Analysis and Shape Optimization of disc Brake with Alternate Material

T. Babu, R. Sudharshan, R. Akil, S. Chiranjeev

***Abstract*: Every decade the automotive industry has seen significant inventions and improvements, which diversified the industry's spectrum in whatever ways possible. One such significant invention cum improvement in the brake systems is the disc brake system. Disc brakes gave way for the commercialization of high-powered racing bikes. The disc brakes had its own way of revolution in their shape, size and application from their inception. This paper deals with the shape and size optimization of the disc brakes and analyzing the same with different probable materials that can be employed for the application considered. Designing three different shapes of discs and analyzing them with two different materials produces a wide range of conclusions with some favoring results.**

***Index Terms*: Analysis, Disc Brakes, Design, Shape Optimization**

I. INTRODUCTION

Disc brakes introduced a sort of higher reliability than it had for drum brakes. Applications of disc brakes in an automobile industry are at their highest usage. Right now, disc brakes with ABS are used in both the front and back wheels in motorbikes and the disc brakes are employed in the front tyres of a midsized car.Vishal Ashokan et al (2015) investigated about the reinforced composite matrix disc and its design and analysis. Here, the author calculated the normal force, shear force and braking torque of the carbon ceramic matrix disc. Ansys software was used to find the deflection of the disc. Thus, the author proved to have a better efficiency among various material [1]. D. Bhadgaonkar et al (2006) investigated about the vibrational analysis of the disc using finite element analysis. the author describes about the size and shape of the disc that has been commonly used. By using finite element analysis, an equation between natural frequency and crack depth has been created. the author concludes that with the help of the generated equation the depth of the crack on the disc rotor could be found easily [2]. Shah E Alam et al (2015) investigated about the Thermal Analysis of the disc brake rotor.

The author compares two-disc brakes, one with vents and holes and another with only holes. a thermal analysis for both the disc was carried out. the author concluded that the disc with vents and holes has a better output performance and having good heat dissipation [3].

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Hui Lu et al (2016) investigated about the optimization design of a disc brake system. the author uses the hybrid probalistic and interval model to deal with the uncertainties exciting with the disc brake system. the Response surface Methodology (RSM) was employed of finite element simulations as the time consumption is high. Combinational algorithm of genetic algorithm and Monte-Carlo method have been used to perform the optimization. Thus, the author concludes that the results with numerical values shows the effectiveness of the optimization and an improved design of disc brake system [4]. Harshal Suresh Shinde (2017) investigated about the structural analysis of disc brake rotor using different materials. the author uses five different materials such as Aluminium, Aluminium-Copper Alloy, Titanium-2, Titanium-5, and Grey Cast Iron. He conducted a test by running the disc brake for five minutes and then suddenly applying the load for every material. Heat flux is obtained theoretically and weights of all materials have been measured. Thus, the author concluded that, by measuring compressive strength, shear stress, friction coefficient among the selected material he chooses Al-Cu alloy has wise and efficient output [5]. Swapnil D Kulkarni et al (2015) investigated about the thermal analysis of the disc brake". In this paper, the author performs various analysis and various test to find the material, which has more efficiency, and good heat dissipation. Heat flux distribution test have been found out for various materials. Thus, the author concluded that the material DB410 have the best heat dissipation and the working life is longer than others are [6]. Prasanth P.Suryawanshi et al (2017) investigated about the "Thermal and structural analysis of Disc Brake". In this paper, the author compares the Apache RTR 180-disc brake material with other materials to know the best heat dissipation. Thermal and structural analysis have been found out for different disc and concluded that the own design modification of disc brake to have better efficiency and better heat dissipation [7]. Lemi Abebe et al (2016) investigated about the thermal analysis of disc brake for different materials". the author selects four materials such as Cast iron, Maraging steel, Aluminium metal matrix composite and E-glass. Maximum principal stresses also calculated by both analytical and FEA analysis. Thus, the author concludes that among the selected materials, ALMMC has less stress and temperature and proved to have a better efficiency [8]. Sumeet Satope et al (2017) investigated about the thermal analysis of disc brake. In this paper, the author performs various analysis and tests by assuming suitable input values.

Calculations with different parameters have been done to obtain thermal analysis of the brake. Thus, the author concluded that Cast Iron is the best-preferred material among the other since it has the low temperature rise.

II. WORKING

The major working principle of disc brakes is the slowing or stopping of vehicles using friction. Additionally, there are many support equipments to achieve the stopping of vehicle such are brake pads, brake caliper, piston etc. when the brake lever is pressed, it actuates a small piston housed inside the caliper. The piston on the other hand is connected to the brake pads placed on opposite sides, which when force applied, exerts a static force on the surface of the disc brakes converting the kinetic energy of the discs into heat energy. By continuous application of force, leads to slowing of vehicles or stopping them. Disc brakes are preferred because of their shorter response time, higher accuracy and increased reliability.

III. ISSUES WITH DISC BRAKES

As said earlier the disc's kinetic energy is converted into heat energy, this liberation of heat if not cooled may lead to serious problems on the build of discs. To cool away this heat, the holes are provided on the discs. In addition, if the number of holes is high then that leads to poor strength of the disc brakes. The ventilation and thickness of the discs is another factor. The thickness of the disc must be below 5mm for motorbikes. Moreover, the thickness of the disc brakes depends on the power of the engine and the wheel size. If the thickness is too high, then the weight of the disc increases causing another branch of issues.It is very much important to maintain an optimum design in order to get the best out of the disc brakes.

IV. DESIGN OF DISC BRAKES

The measurement was taken by looking into various discs designed by various motorbike-manufacturing companies. From the measurements, three types of discs consisting of different number of holes and different shapes were designed in the software to see which shape produces better heat liberation and cooling.

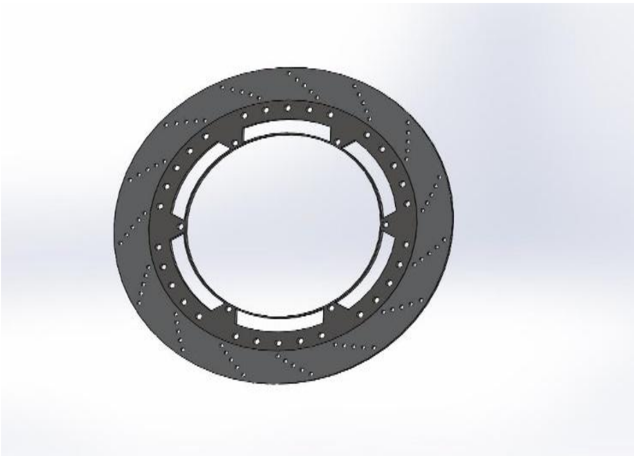

Fig:1 Typea Disc

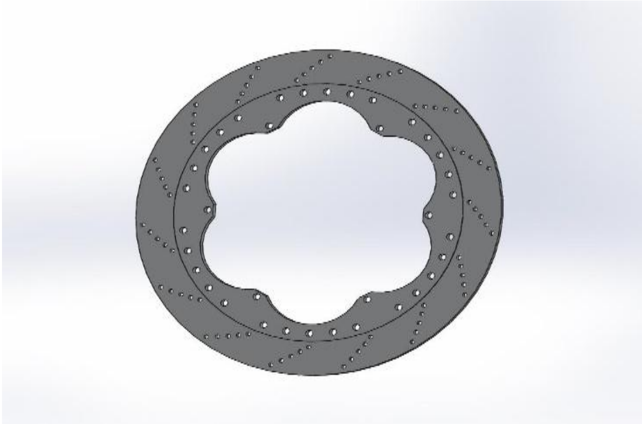

Fig: 2 type b disc

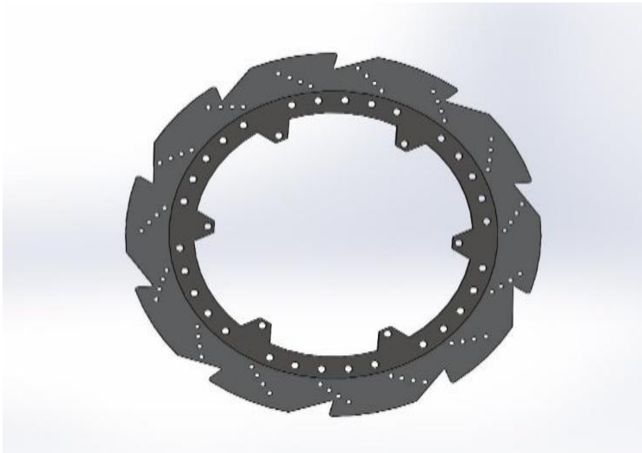

Fig: 3 type c disc

Table 1: Dimensions of the three types of Discs Brakes

Particulars	Type A	Type B	Type C
Outer diameter	260 mm	260 mm	260 mm
Inner Diameter	150 mm	150 mm	150 mm
Thickness	2.5 mm	2.5 mm	2.5 mm
Brake pad surface	54 mm	54 mm	54 mm
Holes	5 mm – 36 numbers 3 mm – 75 numbers	5 mm - 36 numbers 3 mm – 75 numbers	5 mm - 36 numbers 3 mm – 60 numbers
Wheel hub supports	6	6	6

V. MATERIAL PROPERTIES

The study also takes two different types of materials and their properties. These materials are applied during analyses and the corresponding temperature distribution around the discs surface are found. The materials considered are Aluminum (Al 6061) and stainless steel (SUS 410). The reason to choose stainless steel was to find a better alternative material in the place of regular steel. Since, disc brakes are everywhere; they are also available in different shapes, sizes but only in two to three variety of materials.

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This temperature analysis was carried out in order to find the better performing disc type in the three type of disc considered.

Table 2: Material properties of Al6061 and SUS 410

Particulars	Al 6061	SUS 410
Density	2.7 g/cc	7800 kg/m3
Young's modulus	68900 MPa	2000 MPa
Tensile yield strength	276 MPa	203 MPa
Specific Heat	896 J/kg/K	460 J/kg/K
Poisson ratio	0.33	0.275
Bulk modulus	6.7549E+10 Pa	1.4815E+09 Pa
Shear modulus	2.5902E+10 Pa	7.8431E+08 Pa

VI. ANALYSIS

The temperature analysis was carried out using the ANSYS 17.2. ANSYS has been the world leader in commercial analysis system. The steady state thermal system was used to carry out the analysis.

VII. MESHING

The three discs are imported into the ANSYS workbench in the IGES format. Before carrying out the analysis the part is meshed. Here, fine level of meshing is applied on all the three discs to get an accurate and sensible results with refinement depth of 2 and minimum edge length of 0.50 mm for type A and B disc and 2.8894E-03 mm for type C disc.

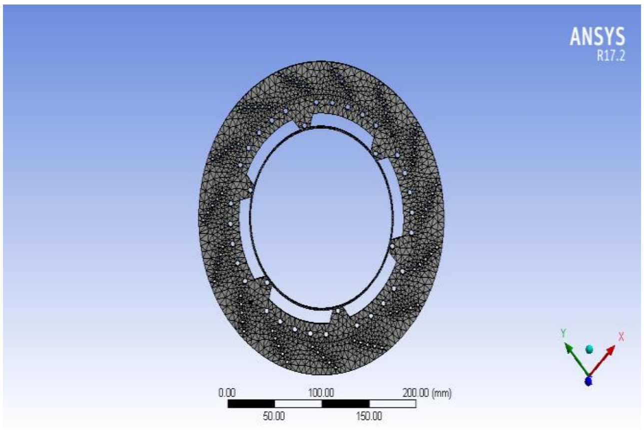

Fig. 4: meshed type a disc

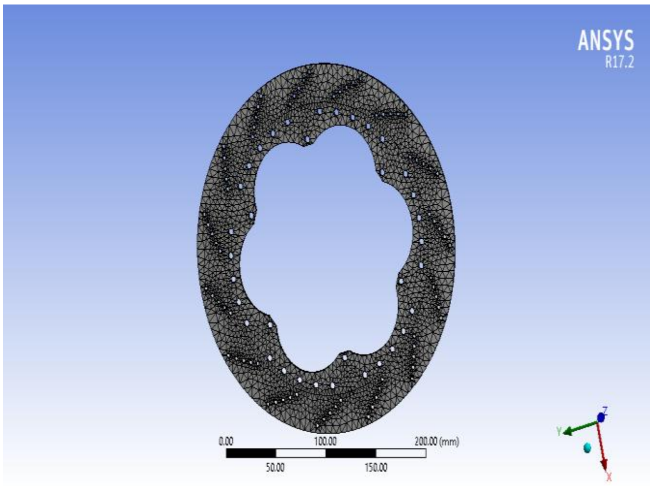

Fig.5: meshed type b disc

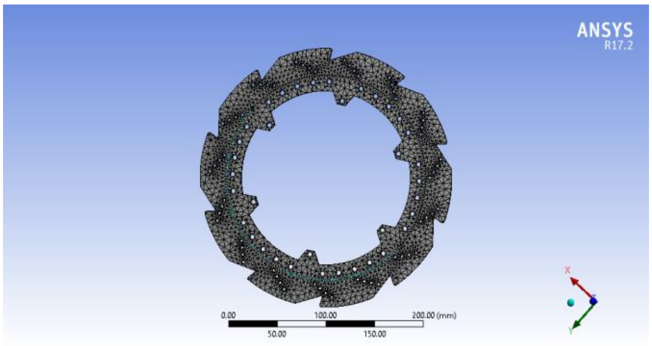

Fig.6: meshed type c disc

VIII. TEMPERATURE

It was found that during the practical application of the disc brakes, the discs are subjected to a temperature up to 650 ºC at the time of braking because of the heat produced. Hence, the initial temperature of the discs was taken as 650 ºC. The ambient temperature was taken to be 22 ºC. The high temperature is seen only on the surface were brake pads meet, hence that surfaces are selected and the temperature was applied. The remaining areas were selected for convection, as they enhance the flow of surrounding air.

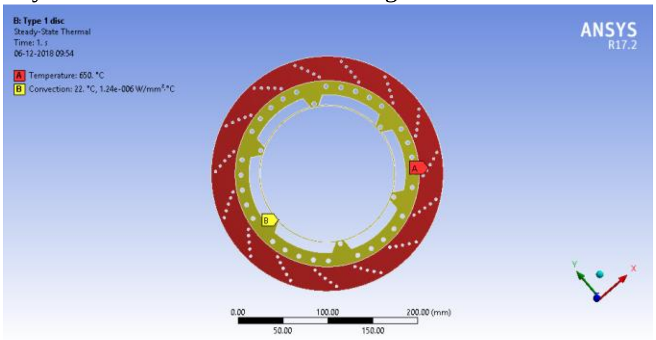

Fig.7: temperature applied type a disc

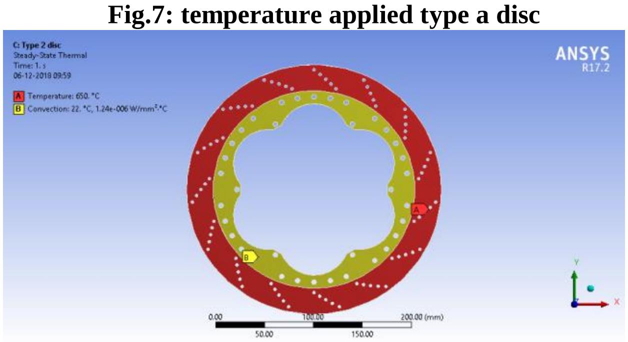

Fig.8: temperature applied type b disc

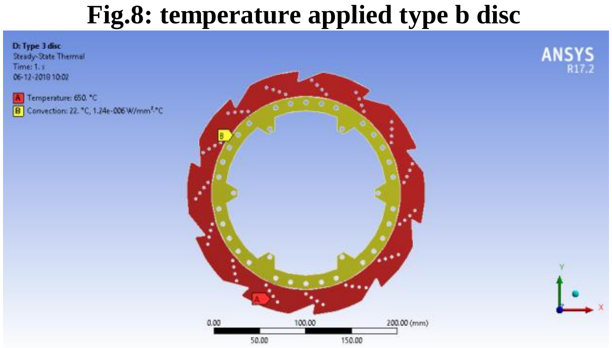

Fig.9: temperature applied type c disc

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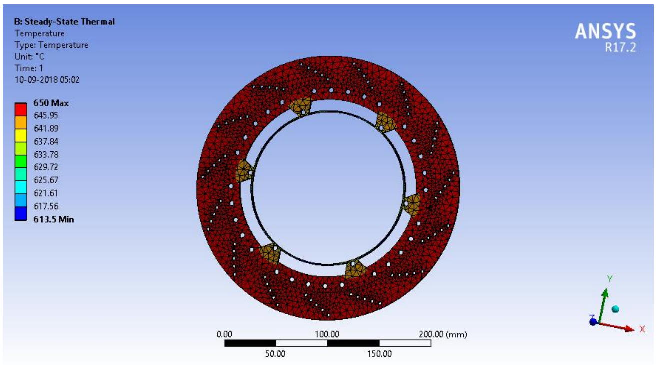
IX. RESULT



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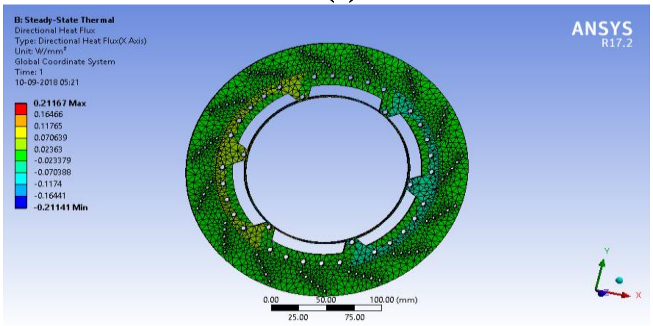

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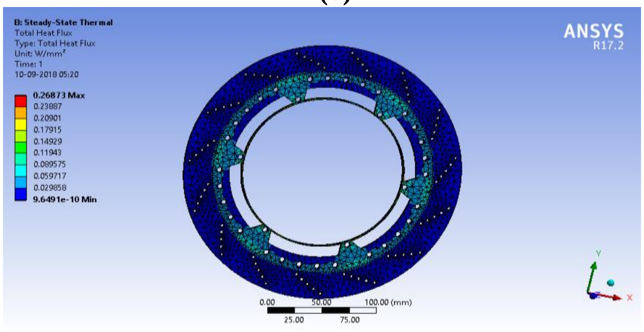
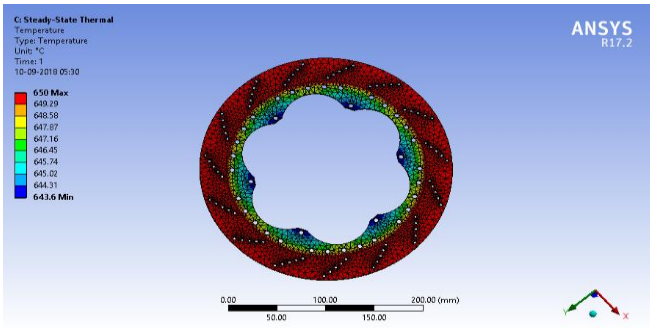


(c)

Fig.10 (a), (b), (c): Temperature, Total Heat Flux and Directional Heat Flux of Type an Al6061 Disc



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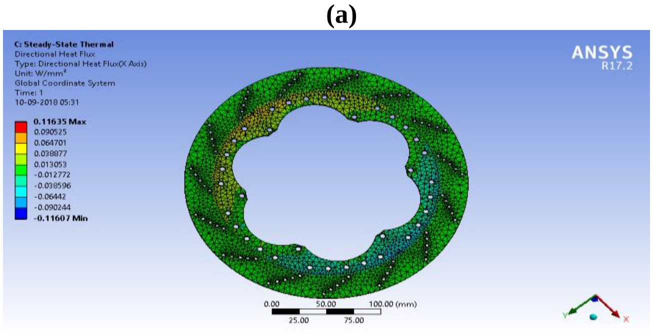

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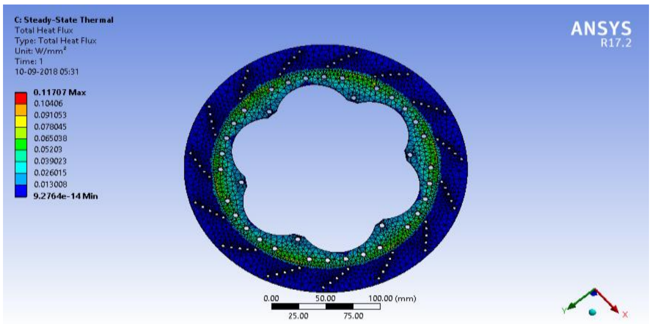

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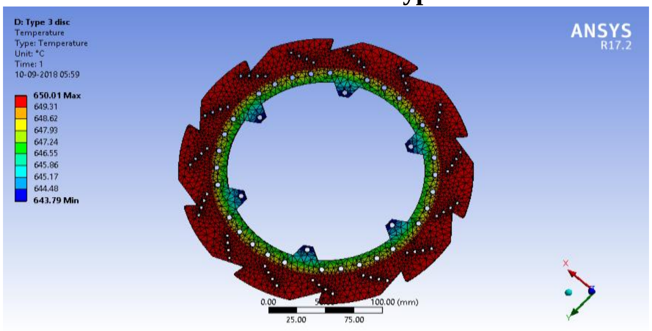
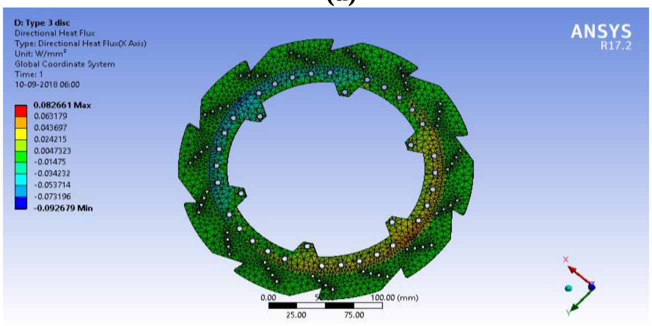
Fig. 11 (a), (b), (c): Temperature, Total Heat Flux and Directional Heat Flux of Type B Al6061



(a)



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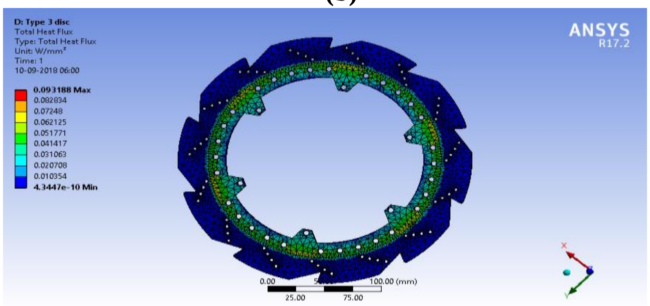

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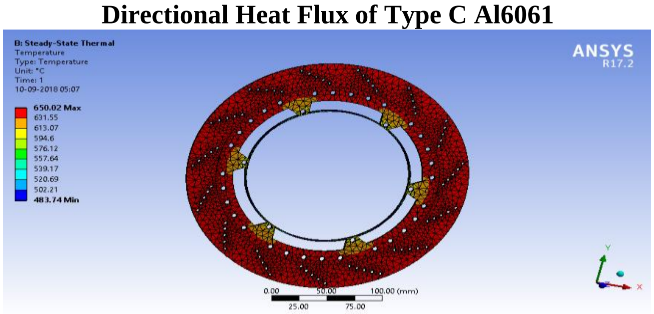
Fig.12 (a),(b),(c): Temperature, Total Heat Fluxand Directional Heat Flux of Type C Al6061



(a)

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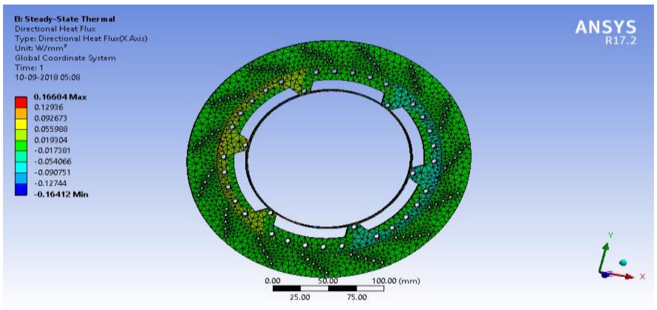

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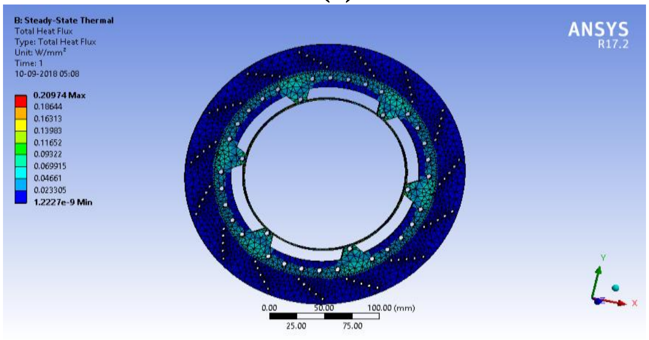
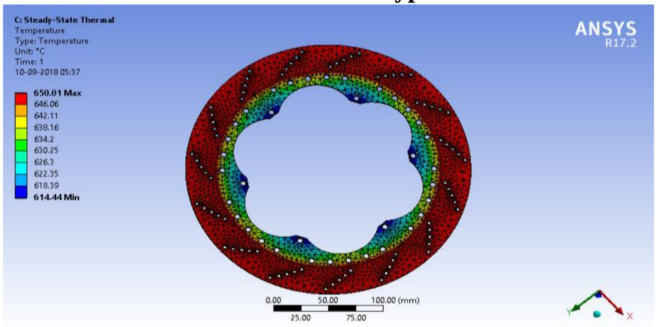


(c)

Fig.13 (a),(b),(c): Temperature, Total Heat Flux and Directional Heat Flux of Type A SUS410.



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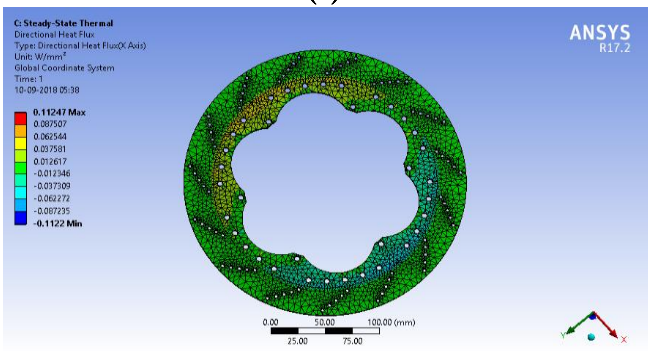

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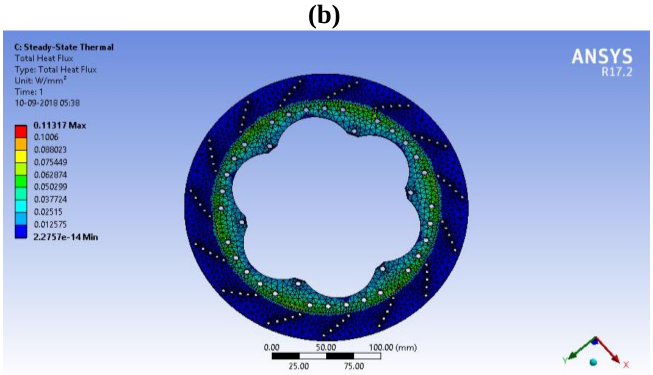

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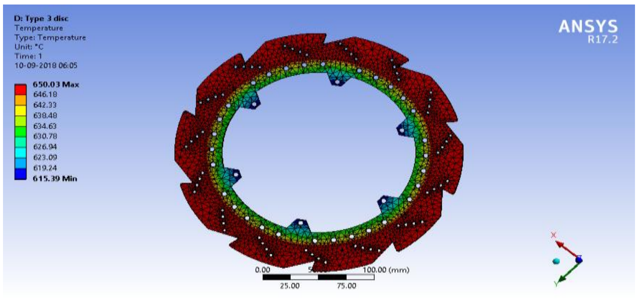
Fig.14 (a),(b),(c): Temperature, Total Heat Flux and Directional Heat Flux of Type B SUS410



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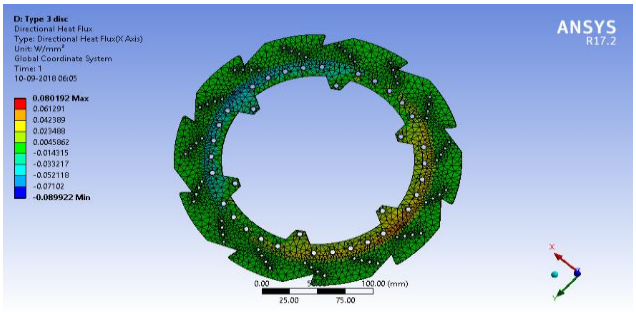

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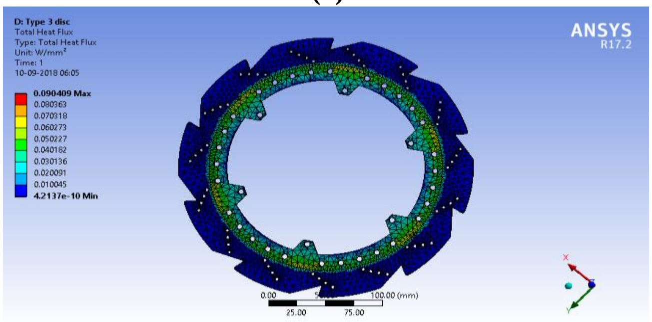

(c)

Fig.15 (a), (b), (c): Temperature, Total Heat Flux and Directional Heat Flux of Type C SUS410

Table 3: Simulated results obtained for Al6061

TYPE	TYPE A	TYPE B	TYPE C
Temperature min *c	613.5	643	643.79
Temperature max	650	650	650.01
Temperature difference	36.5	7	6.21
Min total heat flux	9.65 E-10	9.28 E-14	4.34 E-10
Max total heat flux	0,26873	0,11707	9.32E-02
Minimum directional heat flux	-0.21141	-0.11607	-9.27E-02
Max. Directional heat flux	0.21167	0.11635	8.27E-02

For the considered materials and given boundary conditions the steady state thermal analysis on the discs were done and the results can be analyzed further by dividing them based on the materials employed.

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Table 4: Simulated results obtained for SUS 410

TYPE	TYPE A	TYPE B	TYPE C
Temperature min	483.74	614.44	615.39
Temperature max	650.02	650.01	650.03
Temperature difference	166.26	35,57	34.64
Min total heat flux	1.22E-09	2.28E-14	4.21E-10
Max total heat flux	0.20974	0.11317	9.04E-02
Minimum directional heat flux	-0.16412	-0.1122	-8.99E-02
Max. Directional heat flux	0.16604	0.11247	8.02E-02

By comparing the values in the above table 4 and 3, from the temperature difference column it is obviously evident that the stainless-steel material performs very much better than the Al6061. The temperature difference between the materials show their performance and the heat dissipation properties. This can be concluded when viewed in a surface level. In terms of better design, the type A disc was found to be better cooled and with better air flow in it. This is due to the presence of large size ventilation than the other two types of discs. In the total heat flux perspective, the type B disc has the lowest of all the three. The values are less in both the materials. The type C disc showed poor performance and had not so desirable results in both the materials considered. Only the temperature difference was found to be high when SUS 410 material was applied. Other than that, it displays low directional heat flux values in stainless steel. Type C disc shows that the irregular shaped disc of any size produces not so better results.

X. CONCLUSION

The issues faced by disc brakes are minimized in order to improve their utility. The warpage and uneven rotor wear are main features, which minimizes the efficiency and effectiveness of disc brakes. Since warpage occurs mostly after 800 degree Celsius, it does not have effect on aluminum and stainless steel. Uneven rotor wear can be taken care by reducing the delay period of brake caliper to return its rest position. Thus, overall shape optimization and modification with materials will increase the efficiency and effectiveness of disc brakes.

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