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DESIGN, THERMAL AND STRUCTURAL ANALYSIS OF DISC BRAKE PLATE USING COMPUTATIONAL NUMERICAL ANALYSIS

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ABSTRACT
With advances in technology, safety is one of the most important parameter that is emphasized in the automobile sector. Thus, modern vehicles use Disc Braking system instead of the conventional drum, band and block brakes to insure efficient and quick braking. Disc brakes are used in the front wheels of Hatchback cars, two wheelers and both rear and front wheels of high-end vehicles. To design such efficient disc brakes with minimum consumption of money and time, computational numerical methods are used. In this paper, Finite Element Method (FEM) was used to determine the strength of the designed disc brake after the effects of temperature at the time of braking.

KEYWORDS: Disc Brake Plate; Thermal Analysis; Finite Element Method; ANSYS.

1. INTRODUCTION
For stopping or adjusting the motion of a moving member of a machine by the generation of artificial friction, brake is used. The disc and the brake pads absorb the kinetic energy of the wheel, to execute the operation of breaking. The absorbed energy by brakes generates heat; this heat is then released to the environment and hence stopping the wheels of the vehicle. The basic principle in braking involves converting the kinetic energy of the system into some other form of energy. Disc brake consist of cast iron disc that is bolted to the hub of the wheel and a caliper that is a stationary housing. Caliper is then connected to the axle casing or stub axle, in two parts each of which contains a piston. Between the piton and the disc, a friction pad is held by using retaining pins and spring plates. The passages are drilled in the caliper, for the fluid to enter or leave the housings. As the brakes are applied the pistons that are hydraulically actuated, by applying equal and opposite forces that move the braking pads in contact with the disc. Due to the friction between the surfaces of braking pads and the disc, the kinetic energy of the rotating wheel is converted into heat energy. As the brakes are released, the brake rubber-sealing ring retracts the pistons by acting as a return spring and because of this, the friction pads move away from the disc. The breaking system must possess the ability to maintain constant temperature to transfer heat into atmosphere in order to enhance the performance of the disc. For a good breaking system, it should have less wear. during braking, the vehicle should not skid and should stop the moving member in minimum distance in case of emergency.[1]

While designing the sliding contact system such as clutches and brakes, thermal stresses must be taken into account. Due to high temperature, there are chances of permanent distortion and even surfaces cracks. When the sliding speed is extremely high, a localized high temperature region known as hot spots may occur on the sliding surfaces. These hotspots may cause damage to the material, generation of thermal cracks and can even induce undesirable frictional vibrations. Appearance of these hotspots is called Thermos Elastic Instability (TEI), TEI is usually observed in clutches and brakes. . On the basis of direction of acting force the brakes are classified as

A. Axial Brake - In axial brake, the direction of the force acting on the braking system is axial.
B. Radial Brake - In Radial brake, the direction of the force acting on the braking system is perpendicular to the axial direction. Radial brakes are further sub-divided into Internal as well as external brakes. [2]

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In this paper, focus was made on designing a disc plate and using the Finite Element Method (FEM) for the analysis of the effects of temperature, when the brakes are applied. Taking into account these thermal effects, static structural analysis of the disc was done for the determination of values of stresses and deformation.

2. MATERIALS AND METHODS

A. Material property

Material plays an important role in product design and manufacturing. Disc brakes are made up of a variety of material ranging from steel to cast iron. The material selected for this analysis is Cast iron. Cast iron has sufficient hardenability and contains more than 2% of carbon. The thermal and mechanical properties of Cast iron are mentioned below in Table 1 and Table 2 respectively.[3]

Table 1. Thermal Properties of Cast Iron

Property	**Value**
Thermal conductivity ($w/m.\ k$	46
Density($g/cm3$)	7.2
Specific heat (J/kg.k)	380
Thermal expansion($\mu m/mk$)	11
Elastic modulus (GPa)	110
Coefficient of friction (μ)	0.4

Table 2. Mechanical Properties of Cast Iron

Property	**Value**
Elastic ModulusN/mm^2	*66178.1*
Poisson's Ratio	*0.27*
Shear Modulus N/mm^2	*50000*
Mass Densitykg/m^3	*7200*
Compressive StrengtN/mm^2	*572.165*
Tensile Strength N/mm^2	*151.658*
Thermal Expansion Coefficient /K	*1.2e-005*
Thermal ConductivityW/(m·K)	*45*
Specific HeatJ/(kg·K	*510*

B. Design of disc plate

The disc plate is designed using Soil works software; the diameter of the disc was taken as 381 mm with pad brake area of 2587mm^2. Disc thickness was kept at 16mm. The designing of the disc brake is done using the ISO standard dimensions. Fig.1 shows various views of the designed disc. [4]

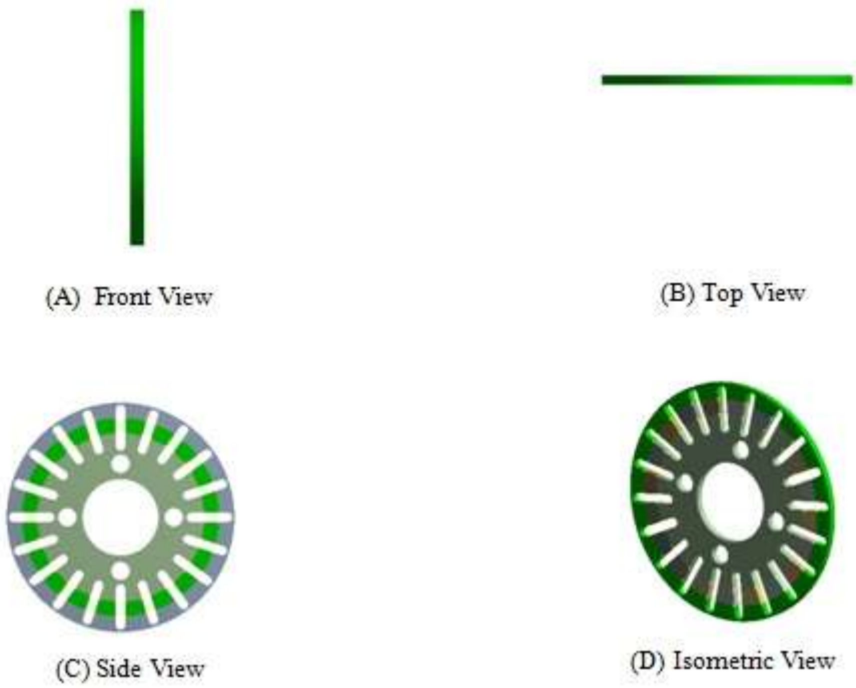

Fig. 1. Various Views of Designed Disc Plate

C. Analysis parameters

In this paper the analysis of the disc plate was done using ANSY workbench software , Both thermal and Structural analysis were interlinked the results obtained from the steady state thermal analysis were made as an input for the static structural analysis and the results were obtained. The mesh was generated using the ANSYS meshing. The details of the meshing are given in table 3.

Table 3. Parameters of Meshed Disc Plate

Detail	Input
Element Order	Linear
Size Function	Proximity and Curvature
Relevance Center	Fine
Transition	Fast
Span Angle Center	Fine
Nodes	130689
Elements	24088

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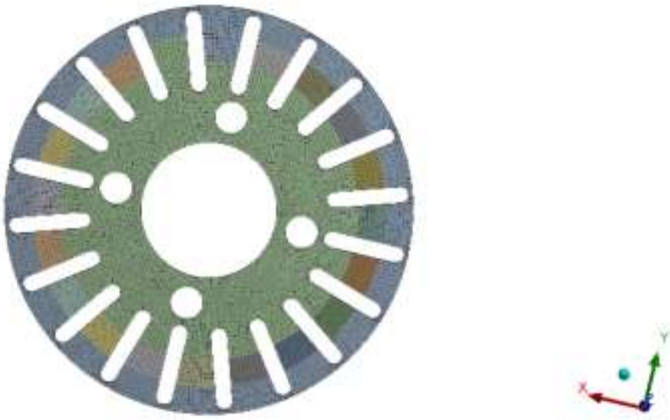

Fig. 2. Meshed Disc Plate

Thermal Analysis

To determine temperature and other thermal quantities that change with respect to time in such a case thermal analysis is used. Change in temperature distribution plays an important role in many applications for example heat treatment, quenching process and many other processes. Temperature distribution also plays an important role in the thermal stresses that result in failure. Heat flux that was applied for this analysis is 0.023 W/mm^2. The disc plate being in exposure to the atmosphere was provided with a natural convection for accurate analysis purpose. Fig. 2 represents the applied input conditions.[2]–[5]

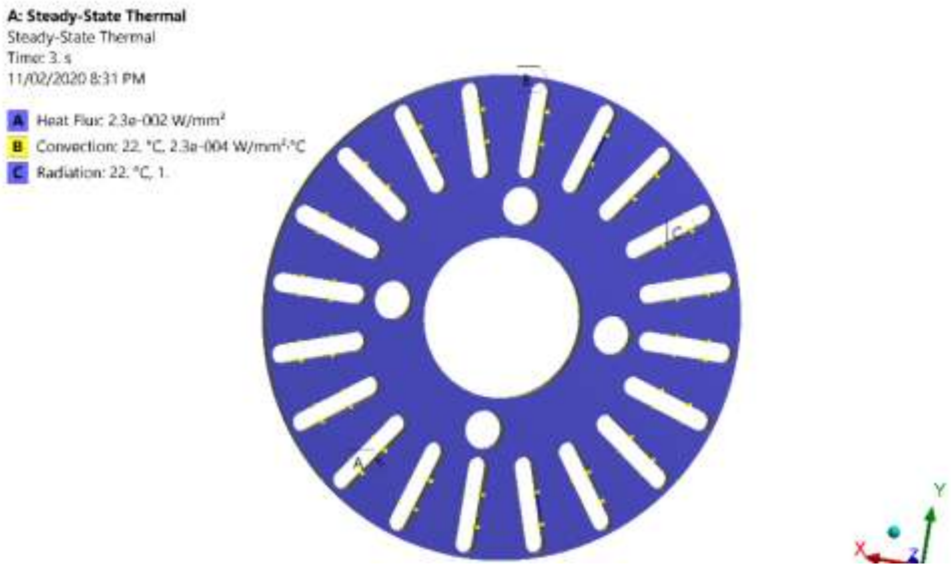

Fig. 3. Steady state thermal input parameters applied on disc plate

Structural Analysis

In the Finite Element Method (FEM), Static structural analysis is the most common application. The Static structural analysis determines deformation stresses, strain and displacements in the structure or component that are caused due to the applied loads. Various constraints were applied; the braking pads applied force of 3,500 N on either side of the disc during the application of braking. The applied constraints are shown in figure 4.[1], [4]

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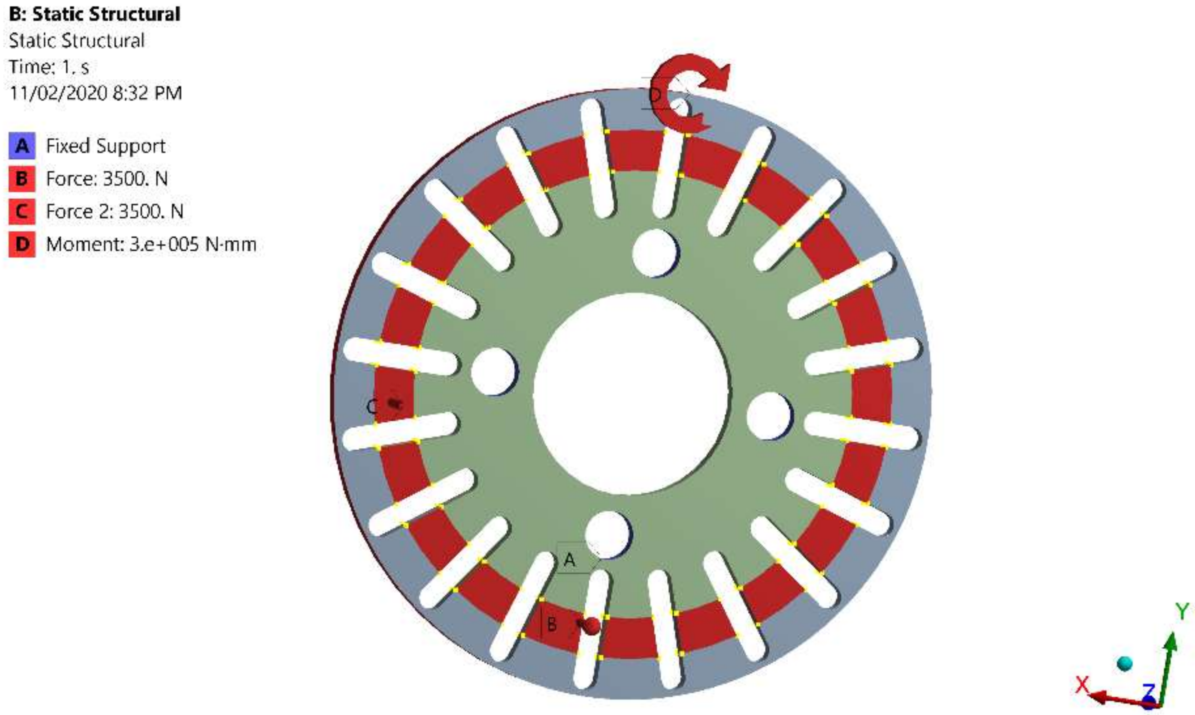

Fig. 4. Static Structural Analysis input parameters applied on disc plate

3. RESULTS AND DISCUSSION

The disc plate was modelled suing Soil works and was exported to ANSYS workbench in STEP format which is readable file exchange format used by analysis software's. The FEM method generally gives an error of about 30%. For testing the compressive and effective tensile modulus of the modelled disc geometry finite element analysis was used. The Disc was analyzed for Changes in temperature, heat flux generation, von-Mises stresses, deformation and safety factor.

Thermal analysis

Steady state thermal analysis was done using the boundary condition at the instant of braking, the maximum and minimum temperature of 42.49°C and 30.23 °C was obtained as the result of the steady state thermal analysis at the applied boundary conditions as given below in figure 5.

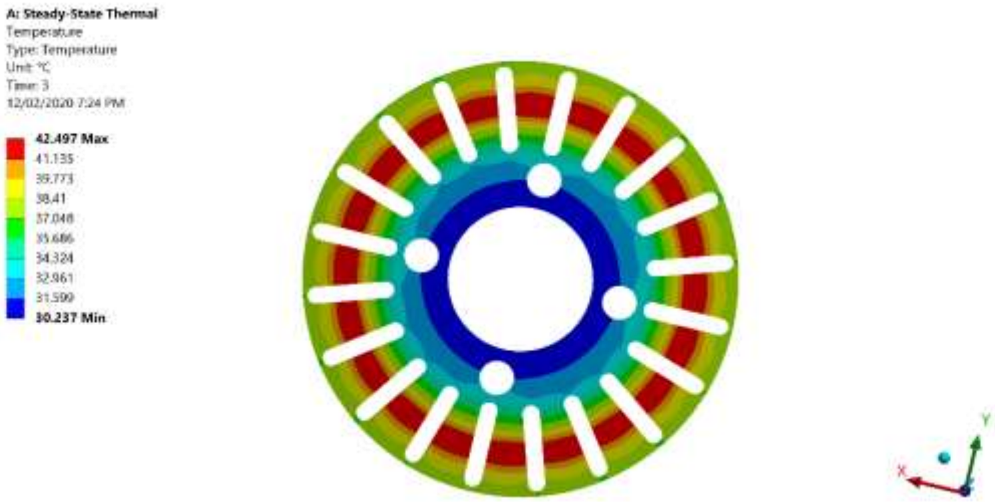

Fig. 5. Contours of Temperature

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The maximum and minimum heat flux of 0.061 W/mm^2 and 0.0002W/mm^2 was observed as given below in figure 6. The maximum temperature and heat flux was observed at the location of braking pads.

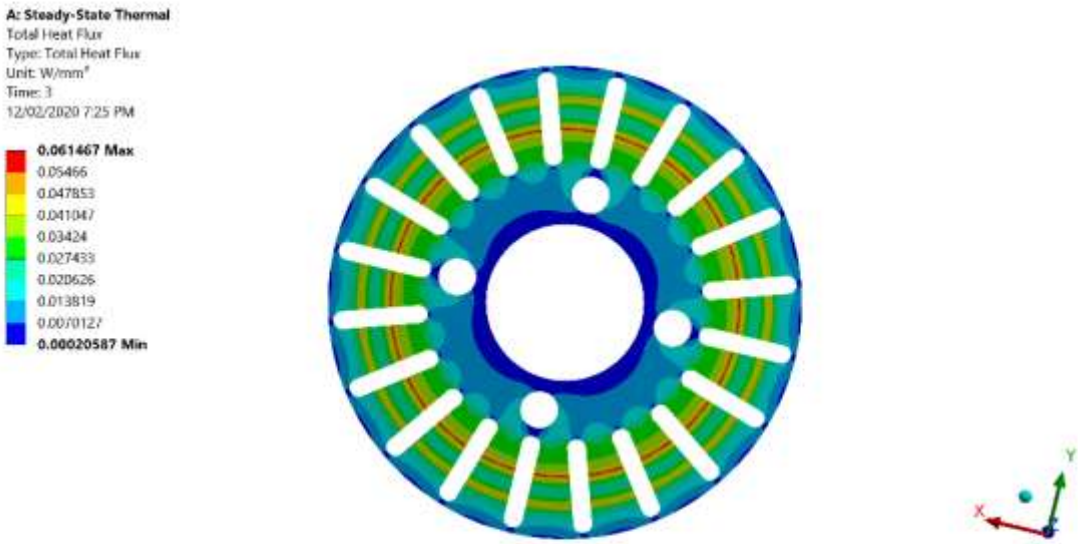

Fig. 6. Contours of Heat Flux

Structural analysis

The results obtained from the steady state thermal analysis were provided as an additional input parameter to the static structural module of the ANSYS workbench. Maximum deformation of 0.0357 mm as shown in figure 7, was observed due to the applied force by the braking pads against the disc and the heat released during braking.

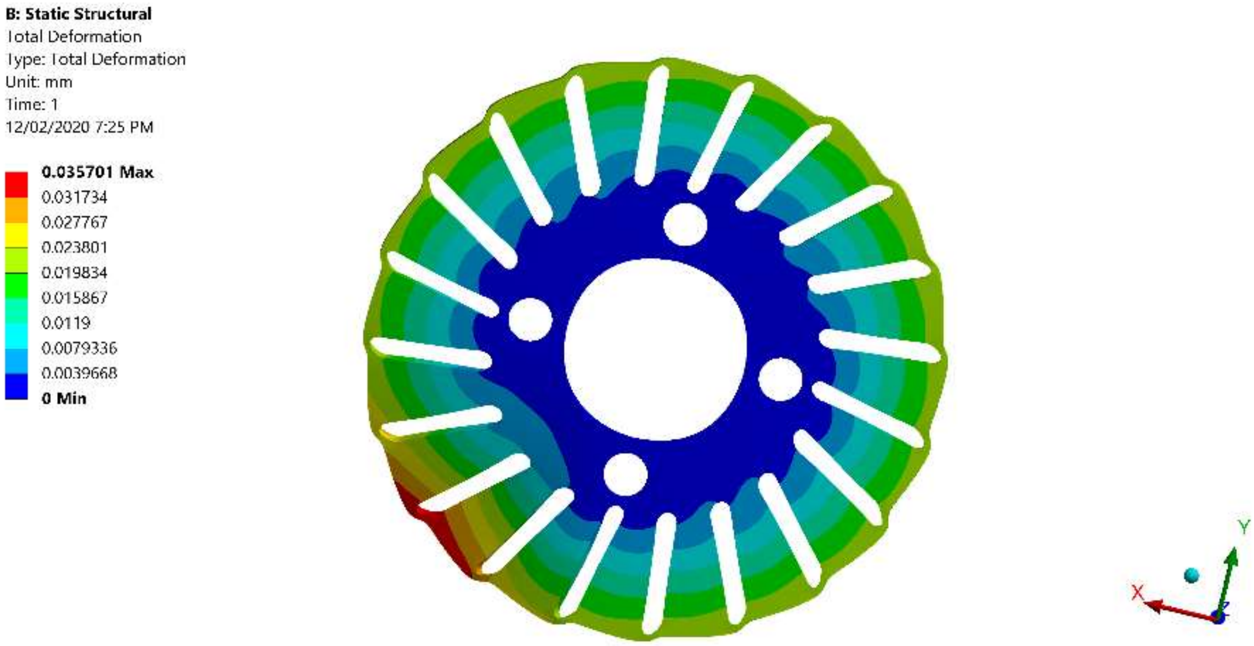

Fig. 7. Contours of Total Deformation

The maximum and minimum von-Mises stress due to the braking was obtained as 0.351 MPa and 167.35 MPa as given in figure 8. The minimum safety factor observed for the disc was 1.493 as shown in figure 9.

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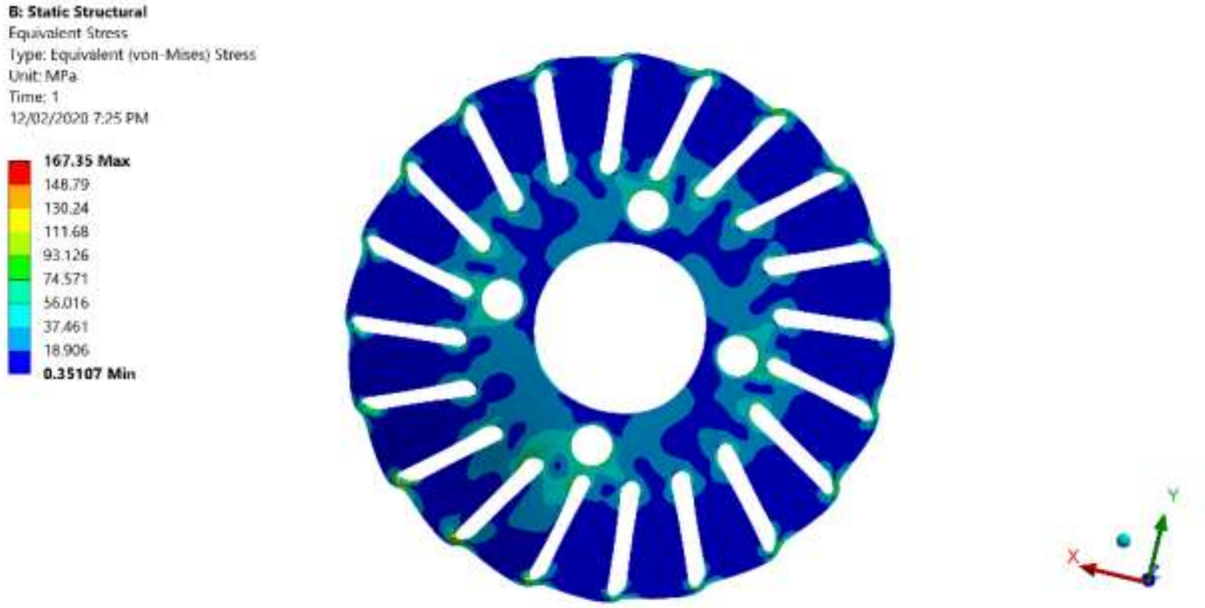

Fig. 8. Contours of Equivalent Stress

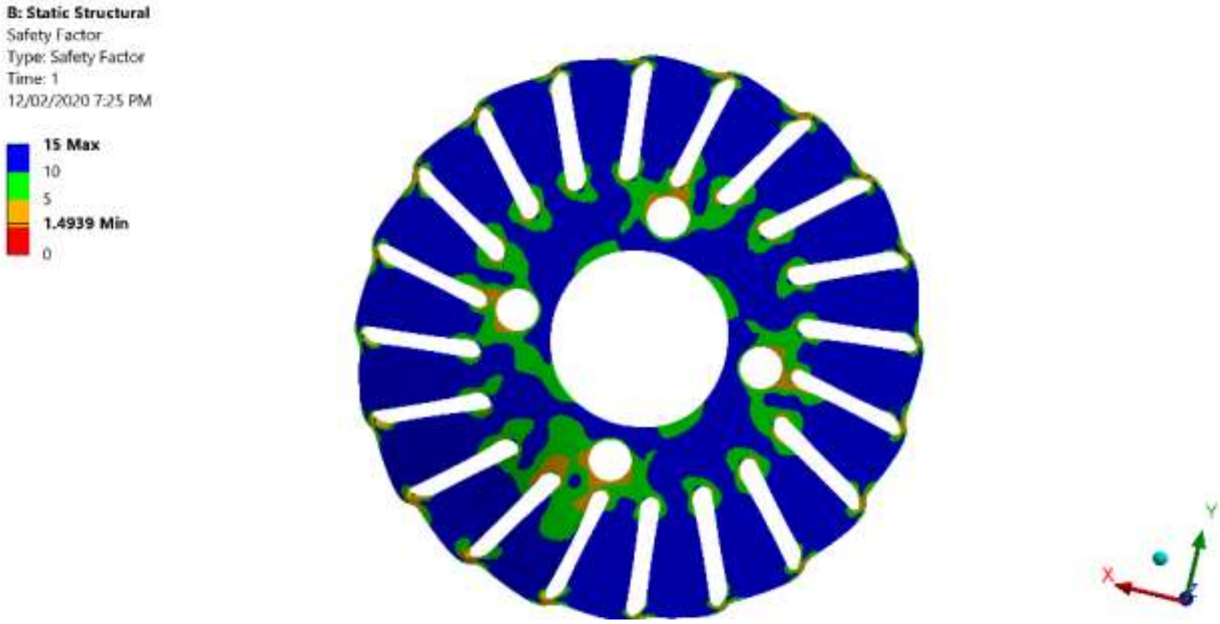

Fig. 9. Safety Factor

The above results were obtained by applying the boundary conditions in ANSYS software in a workstation having configuration of 16 GB of RAM, 4 GB graphic card, Intel i5 8th Generation processor and 7 cores were used for the computation purpose.

4. CONCLUSION

In this study, a new design of the dis was created in order to find out the improvements in the strength of the disc and for providing greater stability to the disc plate during the design stage. The results of the thermal analysis were used an the input for the static structural analysis using MAPDL solver, the maximum deformation of the designed disc was found to be 0.0357 mm and the maximum equivalent stress of 165.49 MPa was observed. Minimum Safety factor of 1.49 determines that the changes of failure of disc can occur only if

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the applied force by the braking pads becomes 1.5 times of its actual force. This study provides the basis of using such similar design of the disc for efficient braking with less chances of failure due to thermal stresses.

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