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Structural and Thermal Analysis for Design and Optimization of Disk Brake with Alternate Materials

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Abstract: *In this present work the temperature fields and structural fields of the solid brake disc during short and emergency braking with four different materials have been analyzed. The distribution of the temperature depends on the various factors such as friction, mechanical properties of material, design of the brake disc, surface roughness and speed. We analyzed the different values of temperature, total deformation, the equivalent strain - stress and deformation for different designs and different materials using analysis software called Ansys with materials namely Stainless-Steel SS 420, SS 316 and Aluminium Al 6061, Al 7075. With the value at the hand the values are determined for best suitable material for the brake disc with higher life span. This work determines the shape and size optimized for disc brake along with chosen material for efficient disc with a better life span. Three different discs were designed with four different materials to produce a wide range of conclusions.*

Keywords: *Disc Brake, ANSYS, Design optimization, SS 420, SS 316, Al 6061-T6, Al 7075-T6, UG NX 10.0*.

I. INTRODUCTION

Disc brakes have now offered higher reliability than formerly used classic drum brakes in automobile industry. Applications of disc brakes in an automobile industry are at their highest usage now because of their greater efficiency. Disc brakes with ABS are now being used in the front and rear wheels of motorbikes. Also, in a midsized car disc brakes are generally employed in the front tyres. Disc brakes use a pair of calipers attached with the brake pads that are mounted on the hub in order to rub against the disc. Due to the friction between the brake pads and the disc, the rotatory motion of the axle/wheel decreases thus bringing it to rest. This, in turn converts the kinetic energy of the axle into thermal energy which is then dissipated from the disc to the surrounding. The basics of the Braking system for bringing the vehicle to a halt is the principle of Pascal's Law. The fluid generates hydraulic pressure that pushes brake pads against the disc. Adrian Thuresson et al (2014) investigated that when pressure is applied on the disc brake, frictional forces are produced which decreases the speed of the rotating disc. The design and material of the brake disc determines the frictional forces that in turn generates heat. The contact area with the brake pads increases as the rotor size increases that in turn increase the amount of grip that the caliper pads have, thus increasing the fictional forces and braking power [1]. It comprises of a wheel hub assembly in which a brake disc is bolted along with a caliper (stationary mount housing) which is linked to the vehicle's stationary part like the axle casing and holding pistons in each part. A friction pad is also present between each piston and the disc which held in position with the help of retaining pins, spring plates etc. For the fluid to enter or leave each housing passages are drilled in the caliper.

Failure of disc brakes - If brake pads are not changed promptly, scarring occurs. Swapnil R. Abhang et al (2014) investigated about the failure of disc and the author told that this failure happens once the service life of the disc is over. Drilled discs may develop small cracks around edges of holes drilled near the edge of the disc because of the disc's non-uniform rate of expansion. The discs have a certain amount of "surface rust". Occasionally when the brakes are applied, a high-pitched shriek occurs. Most brake squeal is produced by vibration (resonance instability) of the brake components, especially the pads and discs (known as force-coupled excitation) [2]. Shah E Alam et al (2015) studied about the thermal analysis of the brake disc rotor. The author investigates about two different types of brake disc, one that consists of both vents and holes and the second one with holes only. The author carried all thermal analysis for both the types of discs by which he came to the conclusion that disc with both vents and holes have better performance with good heat dissipation [3].

Atul Sharma et. al. (2012) investigated that due to various factors such as space constraint and performance requirements, disc brakes shows fluctuating load characteristics that results in local stress and deflections. The temperature induced in brake disc by the action of friction between the pads and the disc surface can cause material carbonization and debonding.

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Further the author explains the design and finite element analysis (FEA) model of brake disc by which local deflections in X, Y, Z direction and Von-mises stress can be calculated by applying boundary conditions [4].This standard disc brake designed for a 4-wheeler model was done using ANSYS 16.0 Simulation with the help of which the various properties like deflection, stress, strain and temperature of disc brake model were calculated. It is necessary to understand the role of friction force, clamping and braking force and even braking torque so that we get to know the efficient working of disc brake, thus reducing the accidents that may happen at any time when sudden brake is applied. Due to their shorter response time, higher accuracy and increased reliability disc brakes are highly used .

In this work, various analysis were performed and test by assuming suitable input values such as Calculations with different parameters have been done to obtain thermal and structural analysis of the brake.

II. METHODOLOGY OF BRAKE DISC

The disc is mounted on the wheel hub assembly. Within the brake caliper, brake pads are installed that are on both the sides of brake disc. The way the pads are installed are such that they can slide on the caliper bracket laterally so that it moves towards and away from the disc. Thomas Gillespie et al (1992) investigated that when the brake pedal is pressed upon by the driver, hydraulic pressure is generated in the master cylinder that is connected to the pedal. This pressure gets transferred to the caliper through the braking system and the brake hose. The piston present inside the caliper extends and pushes the backing plate of the inner brake pad such that the caliper is pushed towards the center of the car due to the opposing force. Thus, the outer pad is pushed towards the disc by the outer caliper. This results in both the pads squeezing the disc present between them. This converts the kinetic energy of discs into heat energy [5]. Continuous application of force leads to slowing of vehicles or eventually making it come to rest.

III. DESIGN OF DISC BRAKE

As said in previous section, heat is liberated due to the conversion of kinetic energy into heat energy. If this heat produced is not cooled down, it may lead to some serious problems on the build of discs. Because of the tremendous amount of heat being generated during a stop, brake components are designed to absorb that heat and dissipate it out into the atmosphere as quickly and efficiently as possible. Because cooler components have a higher thermal capacity than hot ones, shedding that heat between stops is important for optimal stopping power the next time we need it. Holes are present on the discs that are used to cool down the heat. On the other hand, if there are too many holes present on the disc it may lead to the poor strength of the brake disc. The thickness and ventilation of disc also plays a crucial role. The thickness of disc is 4 mm. Moreover, the thickness of the disc brakes depends on the engine power, the weight of the vehicle, and the size of the wheel rim. If the thickness is too high, the weight of the disc would increase thus causing increase in inertia, more dynamic load ratio of the front and rear of the vehicle. So, it is very crucial to manage an optimum more efficient design in order to design a disc brake. The measurement was taken by looking into various discs designed by different automobile manufacturing companies. From the measurements, three types of discs consisting of different number of holes and different shapes were designed in UG NX 10.0 software to see which shape produces better heat liberation and cooling and better structural strength.

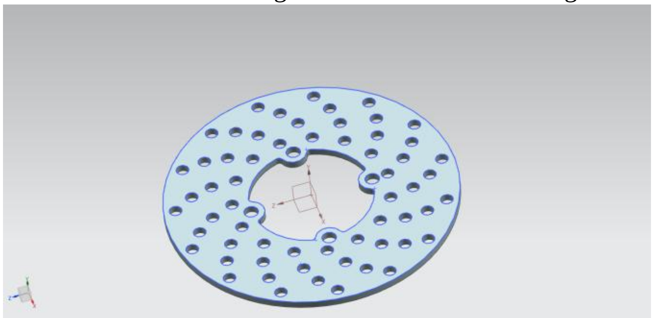

Fig 1. Type A disc

As shown in Fig 1. brake disc design A has 4 holes of diameter 8 mm arranged equally which are bolted to the wheel hub. The outer diameter is 160 mm and pitch circle diameter is 68 mm and 60 holes of diameter of 7 mm diameter arranged equally. The thickness of the disc is 4 mm.

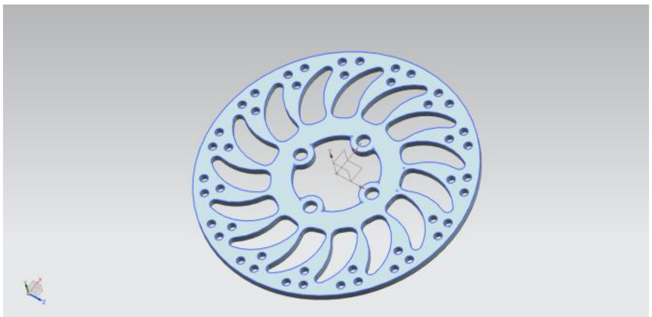

Fig 2. Type B disc

As shown in Fig 2. brake disc design B has 4 holes of diameter 8 mm arranged equally which are bolted to the wheel hub, this disc has been added with cut sections along with surrounding holes of diameter 7 mm. Inlet & outlet airflow is large & small respectively. The outer diameter is 160 mm with pitch circle diameter of 68 mm and the thickness has been 5mm.

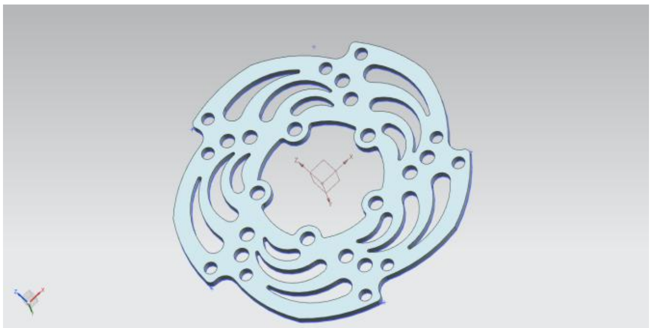

Fig 3. Type C disc

As shown in Fig 3. Brake disc design C has 4 holes of diameter 8 mm arranged equally which are bolted to the wheel hub, this disc has been added with cut sections, surrounding holes of diameter 7 mm along with increased circumferential area with same diameter of 160 mm and pitch circle diameter of 68 mm. The disc thickness is 4 mm.

Table-I: Dimensions of the three types of Discs Brakes

Particulars	Type A	Type B	Type C
Outer Diameter	160 mm	160 mm	160 mm
Pitch Circle Diameter	68 mm	68 mm	68 mm
Thickness	4 mm	4 mm	4 mm
Brake pad surface	29 mm	29 mm	29 mm

IV. MATERIAL SELECTION FOR BRAKE DISC

In this analysis four different types of materials and their properties also considered for each type of design of disc were added to the engineering data sources and the design of brake discs were imported to ANSYS 16.0 during analysis and the corresponding temperature distribution around the discs surface, total deformation, equivalent (von mises) stress and equivalent (von mises) strain were found. The materials considered are Aluminum Al 6061, Al 7075-T6, and Stainless-Steel SS 420, SS 316 [6]-[9]. The reason to choose stainless steel was to find a better alternative material in the place of regular steel providing longer life of the disc and the reason for using Aluminium was due to its high value of thermal conductivity , the disc will rapidly dissipate heat and thus cool the disc thus providing higher efficiency and better performance. Since, disc brakes are everywhere; they are also available in different shapes and sizes. The structural and temperature analysis was carried out in order to find the better performing disc type and material used in the three type of disc considered. Mechanical Properties of four chosen material are summarized in Table II and Table III.

Table-II: Mechanical properties of Al6061, Al7075-T6

Particulars	Al 6061	Al 7075-T6
Density	2.7 g/cc	2810 kg/m^3
Young's modulus	68900 MPa	71700 MPa
Tensile yield stress	276 MPa	503 MPa
Specific heat	897 J/kg-k	960 J/kg-k
Poisson Ratio	0.33	0.33
Bulk modulus	6.7549E+10 Pa	7.0294E+10 Pa
Shear modulus	2.5902E+10 Pa	2.6955E+10 Pa

Table-III: Mechanical properties of SS 420, SS 316

Particulars	SS 420	SS 316
Density	7800 kg/m^3	8000 kg/m^3
Young's modulus	1.9E+5 MPa	1.93E+5 MPa
Tensile yield stress	350 MPa	290 MPa
Specific heat	450 J/kg-k	500 J/kg-k
Poisson Ratio	0.275	0.275
Bulk modulus	1.4444E+11Pa	1.4296E+11Pa
Shear modulus	7.6471E+10Pa	7.5686E+10Pa

V. RESULTS AND DISCUSSION

ANSYS 16.0 was used to carry out the temperature analysis. To carry out the analysis, steady state thermal system and static structural system was used.During the practical application of the disc brakes, it was found that the discs were subjected to a temperature of up to 360 ºC at the time of braking. This happened because of the heat produced due to friction present between the brake pad and disc surface. The ambient temperature of surrounding was taken as 22 ºC. Significant elevated temperatures were seen only on the surface of the disc that was in contact with the brake pads. As for the remaining areas mode of heat transfer will be predominantly by convection.

Disc A:

A. Temperature

Thermal Analysis of brake disc A for materials SS 420, SS 316, Al 6061, Al 7075 were performed as shown in Fig 4,5,6,7 below. With holes all over the disc equally spaced. The temperature generated as high as 352.47^o C for Stainless Steel grade of SS 316 and as low as 57.316^{o}C for Aluminium grade of Al 6061.

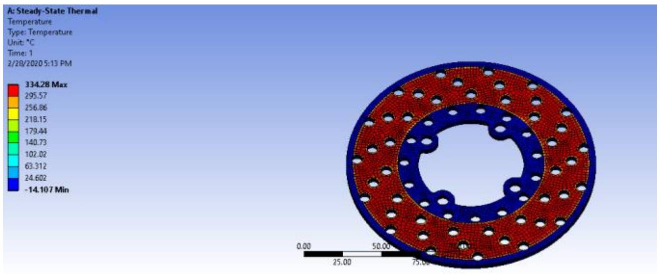

Fig 4. Temperature generated disc A SS420

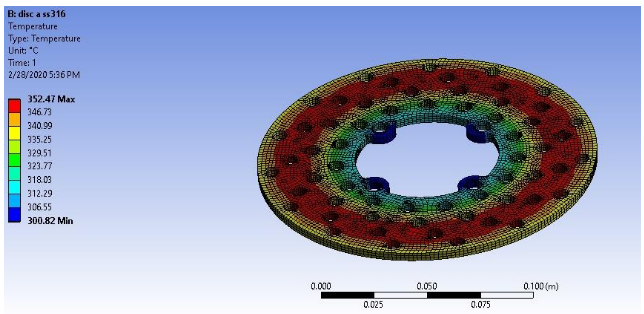

Fig 5. Temperature generated disc A SS 316

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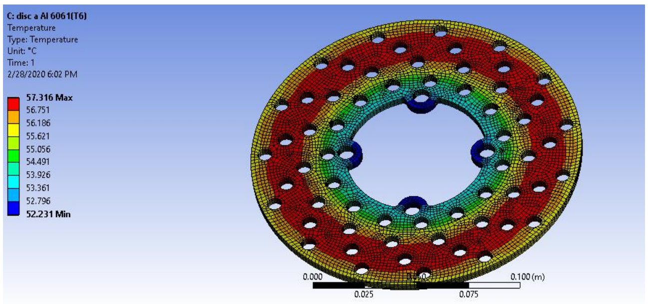


Fig 6. Temperature generated disc A Al 6061

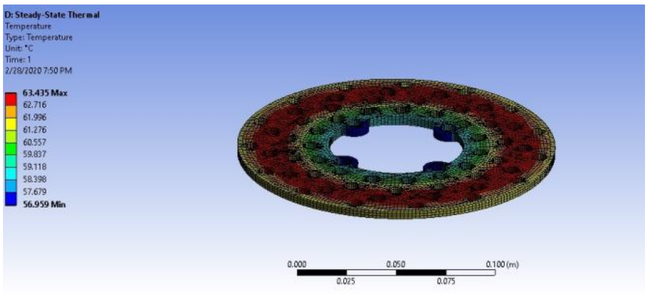
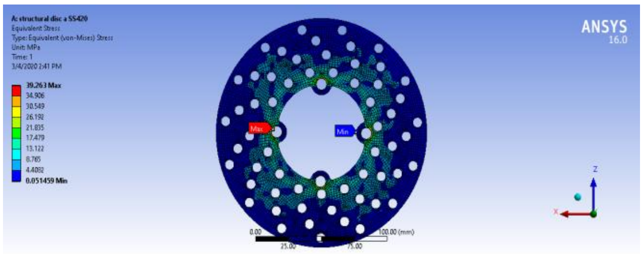
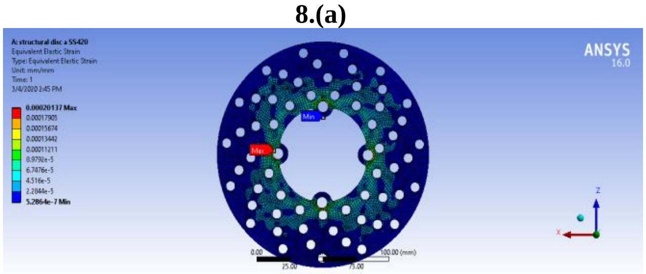


Fig 7. Temperature generated disc A Al 7075

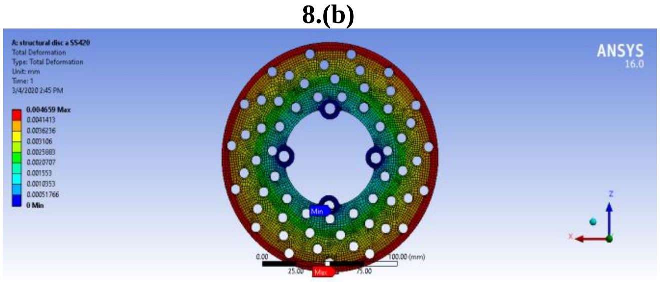
B. Structural Stresses (Von Mises), strains and total deformations



8.(a)

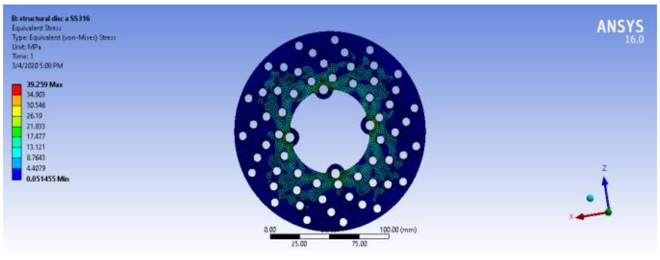


8.(b)

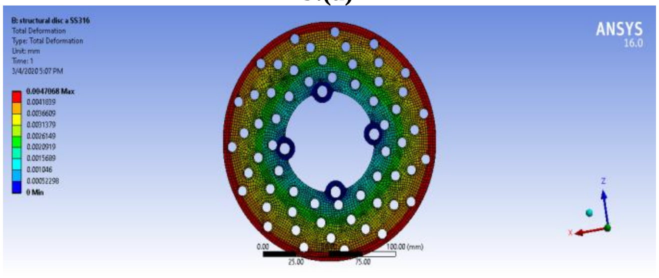


8.(c)

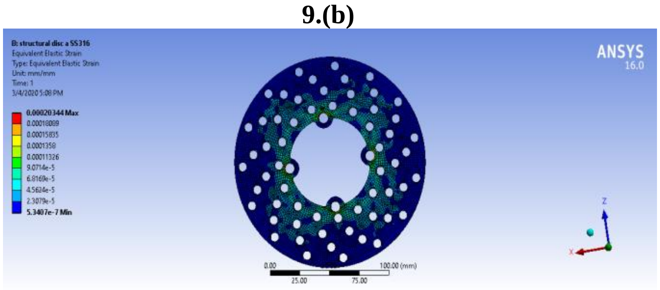
Fig 8 (a): Structural Stresses (Von Mises), (b): strains (von mises) and (c): total deformations on Disc A SS 420



9.(a)

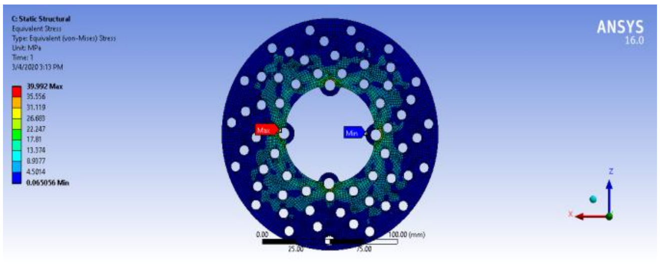


9.(b)

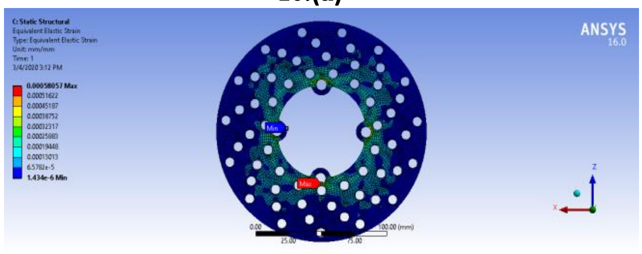


9.(c)

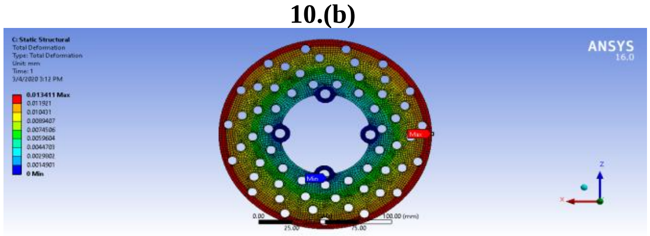
Fig 9 (a): Structural Stresses (Von Mises), (b): total deformations and (c): strains (von mises) on Disc A SS 316.



10.(a)

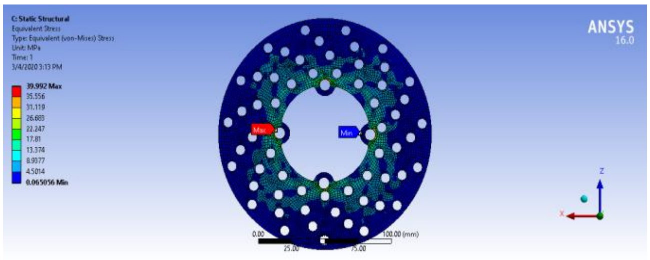


10.(b)

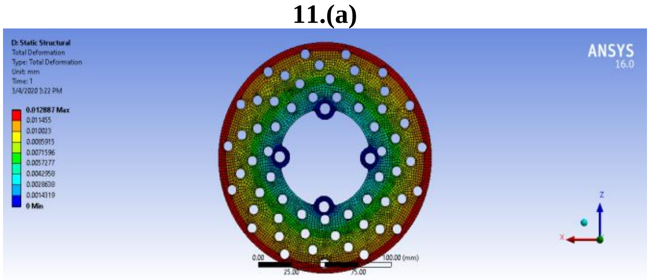


10.(c)

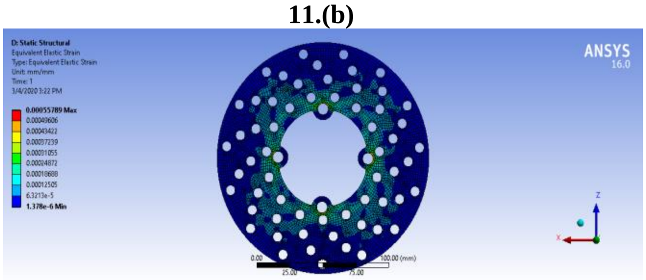
Fig 10 (a): Structural Stresses (Von Mises), (b): strains (von mises) and (c): total deformations on Disc A Al 6061.



11.(a)



11.(b)



11.(c)

Fig 11 (a): Structural Stresses (Von Mises), (b): total deformations and (c): strains (von mises) on Disc A Al 7075.

As shown in Fig 8,9,10,11, after performing structural analysis of disc A for materials SS 420, SS 316, Al 6061, Al 7075, we get von misses stress-strains and total deformation. For disc A it came very less 39.263 MPa for SS 420 and as big as 39.992 MPa for Al 6061 and Al 7075. Since due to very low stresses are developed with very small deformations upto 0.00055789 mm this disc is structurally very stable and preferable. But from its thermal analysis it is also clear that due to its high temperature, it will generate thermal stresses and also cause brittleness in the disc. Thus, it is not an optimal design.

Disc B:

A. Temperature

Thermal Analysis of brake disc B for materials SS 420, SS 316, Al 6061, Al 7075 were performed as shown in Fig 12,13,14,15 below. With holes now we also have cut sections here all over the disc equally spaced. The temperature generated are as high as 264.9^{o} C for Stainless Steel grade of SS 316 and as low as 48.3 ^{o} C for Aluminium grade of Al 6061.

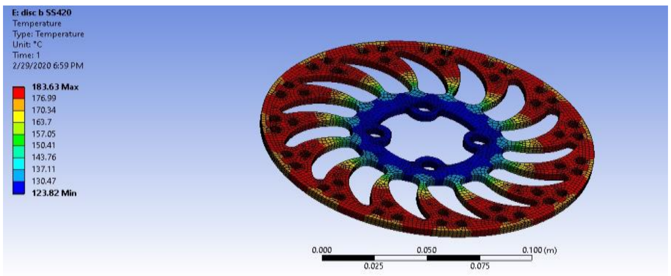


Fig 12. Temperature generated disc B SS420

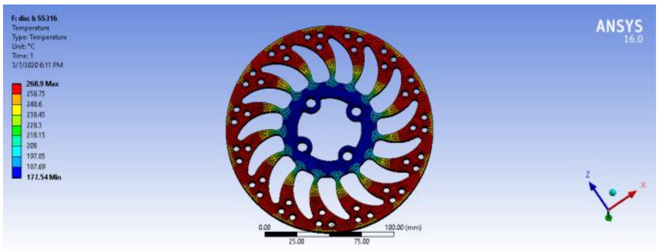


Fig 13. Temperature generated disc B SS316

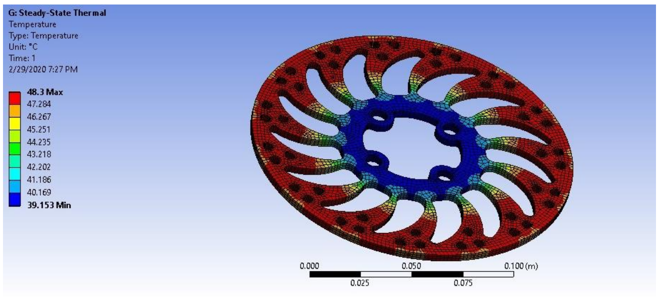


Fig 14. Temperature generated disc B Al 6061

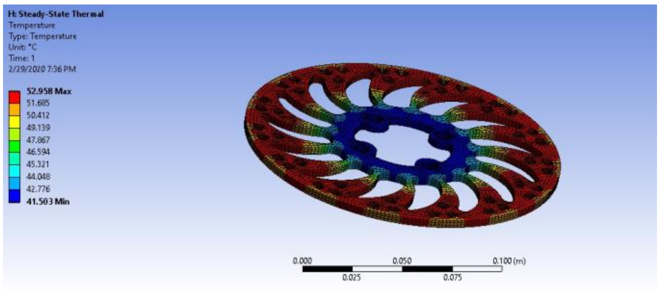
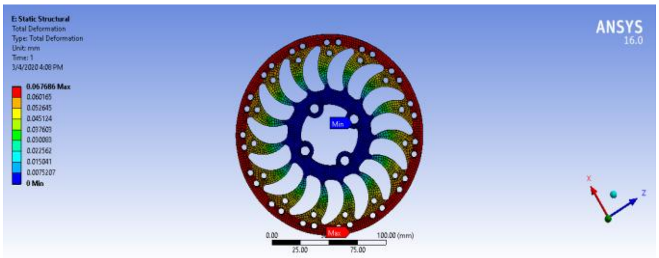


Fig 15. Temperature generated disc B Al 7075

B. Structural Stresses (Von Mises), strains and total deformations respectively



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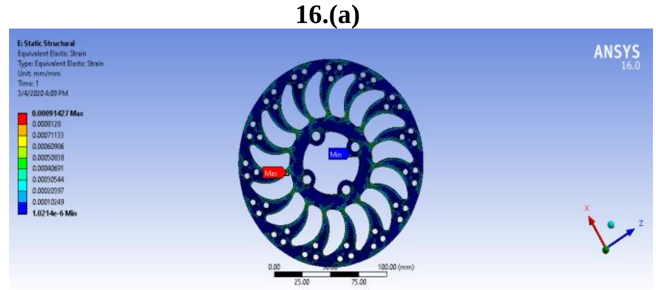
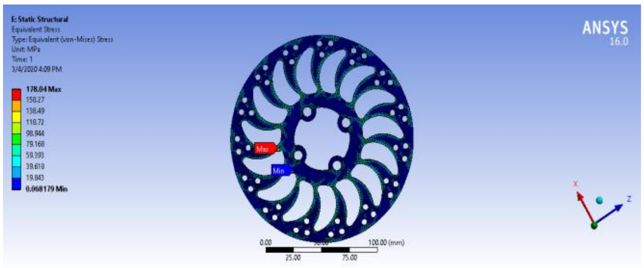
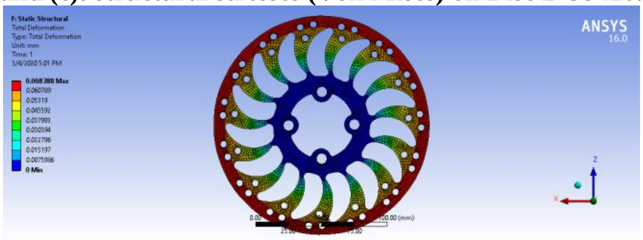


16.(b)



16.(c)

Fig 16 (a): Total deformations, (b): strains (von mises) and (c): structural stresses (Von Mises) on Disc B SS420.



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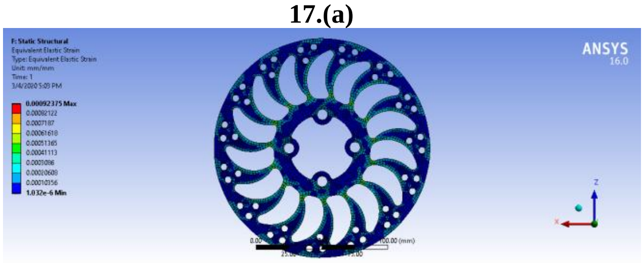

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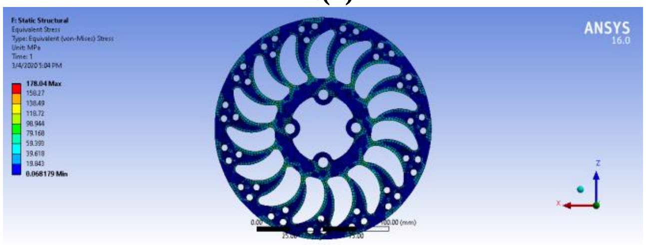
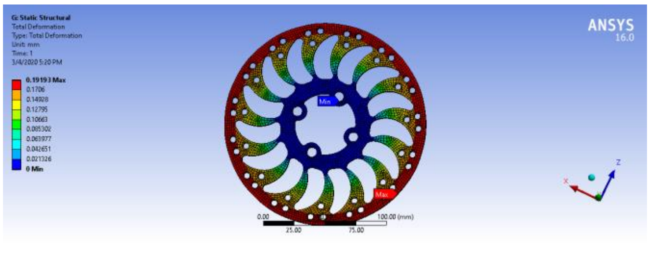


17.(c)

Fig 17 (a): Total deformations, (b): strains (von mises) and (c): structural stresses (Von Mises) on Disc B SS316.



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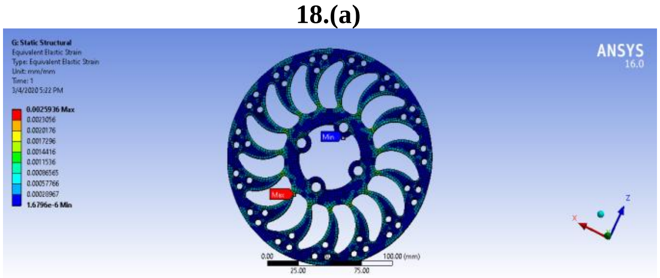

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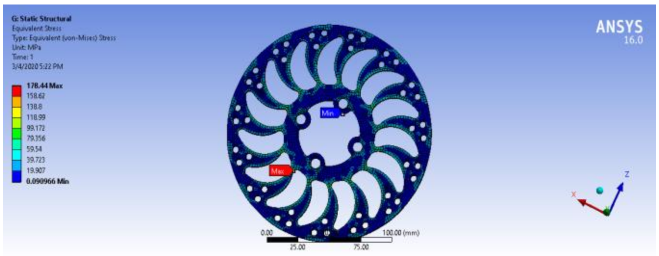
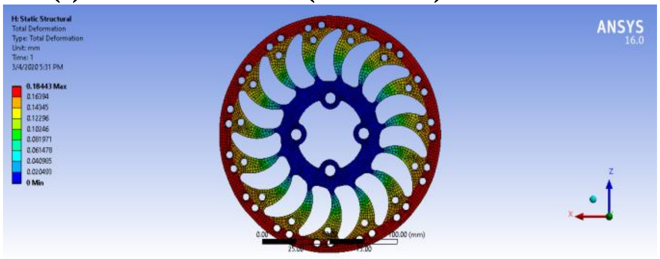
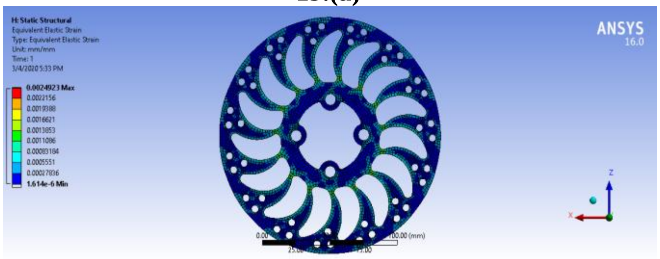


18.(c)

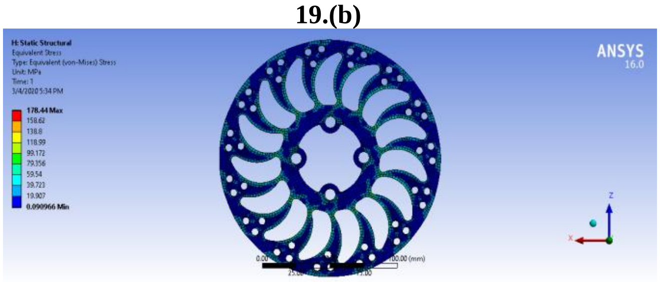
Fig 18 (a): Total deformations, (b): strains (von mises) and (c): structural stresses (Von Mises) on Disc B Al 6061.



19.(a)



19.(b)



19.(c)

Fig 19 (a): Total deformations, (b): strains (von mises) and (c): structural stresses (Von Mises) on Disc B Al 7075.

As shown in Fig 16,17,18,19, after performing structural analysis of disc B for materials SS 420, SS 316, Al 6061, Al 7075, we get von misses stress-strains and total deformation. For disc B it came as low as 178.04 MPa for SS 420, SS 316 and as high as 178.44 MPa for Al 6061 and Al 7075. Since due to cut sections along with surrounding holes, it can be observed from the structural analysis that there is a lot of stress (von mises) developed on disc B and a small yet significant deformation of 0.19193 mm. But from its thermal analysis it is also clear that due to its high thermal conductivity, it generates low temperature, thus providing better performance of the disc and higher efficiency.

Disc C:

A. Temperature

Thermal Analysis of brake disc C for materials SS 420, SS 316, Al 6061, Al 7075 were performed as shown in Fig 20,21,22,23 below respectively. With holes now we also have cut sections here all over the disc equally spaced along with increased circumferential area cue
to its petal disc design.

The temperature generated are as high as 337.11° C for Stainless Steel grade of SS 316 and as low as 55.473 °C for Aluminium grade of Al 6061.

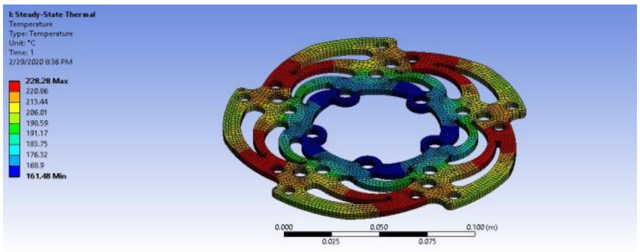


Fig 20. Temperature generated disc C SS420

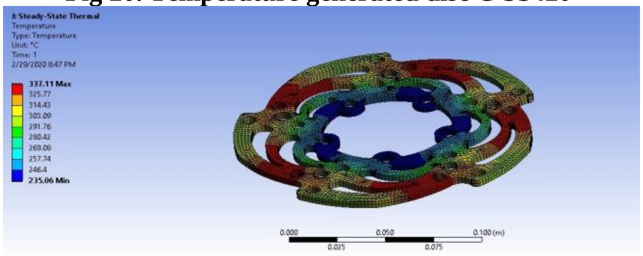


Fig 21. Temperature generated disc C SS316

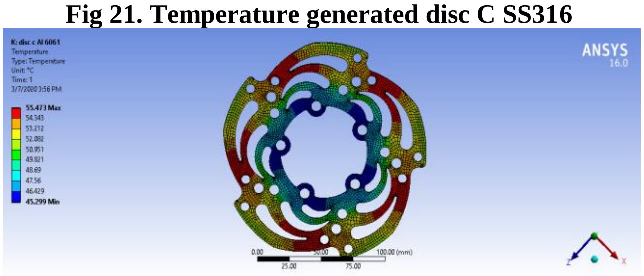


Fig 22. Temperature generated disc C Al 6061

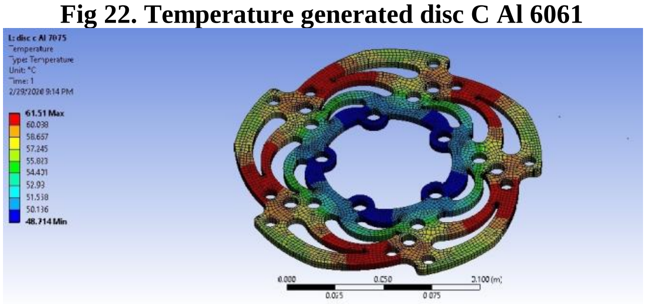
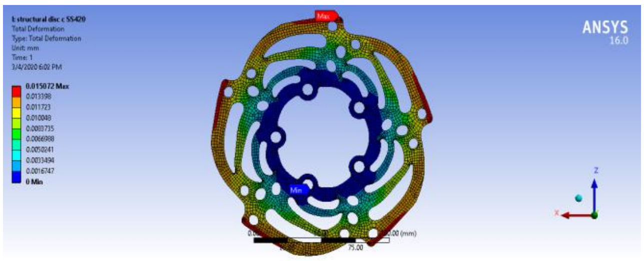
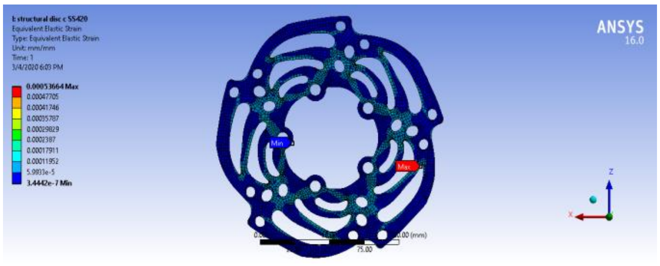


Fig 23. Temperature generated disc C Al 7075

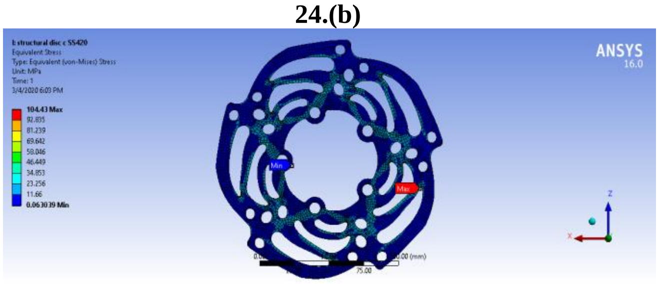
B. Structural Stresses (Von Mises), strains and total deformations respectively



24.(a)

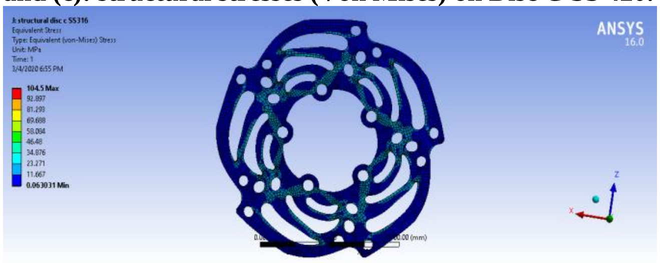


24.(b)

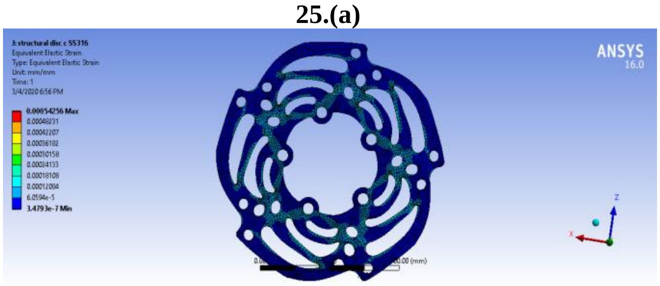


24.(c)

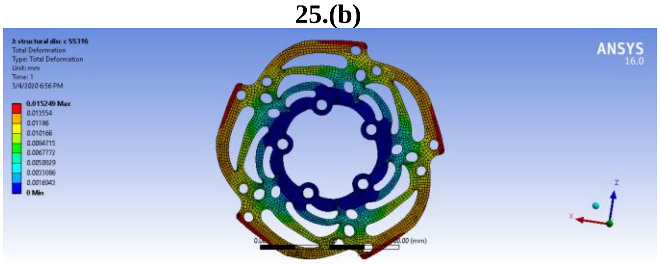
Fig 24 (a): Total deformations, (b): strains (von mises) and (c): structural stresses (Von Mises) on Disc C SS 420.



25.(a)

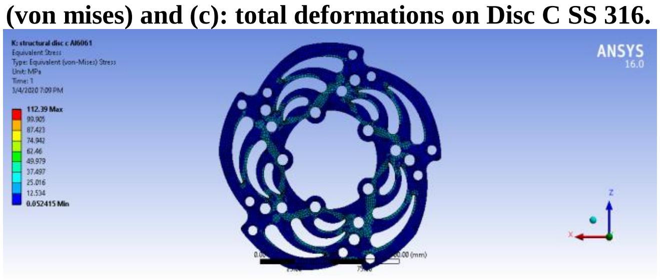


25.(b)

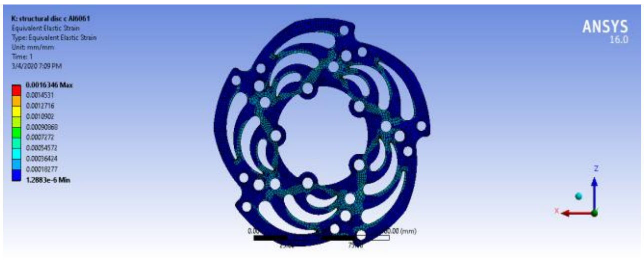


25.(c)

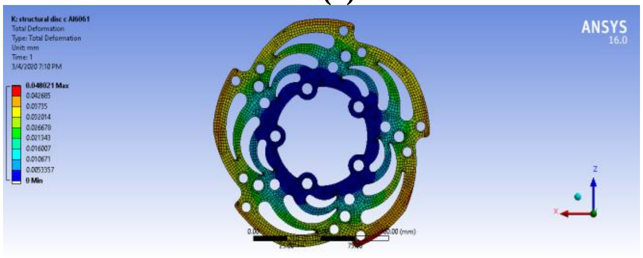
Fig 25 (a): Structural Stresses (Von Mises), (b): strains (von mises) and (c): total deformations on Disc C SS 316.



26.(a)

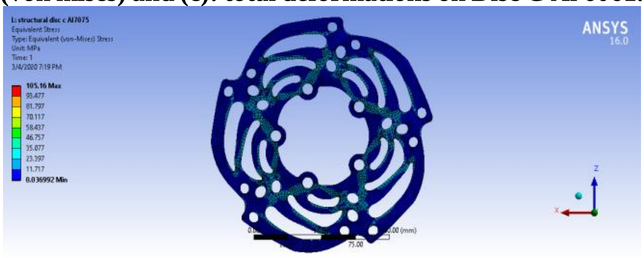


26.(b)

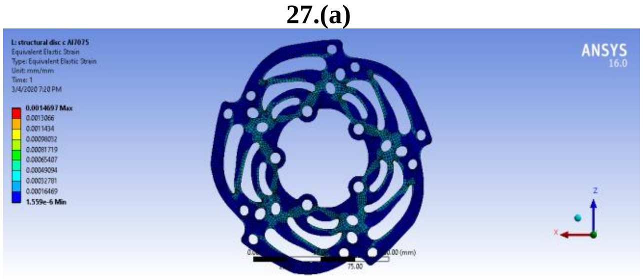


26.(c)

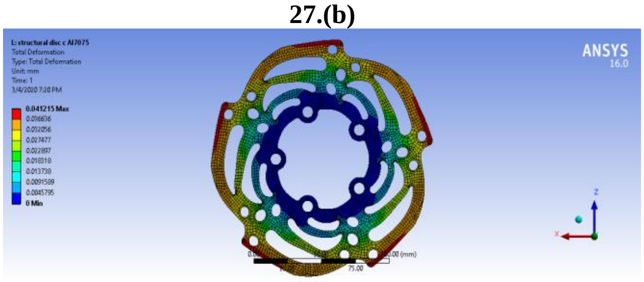
Fig 26 (a): Structural Stresses (Von Mises), (b): strains (von mises) and (c): total deformations on Disc C Al 6061.



27.(a)



27.(b)



27.(c)

Fig 27 (a): Structural Stresses (Von Mises), (b): strains (von mises) and (c): total deformations on Disc C Al 7075.

As shown in Fig 24,25,26,27 after performing structural analysis of disc C for materials SS 420, SS 316, Al 6061, Al 7075, we get von misses stress-strains and total deformation. For disc C it came as low as 104.43 MPa for SS 420, 104.5 MPa for SS 316, 112.39 MPa for Al 6061 and 105.16 MPa for Al 7075. Since due to cut sections along with surrounding holes and increased circumferential area it can be observed from the structural analysis that there is low stress (von mises) developed on disc C and a small maximum total deformation of 0.048021 mm in case of Al 6061. But from its thermal analysis it is also clear that due to its high thermal conductivity, it generates comparatively low temperature and also better strength from other discs A and B, thus providing better performance of the disc and higher efficiency.

The Table IV, V, VI shown below shows the detailed result of thermal analysis along with structural analysis of disc A, B and C respectively.

Table-IV: Simulated results obtained for Disc A

Particulars	Al 6061	Al 7075
Temperature min. (ºC)	57.316	63.435
Temperature max. (ºC)	52.231	56.959
Equivalent stress (von mises) max. (MPa)	39.992	39.992
Equivalent stress (von mises) min. (MPa)	0.065056	0.065056
Equivalent strain (Von Mises) max. (mm/mm)	0.00058057	0.00055789
Equivalent strain (Von Mises) min. (mm/mm)	1.434E-6	1.378E-6
Total Deformation max. (mm)	0.013411	0.012887
Total Deformation min. (mm)	0	0

Particulars	SS 420	SS 316
Temperature min. (ºC)	334.28	352.47
Temperature max. (ºC)	-14.107	300.82
Equivalent stress (von mises) max. (MPa)	39.263	39.259
Equivalent stress (von mises) min. (MPa)	0.051459	0.051455
Equivalent strain (Von Mises) max. (mm/mm)	0.00020137	0.00020344
Equivalent strain (Von Mises) min. (mm/mm)	5.2864E-7	5.3407E-7
Total Deformation max. (mm)	0.004659	0.0047068
Total Deformation min. (mm)	0	0

The above Table-IV shows the result of disc A for different materials in which two materials are of Stainless Steel of grade SS 316 and SS 420 while other two materials which are considered here are the grade of Aluminium Al 6061 and Al 7075-T6.

Table-V: Simulated results obtained for Disc B

Particulars	SS 420	SS 316
Temperature min. (ºC)	183.63	268.9
Temperature max. (ºC)	123.82	177.54
Equivalent stress (von mises) max. (MPa)	178.04	178.04
Equivalent stress (von mises) min. (MPa)	0.068179	0.068179
Equivalent strain (Von Mises) max. (mm/mm)	0.0009142	0.0009237
Equivalent strain (Von Mises) min. (mm/mm)	1.0214E-6	1.032E-6
Total Deformation max. (mm)	0.067686	0.068388
Total Deformation min. (mm)	0	0

Particulars	Al 6061	Al 7075
Temperature min. (ºC)	48.3	52.958
Temperature max. (ºC)	39.153	41.503
Equivalent stress (von mises) max. (MPa)	178.44	178.44
Equivalent stress (von mises) min. (MPa)	0.090966	0.090966
Equivalent strain (Von Mises) max. (mm/mm)	0.0025936	0.0024923
Equivalent strain (Von Mises) min. (mm/mm)	1.6796E-6	1.614E-6
Total Deformation max. (mm)	0.19193	0.18443
Total Deformation min. (mm)	0	0

The above Table-V shows the result of disc B for different materials in which two materials are of Stainless Steel of grade SS 316 and SS 420 while other two materials which are considered here are the grade of Aluminium Al 6061 and Al 7075-T6.

Table-VI: Simulated results obtained for Disc C

Particulars	Al 6061	Al 7075
Temperature min. (ºC)	55.473	61.51
Temperature max. (ºC)	45.299	48.714
Equivalent stress (von mises) max. (MPa)	112.39	105.16
Equivalent stress (von mises) min. (MPa)	0.052415	0.036992
Equivalent strain (Von Mises) max. (mm/mm)	0.0016346	0.0014697
Equivalent strain (Von Mises) min. (mm/mm)	1.2883E-6	1.559E-6
Total Deformation max. (mm)	0.048021	0.041215
Total Deformation min. (mm)	0	0

Particulars	SS 420	SS 316
Temperature min. (ºC)	228.28	337.11
Temperature max. (ºC)	161.48	235.06
Equivalent stress (von mises) max. (MPa)	104.43	104.5
Equivalent stress (von mises) min. (MPa)	0.063039	0.063031
Equivalent strain (Von Mises) max. (mm/mm)	0.00053664	0.00054256
Equivalent strain (Von Mises) min. (mm/mm)	3.442E-7	3.4793E-7
Total Deformation max.(mm)	0.015072	0.015249
Total Deformation min.(mm)	0	0

The above Table-VI shows the result of disc C for different materials in which two materials are of Stainless Steel of grade SS 316 and SS 420 while other two materials which are considered here are the grade of Aluminium Al 6061 and Al 7075-T6.

By comparing the values in the above Table IV, V and VI, on observing the temperature differences, it is quite noticeable that the grades of Stainless-Steel material perform very much better than that of Aluminium for a longer period of time as due to better structural strength and less deformation produced. On disc A, the stress generated was very less on the pad surface thus showing better structural design. The temperature difference among the different designs and the different materials show their performance and the heat dissipation properties. In terms of better design, the disc C was found to be better cooled and with better air flow in it and better ventilation than the other two types of discs because of the presence of cut sections, surrounding holes and also significantly by the increased circumferential area of the disc periphery like a petal disc. Also, disc C was structurally more appealing than disc B because of better structural strength. The type A disc showed poor performance due to poor heat dissipation and noticeably, very large temperature difference was also observed due to which thermal stresses would also induce and would cause brittleness of the disc. Only the temperature difference was found to be high when SS 316 material was applied due to which large thermal stresses will develop thus making the material more prone to brittle fracture. Thus, Al 6061 serves as the best material on the basis of thermal analysis but there is one problem that it is very soft. It can be clearly seen from all the disc, Al 6061 has very high deformation and equivalent strain. Thus Al 7075 of disc C serves as the most optimum disc design in both the cases, on the basis of structural strength as well as on the basis of temperature developed.

Future Scope: based on the above analysis and observation, the future work will be included in the manufacturing of disc C of Al 7075.

VI. CONCLUSION

To improve the utilization of the brake disc, the problems faced were considerably reduced. The main problems arise due to warpage and uneven rotor wear that lower the efficiency of brake disc. Warpage occurs at high temperatures of 600^{o} C, so it does not affect on different designs of brake discs with different grades of Aluminum and Stainless-Steel material. The other important factor will be uneven rotor wear which can be controlled by decreasing the delay period of the caliper to return to rest. Thus, overall design optimization with modification of best suited material

will increase the efficiency as well as the effectiveness of the brake disc.

REFERENCES

1. Adrian Thuresson. “CFD and Design Analysis of Brake Disc”, Master’s Thesis in Automotive Engineering, Department of Applied Mechanics, Division of Vehicle, Engineering and Autonomous Systems. Gothenburg, Sweden; Road Vehicle Aerodynamics and Thermal Management, Chalmers University of Technology, Master’s Thesis 2014:11.
2. Swapnil R. Abhang& D.P. Bhaskar. “Design and Analysis of Disc Brake”, International Journal of Engineering Trends and Technology (IJETT), Volume 8 Number 4 (ISSN: 2231-5381) 2014, February.
3. Shah E Alam, Yuvraj Vidhyadhar, Prashant Sharma, Abhishek Jain. “Thermal Analysis of Disc Brakes Rotor: A Comparative Report”. SciTech Volume 3, Issue 2 Research Organization April 20, 2015.
4. Atul Sharma & M.L. Aggrawal. “Deflection & Stress Analysis of Disc Brake using FEM”, at National Conference on Trends & Advances in Mechanical Engineering, YMCA University of Science & Technology, Faridabad, Haryana, 2012.
5. Thomas D. Gillespie, *Fundamentals of Vehicle Dynamics*, SAE International, ISBN of 978-1-56091-199-9, 1992, pp. 1-76
6. https://www.azom.com/article.aspx?ArticleID=6652 .
7. https://www.azom.com/article.aspx?ArticleID=6636 .
8. https://www.azom.com/article.aspx?ArticleID=972 .
9. https://www.azom.com/properties.aspx?ArticleID=863 .

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