Engineering 1123 (2021) 012035.

[2] Oğuz Doğan, Onur Can Kalay, Emirhan Kartal and Fatih Karpat "optimum design of brake pedal for trucks using structural optimization and design of experiment techniques". International journal of automotive science and technology 2020, vol. 4, no: 4, 272-280.

[3] Pritesh Muralidhar Ingale, "Topology Optimization of an All-Terrain Vehicle" Brake Pedal International Journal of Engineering Research & Technology (IJERT), Vol. 8 Issue 06, June-2019, ISSN: 2278-0181.

[4] Miss. Ashwini n.gawande, prof.g.e.kondhalkar, prof. Ashish r. Pawar, " Static Structural Analysis And Optimization Of Brake Pedal", International Research Journal of Engineering and Technology (IRJET), ISSN : 2395-0056, Volume 4, May 2017.

[5] Mohd Nizam Sudin, Musthafah Mohd Tahir, Faiz Redza Ramli, Shamsul Anuar Shamsuddin, "Topology Optimization in Automotive Brake Pedal Redesign", International Journal of Engineering and Technology (IJET), ISSN : 0975-4024, Volume 6, No 1 Feb-Mar 2014.