IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Structural Analysis on the Effect of Drilled Holes on Disc Brake Rotor for Optimum Design

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Abstract: The effectiveness of disc brake mainly depends on the rotor, and this the part which takes active part in development of required friction force to stop the vehicle. The disc brake rotor is provided with drilled holes to improve its cooling rate, which affects the structural stability of the rotor. Therefore the drilled holes on the rotor of disc brake is the origin of this investigation, to make possible modifications regarding the size, shape and orientation of drilled holes to reduce the stress concentrations.

In the present work, model of disc brake rotor is created using Catia V5 and thus obtained model is analyzed using Ansys 15.0 towards the development of equivalent von-mises and maximum shear stresses and deformations.

The analysis is repeated with series of disc brake rotors by varying the size of holes, and shape like elliptical and circular shapes and their orientation along the rotor to find the optimum combination for effective disc brake rotor with highest safety factor.

***Index Terms* - Disc brake rotor, vented holes, Structural analysis.**

I. INTRODUCTION

A disc brake is a type of brake that uses the calipers to squeeze pairs of pads against a disc or a "rotor" to create friction. This action slows the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed.

The brake disc (or rotor) is the rotating part of a wheel's disc brake assembly, against which the brake pads are applied. The "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily loaded front discs.

Discs for motorcycles, bicycles, and many cars often have holes or slots cut through the disc. This is done for better heat dissipation, to aid surface-water dispersal, to reduce noise, to reduce mass, or for marketing cosmetics.

II. OBJECTIVES

To study the structural stability of the disc brake rotor by providing vented holes by varying shape (circular and ellipse), size and orientation (angular spacing).

III. MODELING OF DISC BRAKE ROTOR

The step by step procedure followed in creating the model of disc brake rotor is shown in the following figures.

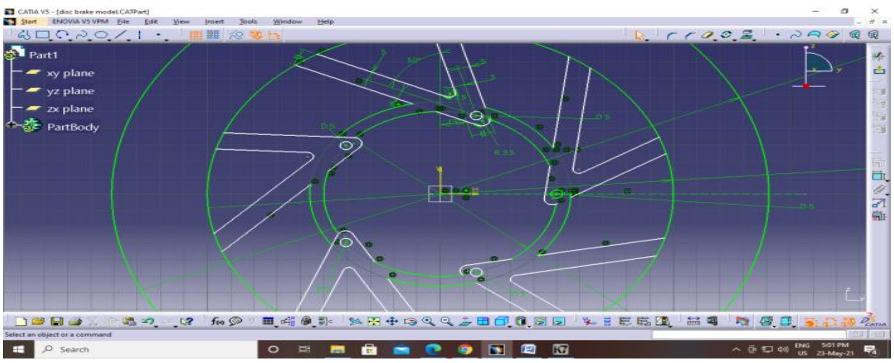


Fig 3.1 Complete sketch with all ribs of rotor disc

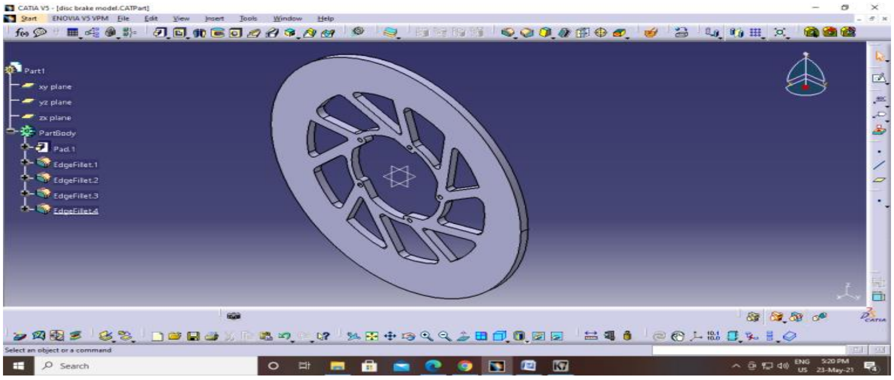


Fig 3.2 Created model of Disc brake rotor in Catia V5

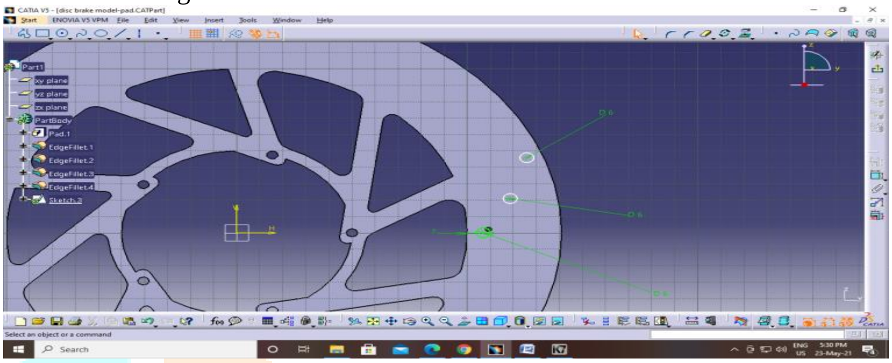


Fig 3.3 Creating holes on the rotor disc

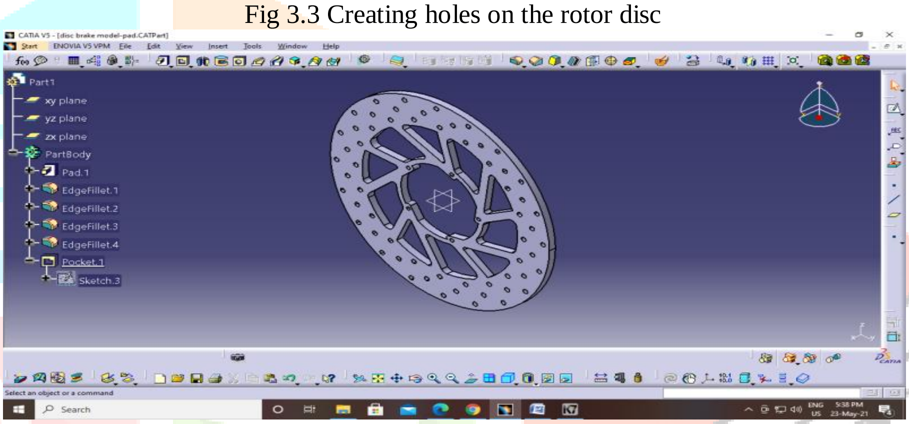


Fig 3.4 Complete model of rotor disc plate with circular holes created in Catia V5

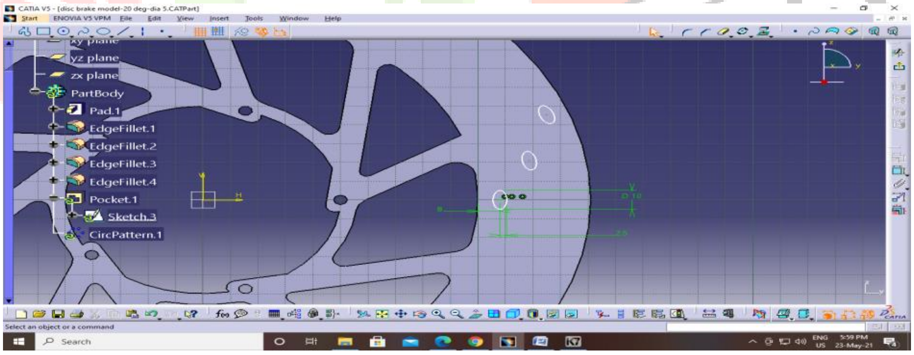


Fig 3.5 Creation of elliptical holes on rotor disc

Similarly different models were created by varying size , shape and position of holes on the rotor disc as follows.

Model-1: 20^0 angular spacing , ellipse(5X10)
Model-2: 20^0 angular spacing , ellipse(6X10)
Model-3: 20^0 angular spacing , ellipse(7X10)
Model-4: 20^0 angular spacing, ellipse(8X10)
Model-5: 20^0 angular spacing , circular(5mm diameter)
Model-6: 20^0 angular spacing, circular(6mm diameter)
Model-7: 20^0 angular spacing , circular(7mm diameter)
Model-8: 20^0 angular spacing, circular(8mm diameter)
Model-9: 30^0 angular spacing, circular(8mm diameter)
Model-10: 40^0 angular spacing , circular(8mm diameter)
Model-11: 50^0 angular spacing , circular(8mm diameter)

IV. ANALYSIS OF THE DISC BRAKE ROTOR

Step by Step Structural Analysis Procedure

Step 1: At first the ansys structural analysis is to be loaded. Then the material required is selected as shown in fig 4.1.

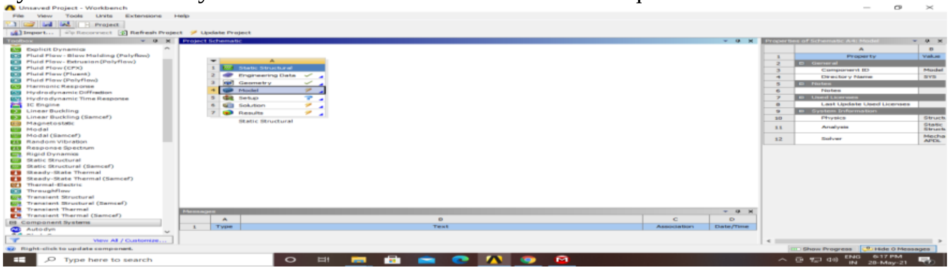


Fig 4.1 The selection of material in Ansys 15.0

Step 2: The Catia model is to be imported in igs format as shown in fig 4.2

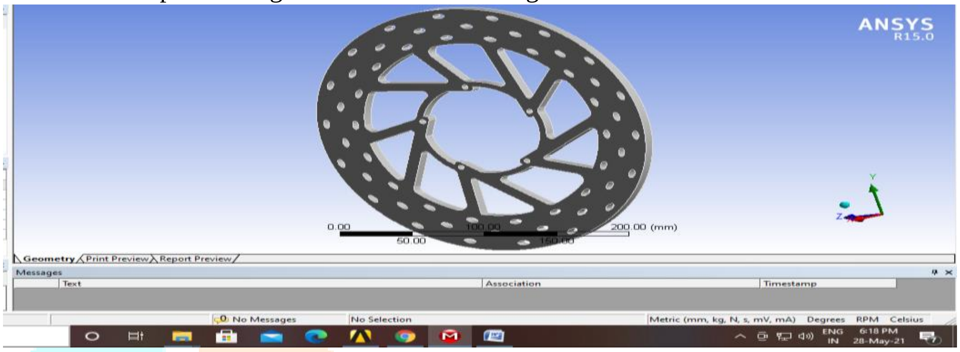


Fig 4.2 The catia model of rotor disc imported to Ansys 15.0

Step 3: The model is divided in finite parts and meshed model is as shown in fig 4.3

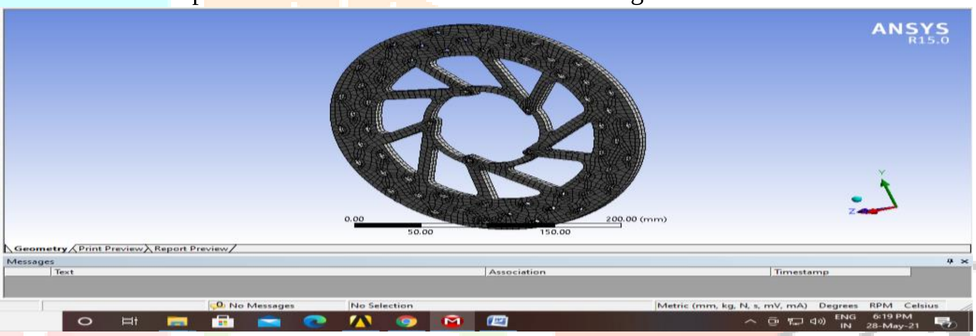


Fig 4.3 Meshed model of disc rotor in Ansys 15.0

Step 4: The fixed constraints are applied as shown in fig 4.4.

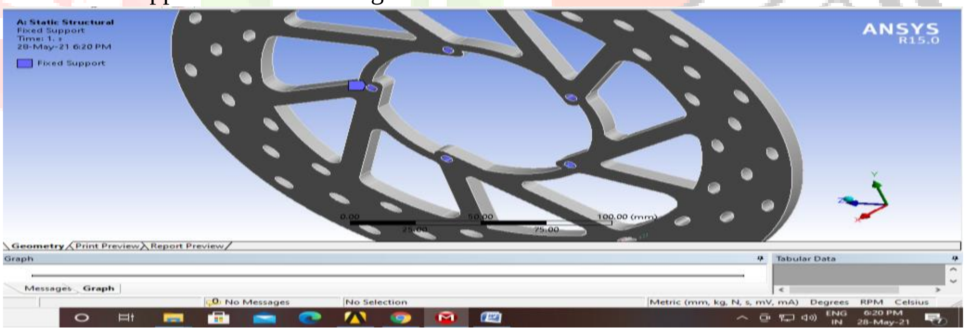


Fig 4.4 Applying fixed constraints in Ansys 15.0

Step 5: The rotational speed is applied to the model as shown in fig 4.5.

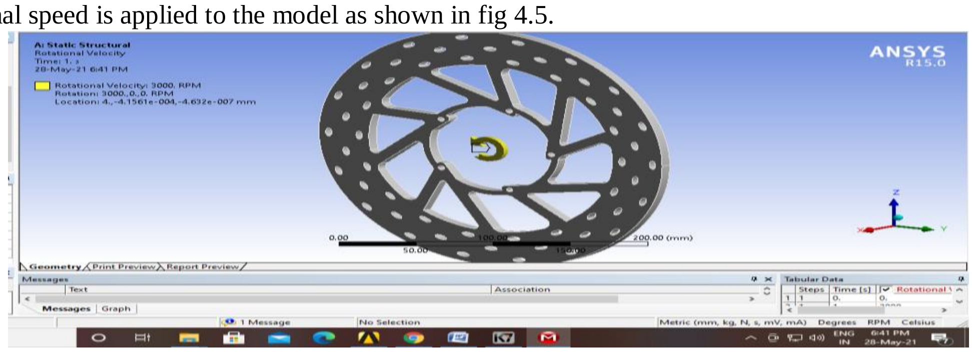


Fig 4.5 Applying rotational speed to the model in Ansys 15.0

Step 5: The torsional moment is applied to the model as shown in fig 4.6.

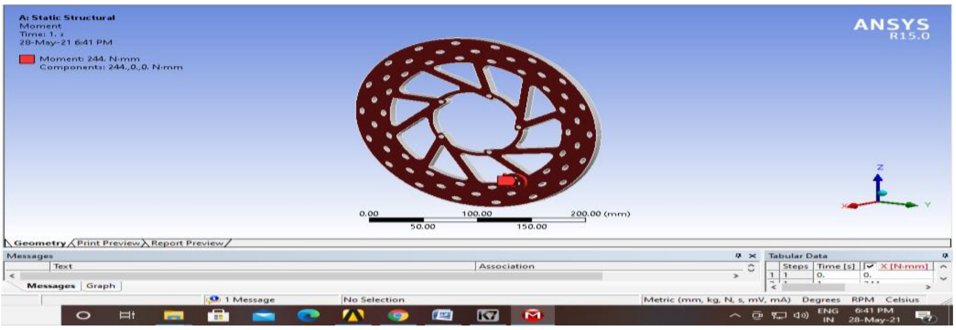


Fig 4.6 Applying torsional moment to the model.

Step 6: Then to solve the problem using solver option.

Similar procedure is applied to all the models and results are discussed in the next section.

V. RESULTS AND DISCUSSION

5.1 Structural Analysis: Ansys results of Disc brake rotos with elliptical holes provided at fixed angular pitch of 20^0

5.1.1 Ansys results of Disc Brake Rotor with Elliptical hole (5X10)-Model-1

The fig 5.1 shows the equivalent von-mises stress distribution in disc brake rotor model-1. The resulting color image shows that the stress intensity is almost moderate through out the disc plate, being with higher intensities restricted to only few zones. The surface of rotor plate which under the action of moderate stress magnitudes represented by light blue color in the image, but the edges of the holes along their major axis direction (diametral direction of imaginary circle of arrangment of elliptical holes) is highlighted with dark blue color. This reveals that the stress intensity is less their, which might be due to rearrangement of stress lines, which took diversion due to the presence of the holes. Thus the stream lines of stress considering to be acted along the imaginary diameter of arrangement of holes leads to diverson, that makes the development of low stress zones at the ends of major axis of ellipse. Due to the same reason the diverted stress lines gets densed while crossing the holes at the ends of elliptical hole along its minor axis. This can be observed clearly by the representation of light green color.

Also it can be observed that maximum stress was developed towards the fixed ends representaed with red color, with a maximum magnitude of 54.634MPa. Even the stress distribution among all the ribs is not uniform, the stress in alternate ribs are under the action of low stress intensity represented with dark blue color, whereas the remaining are under action of moderate stress represented with light blue to green color.

The fig 5.2 shows the total deformation distribution in the disc brake rotor model-1. The deformation decreases with radial distance, as expected just like in a cantelever beam. Also it is being observed that the maximum deformation zone represented by red color is spread to same level of radial distance throughout the disc plate. The deformation corresponding to single hole in the radial direction is shown with slight over stread representing more deformation. The maximum deformation developed is found to be 0.01963mm.

The fig 5.3 shows the safety factor attained in disc brake rotor model-1. The resulting color image shows that the ccritical safety factor was attained at the junctions oh ribs to the hub of rotor with a magnitude of 4.5759. Especially it can be seen that junctions of higher angular placed ribs are under critical situation with low safety factor.

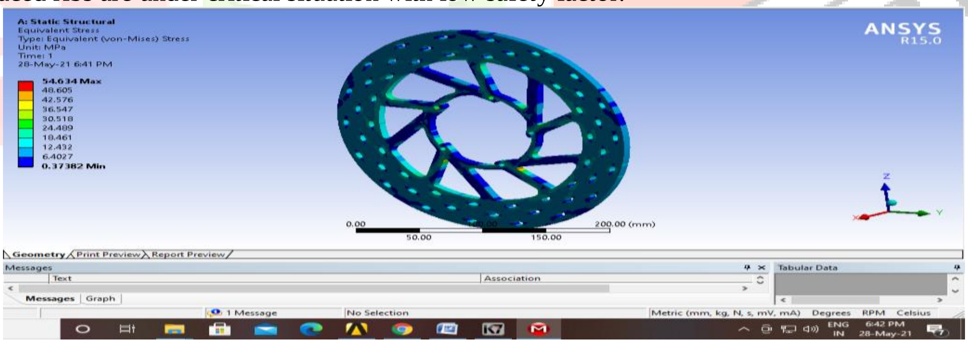
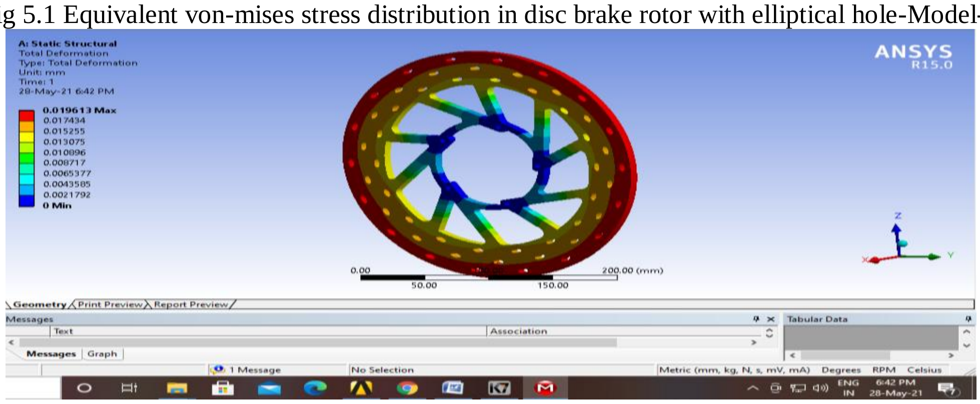


Fig 5.1 Equivalent von-mises stress distribution in disc brake rotor with elliptical hole-Model-1



5.2 Total deformation developed in disc brake rotor with elliptical hole-Model-1

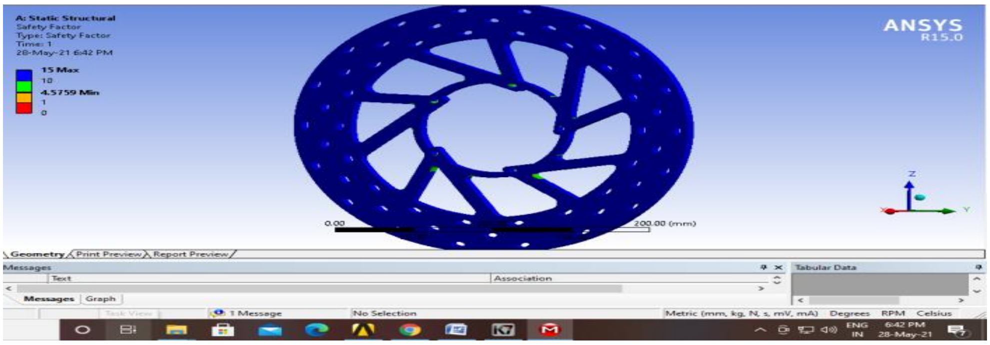


Fig 5.3 Safety factor attained in disc brake rotor with elliptical hole-Model-1

5.1.2 Ansys results of Disc Brake Rotor with Elliptical hole(6X10)-Model-2

The fig 5.4 shows the von-mises stress distribution in disc brake rotor with elliptical holes model-2. The stress distribution in this model is following the same trend as in the previous model-1, but with lower intensities. The maximum stress developed is found to be 35.35MPa, which is 35.3% lower than that of stress in the model-1. The reason is that due to increase in minor axis size of elliptical hole. The stress lines can freely change its direction, compared to the model-1. Thus the disturbance in rearranging of stress lines can be reduced so far, which might result in lower stress intensities in this model-2.

The fig 5.5 shows the deformation development in disc brake rotor with elliptical holes model-2. The resulting color image shows the same pattern of distribution like in model-1. The maximum deformation developed is found to be 0.020057mm, which is 2.3% higher than that of deformation in model-1.

The fig 5.6 shows the safety factor attained in disc brak erotor model-2. The pattern of safety factor is similar to the previous model-1 with a critical value of 7.0721, which is 54.6% higher than that of in model-1.

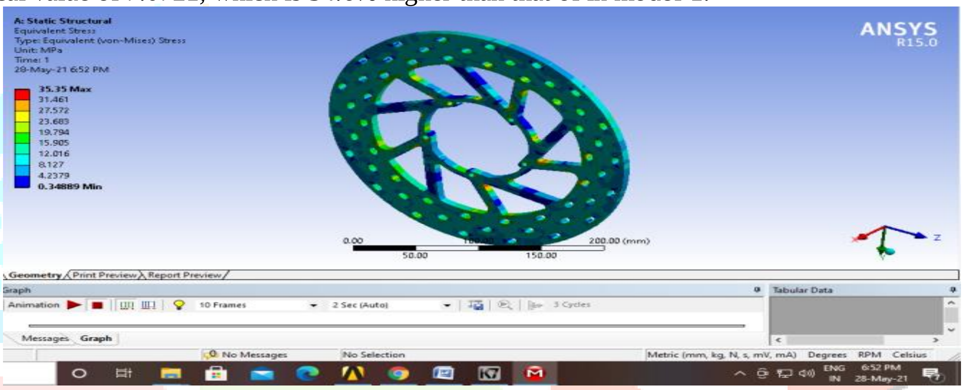
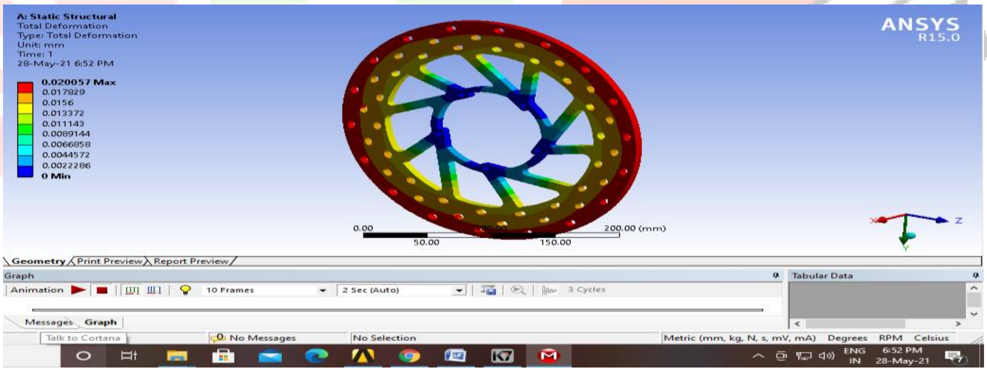


Fig 5.4 Equivalent von-mises stress distribution in disc brake rotor with elliptical hole-Model-2



5.5 Total deformation developed in disc brake rotor with elliptical hole-Model-2

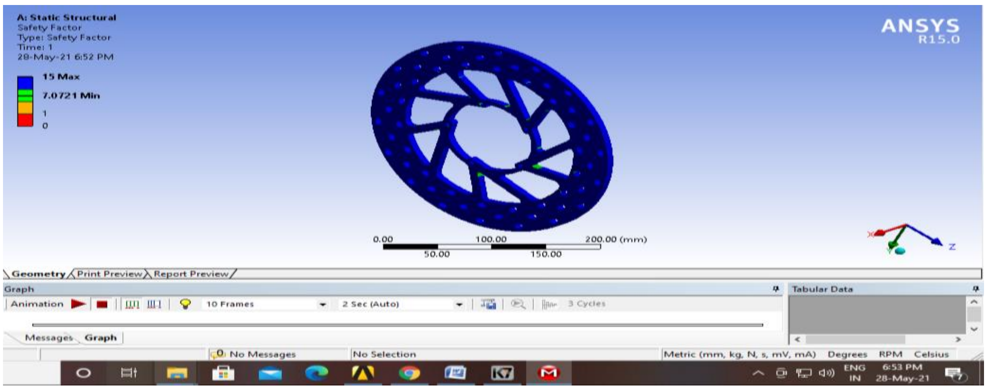


Fig 5.6 Safety factor attained in disc brake rotor with elliptical hole-Model-2

5.1.3 Ansys results of Disc Brake Rotor with Elliptical hole(7X10)-Model-3

The fig 5.7 shows the von-mises stress distribution in the disc brake rotor with elliptical holes model-3. The resulting color image shows that the distribution of stress follows the same trend as in previous models. But the intensity of stress increased further compared to model-2. The maximum stress developed is found to be 45.646MPa, which is 29.1% higher than that of model-2 and 16.5% lower than that of in model-1.

The fig 5.8 shows the total deformation developed in the disc brake rotor model-3, with the trend of development similar to the previous models, decreases radial inwards. The maximum deformation developed is found to be 0.02055mm, which is 2.5% higher than that of in model-2 and 4.8% higher than that of model-1. Though the stress intensity decreases in this model-3 compared to the model-1, the deformation is still higher. This is the peculiar behaviour needs a special attention to study the reason for it. The reason might be difference in amount of material, due to variation in hole sizes. Ofcourse, even the same effect can be observed between model-2 and model-1. Thus, though the holes make a better stress distribution, the reduced amount of material and corresponding ribs position might hav eincreased its deformation. Therefore it is needed to study further for different positoned holes along the rotor.

The fig 5.9 shows the safety factor attained in rotor disc plate model-3. The attained safety factor follows the same trend as in previous models with a critical value of 5.4769, which is 22.6% lower than that of model-2 and 19.7% higher than that of model-1.

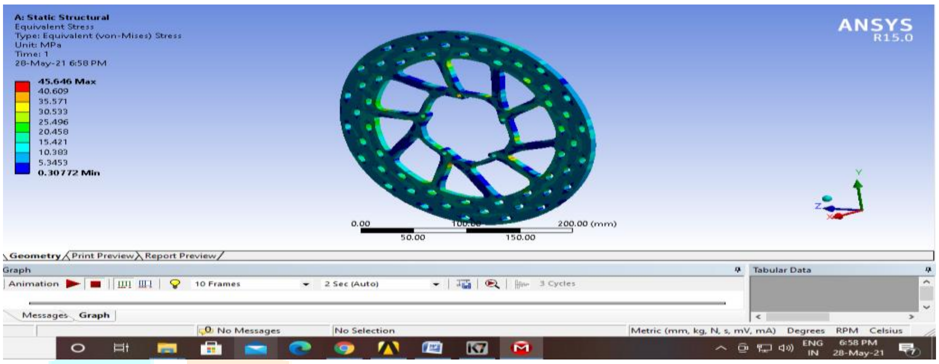
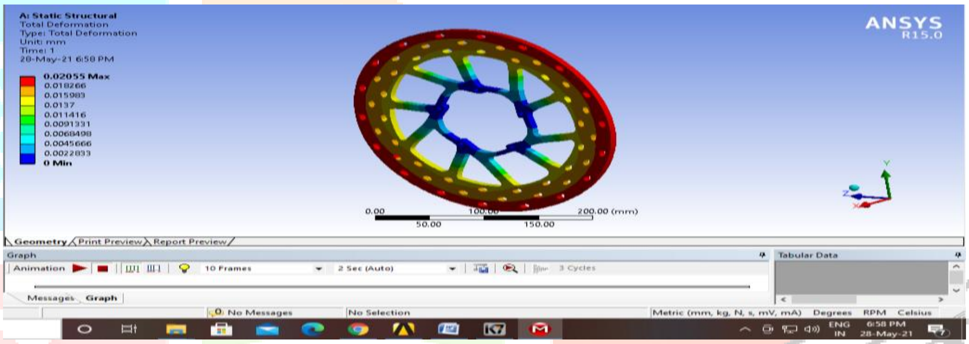


Fig 5.7 Equivalent von-mises stress distribution in disc brake rotor with elliptical hole-Model-3



5.8 Total deformation developed in disc brake rotor with elliptical hole-Model-3

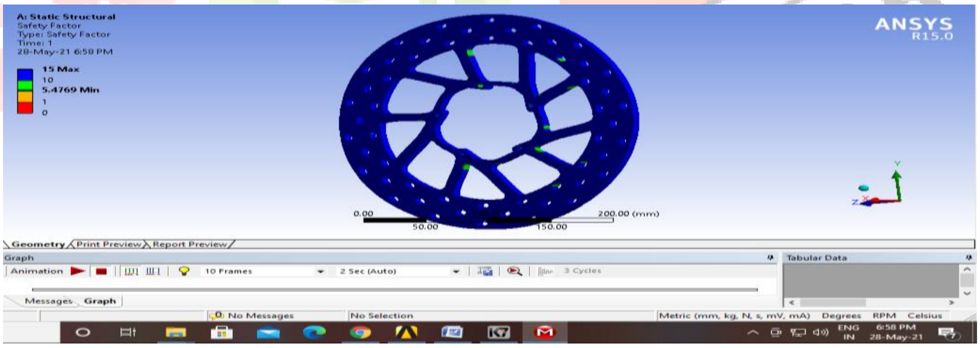


Fig 5.9 Safety factor attained in disc brake rotor with elliptical hole-Model-3

5.1.4 Ansys results of Disc Brake Rotor with Elliptical hole(8X10)-Model-4

The fig 5.10 shows the von-mises stress distribution in the rotor model-4. The pattern of distribution is same as in previous models. Compared to previous model-3, it can be observed that the color representation in the space between holes in adjacent circular lines found to be with increase in stress intensity, which might be due to too much reduction of material that leads to highly dense stress lines. The maximum von-mises stress developed is found to be 49.75MPa, which is 9% higher than that of model-3.

The fig 5.11 shows the deformation developed in the disc rotor model-4. The pattern of distribution is same as in previous model, but with slight increase in magnitudes. The maximum deformation developed is found to be 0.021482mm, which is 4.5% higher than that of in model-3.

The fig 5.12 shows the safety factor attained in disc rotor model-4. The pattern of attainment is same as in previous model with lower values at the connections of the ribs at either ends. The critical safety factor is found to be 5.0251, which is 8.2% lower than that of model-3.

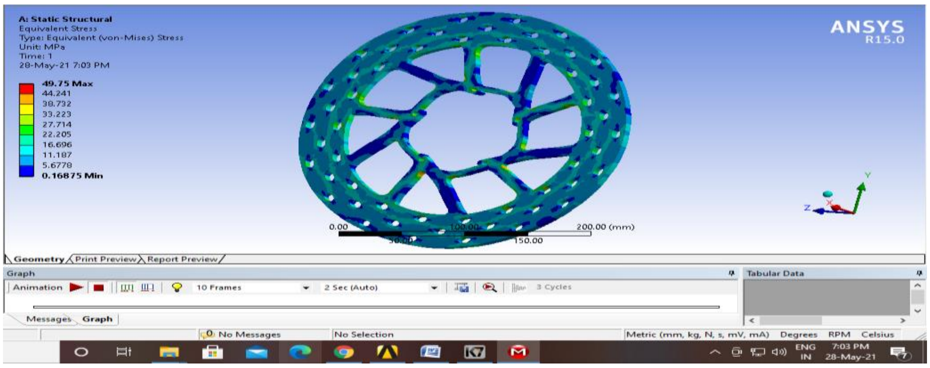
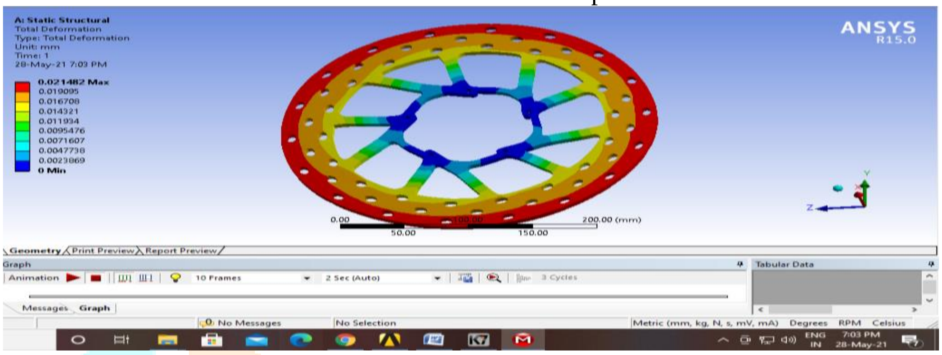


Fig 5.10 Equivalent von-mises stress distribution in disc brake rotor with elliptical hole-Model-4



5.11 Total deformation developed in disc brake rotor with elliptical hole-Model-4

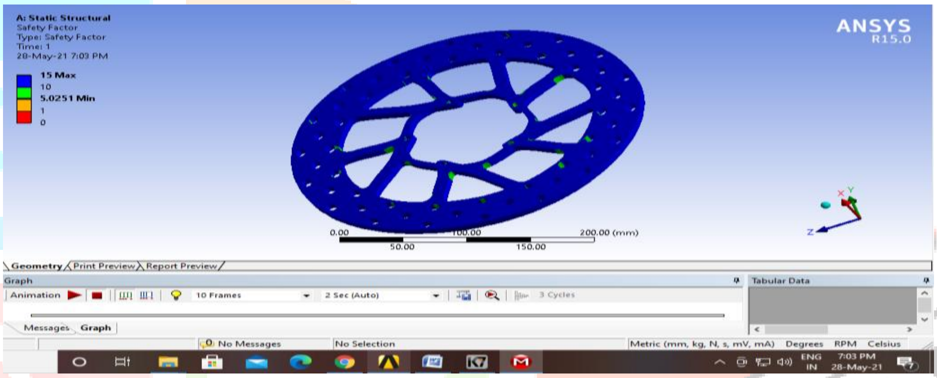


Fig 5.12 Safety factor attained in disc brake rotor with elliptical hole-Model-4

5.2 Structural Analysis: Ansys results of Disc brake rotos with Circular holes provided at fixed angular pitch of 20^0

5.2.1 Ansys results of Disc Brake Rotor with 5mm diameter Circular hole-Model-5

The fig 5.13 shows the von-mises stress distribution in the disc plate rotor provided with circular holes of 5mm diameter. The resulting color image shows that the intensity of stress beween the holes in the adjacent lines (circular) is higher especially between first and second row , as wellas between first row and inner edge of rotor plate, which was clearly represented with light green color. This might be due to lower gap between successive holes in the same circular line at lower radiasl distance. Thereby the stress lines cant get sufficient time/ distance for rearrangement of lines.Thus resulting in higher stress intensities. The maximum stress developed in this model-5 is found to be 48.86MPa, which was developed at the junction sof the ribs connection s at either ends.

Also due to circular shape the stress lines could not get sufficient space for rearrangment, while crossing the holes, compared to elliptical holes, where the major axis is larger which permits sufficient space for rearrangement. Thus rotor with circular holes leads to higher stress intensities.

The fig 5.14 shows the total deformation developed in disc plate rotor with 5mm diameter holes model-5. The deformation developed in this model shows similar pattern as in previous models with elliptical holes. Also it can be observed that shorter ribs (with higher inclination) gives more support to the rotor disc, which results in lower deformation, which can be observed with distribution of yellow color near the connections of ribs to rotor plate. The maximum deformation developed is found to be 0.019512mm.

The fig 5.15 shows the safety factor attained in disc rotor model-5. The resulting image shows that total plate is under maximum safe zone except the junctions, where ribs are connected at either ends. Thus by taking care of these areas the critical safety factor can be further improved. The critical safety factor is found to be 5.11 in this model-5.

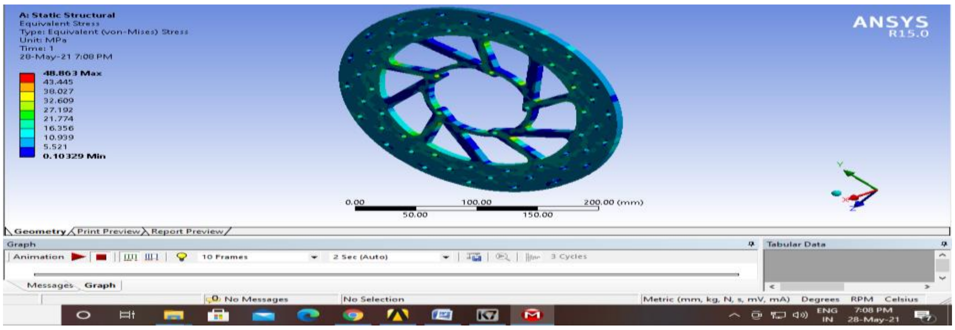


Fig 5.13 Equivalent von-mises stress distribution in disc brake rotor with circular hole-Model-5

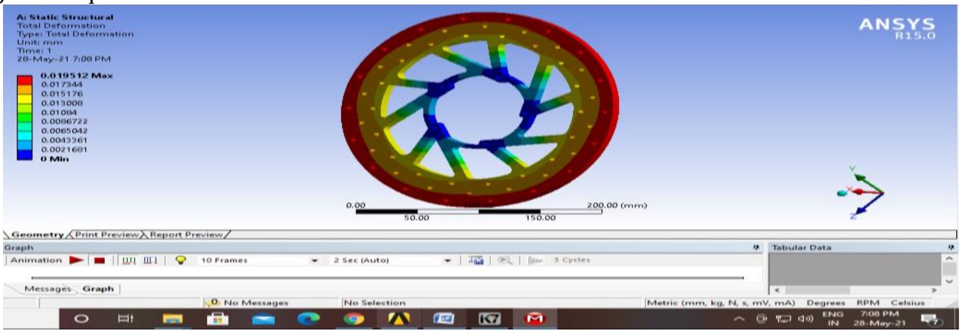


Fig 5.14 Total deformation developed in disc brake rotor with circular hole-Model-5

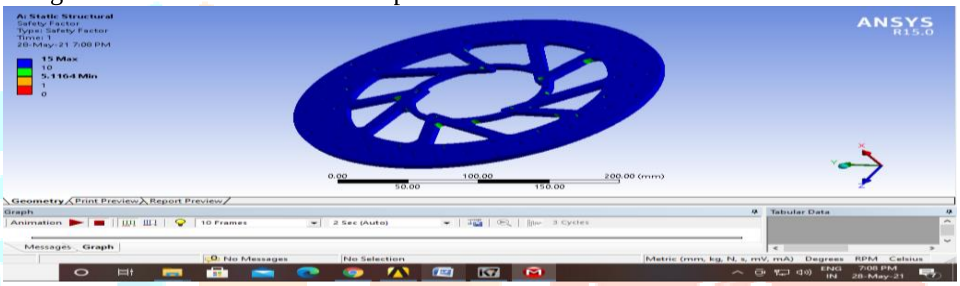


Fig 5.15 Safety factor attained in disc brake rotor with circular hole-Model-5

5.2.2 Ansys results of Disc Brake Rotor with 6mm diameter Circular hole-Model-6

The fig 5.16 shows the von-mises stress distribution in disc rotor model-6. The resulting color image shows the same pattern of distribution of stress in this model as in previous model. The maximum stress developed is found to be 50.24MPa, which is 2.8% higher than that of the model-5. By clear observation it can be seen with highlighiting with light green color throguh the major area compared to previous model-5.

The fig 5.17 shows the deformation developed in disc rotor model-6. The pattern of development of deformation is similar to the previous model-5. The maximum deformation developed is found to be 0.02003mm, 2.7% higher than that of previous model-5.

The fig 5.18 shows the safety factor attained in disc rotor model-6. The pattern of attainment is similar to the previous model-5. The critical safety factor is found to be 4.97, which is 2.8% lower than that of in model-5.

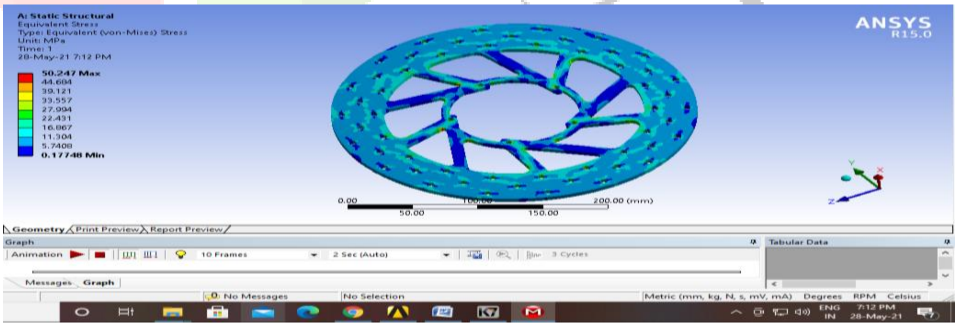


Fig 5.21 Equivalent von-mises stress distribution in disc brake rotor with circular hole-Model-6

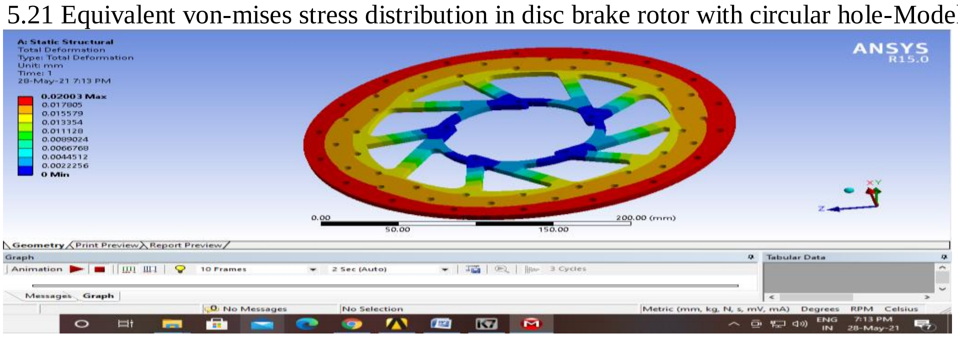


Fig 5.23 Total deformation developed in disc brake rotor with circular hole-Model-6

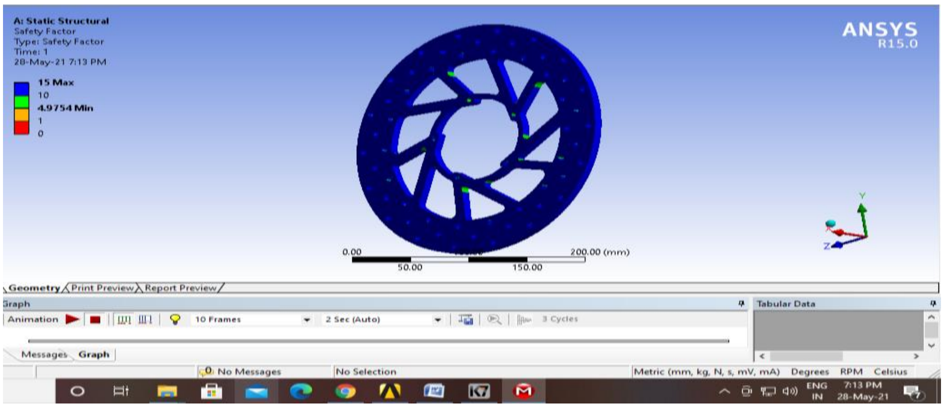


Fig 5.24 Safety factor attained in disc brake rotor with circular hole-Model-6

5.2.3 Ansys results of Disc Brake Rotor with 7mm diameter Circular hole-Model-7

The fig 5.19 shows the von-mises stress developed in the disc rotor model-7. The distribution of the stress follows the same trend as in the previous models. But the intensity of the stress was found to be increased further with a maximum magnitude of 56.35MPa, which is 12.2% higher than that of model-6.

The fig 5.20 shows the deformation developed in the disc rotor model-7. The resulting diagram shows that the development of deformation in this model is similar to the previous model. The maximum deformation developed is found to be 0.0206mm, which is 3.1% higher than that of the previous modle-6.

The fig 5.21 shows the safety factor attained in disc rotor model-7, which reveals that the critical safety factor is of 4.43, which is 10.8% lower than that of the value in model-6.

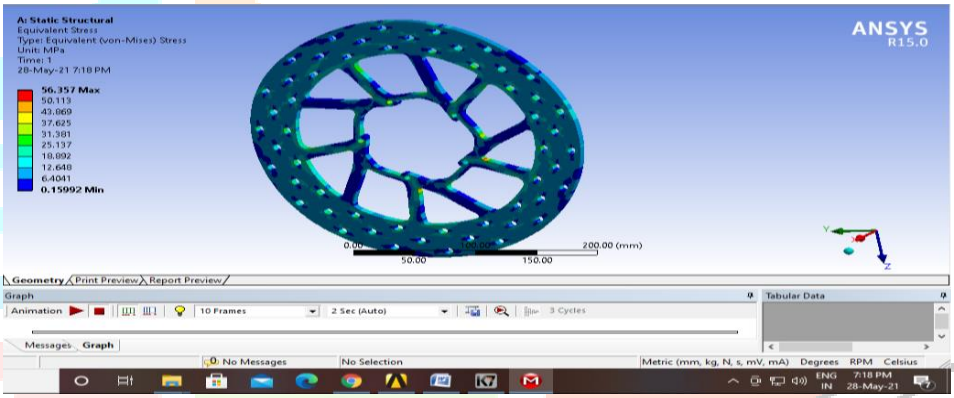


Fig 5.19 Equivalent von-mises stress distribution in disc brake rotor with circular hole-Model-7

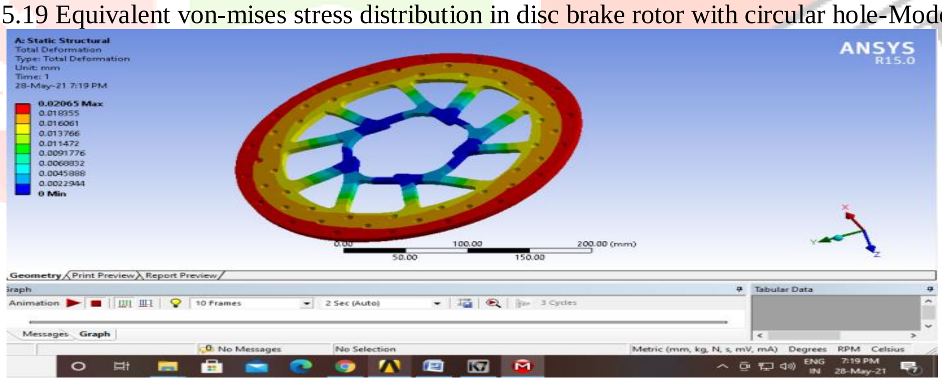


Fig 5.20 Total deformation developed in disc brake rotor with circular hole-Model-7

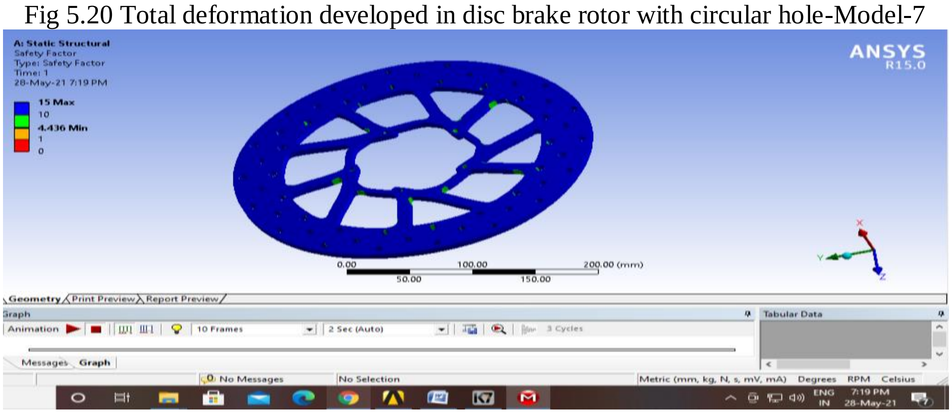


Fig 5.21 Safety factor attained in disc brake rotor with circular hole-Model-7

5.2.4 Ansys results of Disc Brake Rotor with 8mm diameter Circular hole-Model-8

The fig 5.22 shows the von-mises stress distribution in the disc rotor model-8. The resultin gcolor image shows that the pattern of distribution is similar to that of previous models. But the intensity of the stress has been reduced in this model-8, compared to the previous model-7. The maximum stress developed is found to be 50.81MPa, which is 9.8% lower than that of previous model-7. The reason for reduction in stress intensity might be due to suitable placing of holes, by which the stress lines across a hole in a row(circular), might got the passage to travel over the hole in the adjacent row. This can be observed by color representation which connects the holes as mentioned above between adjacent rows.

The fig 5.23 shows the deformation distribution in the rotor model-8. The pattern of development of deformation follows the same trend as in previous models. The maximum deformation developed is found to be 0.0214mm, which is 3.7% higher than that of the model-7.

The fig 5.24 shows the safety factor attained in the rotor disc model-8, with a critical value fo 4.9202, which is 10.9% higher than that of the model-7.

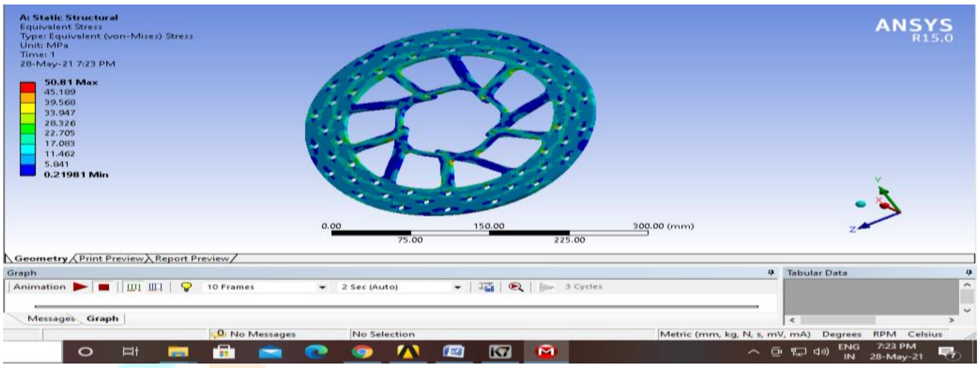


Fig 5.22 Equivalent von-mises stress distribution in disc brake rotor with circular hole-Model-8

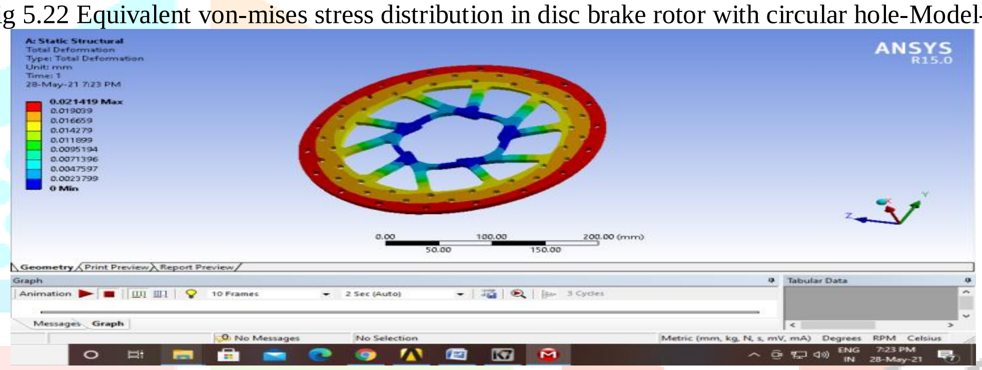


Fig 5.23 Total deformation developed in disc brake rotor with circular hole-Model-8

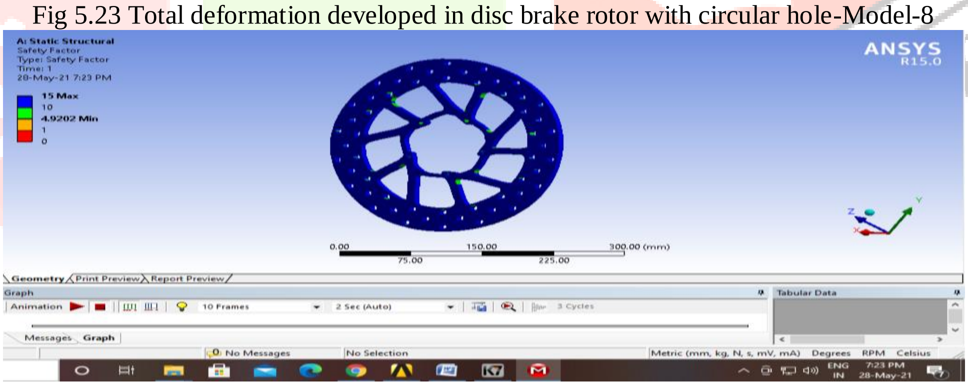


Fig 5.24 Safety factor attained in disc brake rotor with circular hole-Model-8

5.3 Structural Analysis: Ansys Results of Disc Brake rotor with different Angular positions of 8mm circular holes

5.3.1Ansys results of Disc Brake Rotor with 30^0 angular position (Circular Hole)-Model-9

The fig 5.25 shows the von-mises stress distribution in the rotor disc brake provide with holes at angular position of 30^0 model-9. The stress distribution in this pattern similar to the previous model of with 20^0 angular position. But the intensity of stress was increased compared to the previous model. The reason for this might be due to increase of distance between adjacent holes beyond certain limit that effect of stress line distribution may result in dense distribution, which result in higher stress intensity. The maximum stress developed in this model is found to be 54.2MPa, which is 6.7% higher than that of previous model-8.

The fig 5.26 shows the deformation development in the model-9. The pattern of development of deformation is similar ot the previous model-8. The maximum deformation developed in this model is 0.0206mm, which is 3.4% lower than that of previous model-8.

The fig 5.27 shows the safety factor attained in the rotor disc model-9. The pattern of attainment is similar to the previous model, but the critical safety factor is found to be 4.611, which is 6.2% lower than that of the model-8.

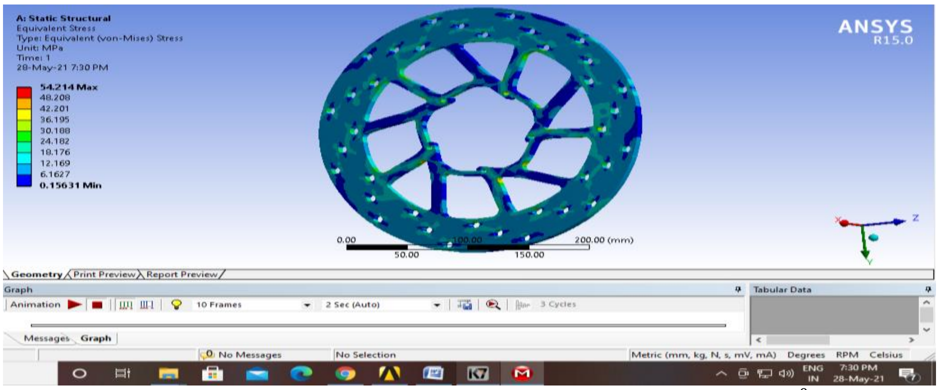


Fig 5.25 Von-mises stress distribution in disc brake rotor with holes at 30^0 –Model-9

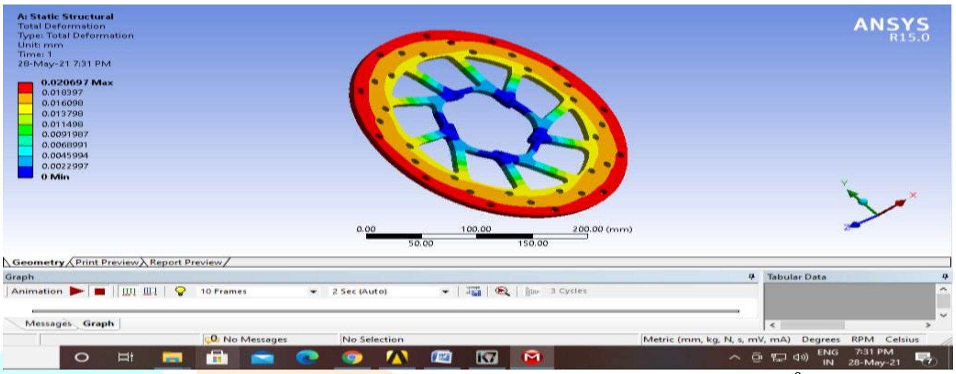


Fig 5.26 Deformation development in disc brake rotor with holes at 30^0 –Model-9

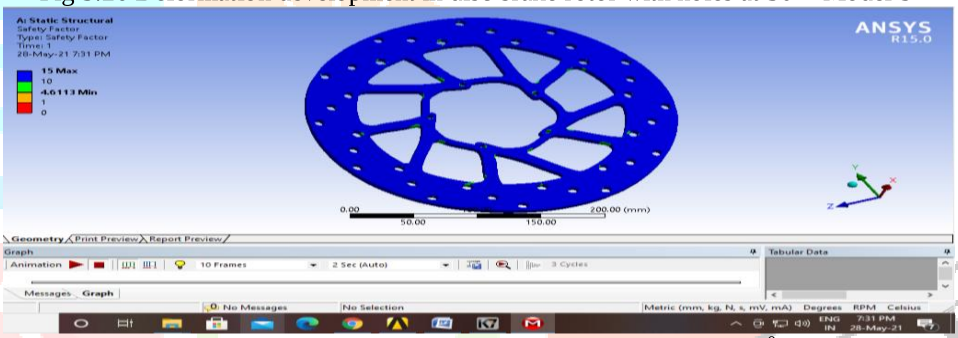


Fig 5.27 Safety factor attained in disc brake rotor with holes at 30^0 –Model-9

5.3.2 Ansys results of Disc Brake Rotor with 40^0 angular position (Circular Hole)-Model-10

The fig 5.28 shows the von-mises stress developed in the rotor disc model-10. The pattern of distribution in this model is similar to the previous model. The maximum stress developed in this model is 54.68MPa. The maximum stress in this model is close to the maximum value in previous model. Thus the differnce in the angular position from 30^0 to 40^0 does not shows much variation in the intensity of stress development.

The fig 5.29 shows the deformation development in the rotor disc model-10. The pattern is similar to the previous models and the maximum deformation developed is found to be 0.0203mm.

The fig 5.30 shows the safety factor attained in the rotor disc model-10. The critical value obtained is 4.571 which is slightly lower than that of previous model.

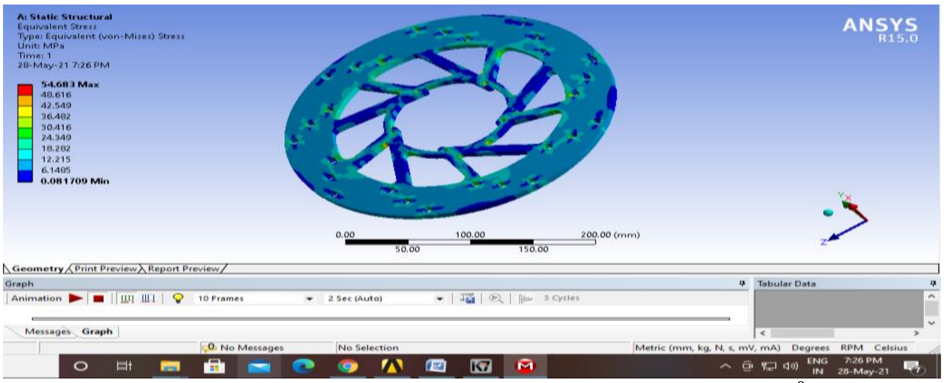


Fig 5.28 Von-mises stress distribution in disc brake rotor with holes at 40^0 –Model-10

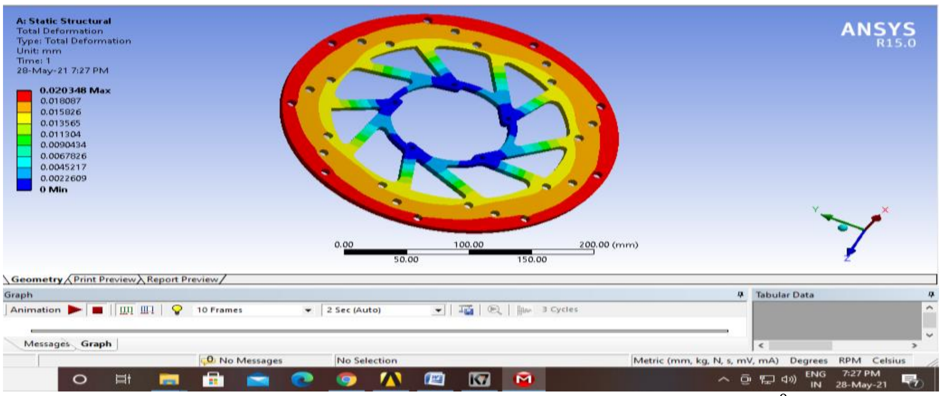


Fig 5.29 Deformation development in disc brake rotor with holes at 40^0 –Model-10

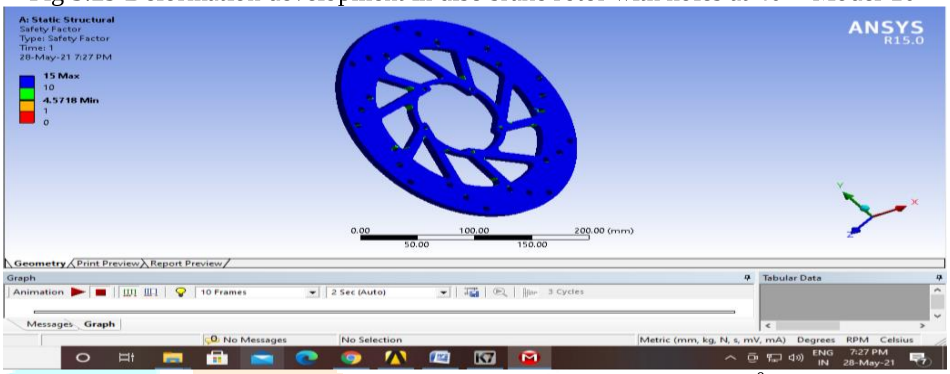


Fig 5.30 Safety factor attained in disc brake rotor with holes at 40^0 –Model-10

5.3.3 Ansys results of Disc Brake Rotor with 50^0 angular position (Circular Hole)-Model-11

The fig 5.31 shows the von-mises tress developed in the rotor disc model-11. The resulting image shows that the pattern of stress development is similar to the previous model. The maximum stress dveloped is found to be 54.73MPa, which is slightly higher than that of model-10.

The fig 5.32 shows the deformation developed in the rotor disc model-11. The deformation developed is similar to the previous model with a maximum magnitude of 0.02001mm, which is very slightly more than that of model-10.

The fig 5.33 shows the safety factor attained in the model-11. The critical safety factor attained is 4.5675, which is slightly lower than that of model-10.

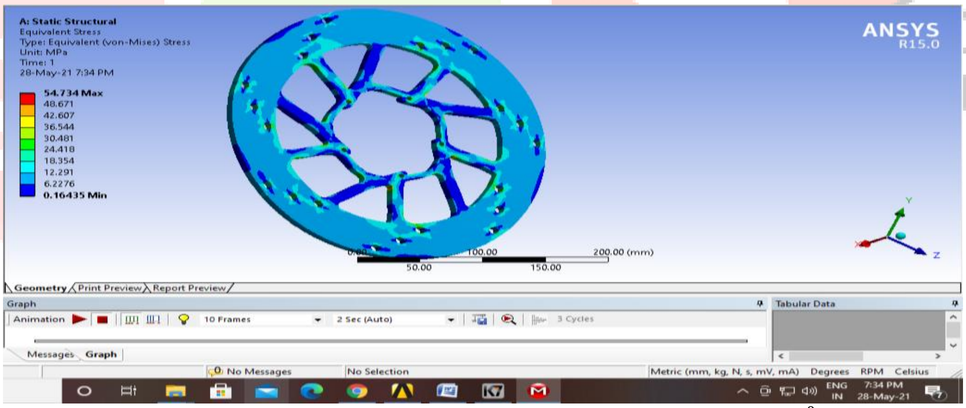


Fig 5.31 Von-mises stress distribution in disc brake rotor with holes at 50^0 –Model-11

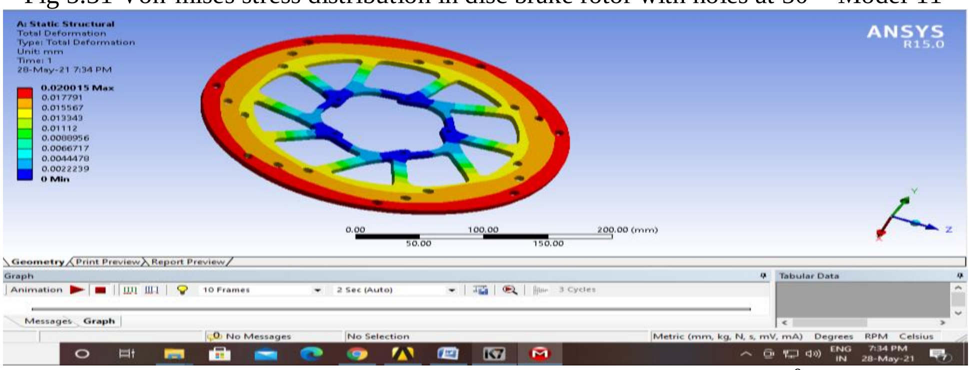


Fig 5.32 Deformation development in disc brake rotor with holes at 50^0 –Model-11

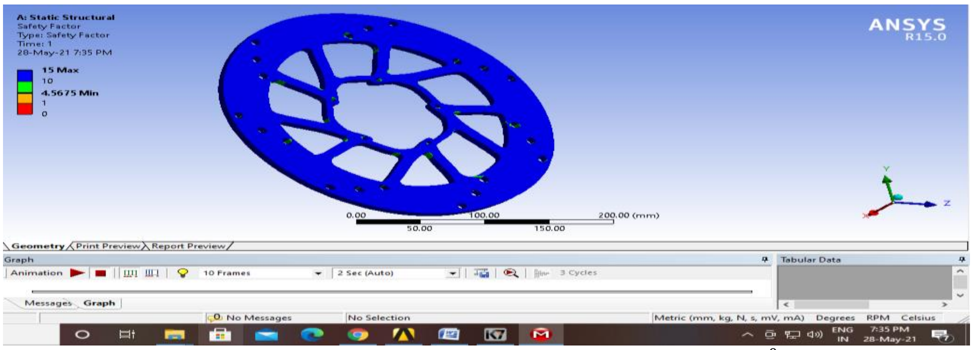


Fig 5.33 Safety factor attained in disc brake rotor with holes at 50^0 –Model-11

5.4 Comparison of stresses of all the disc brake rotor models

The fig 5.34 shows the comparison of von-mises stress development on rotors with different sized elliptical holes. The Graphical fig shows that the stress initially decreases and again increases. The rate of variation of stress is high initially rather than later.

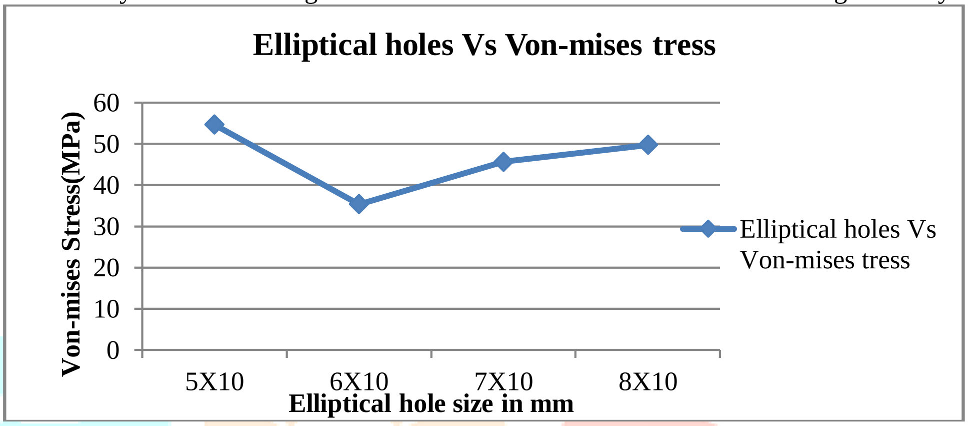


Fig 5.34 Comparison of rotors disc holes with different elliptical size

The fig 5.35 shows the comparison of von-mises stress developed on rotors with different size of circular holes. The fig shows that the stress increases with holes size but again decreases at too higher hole size.

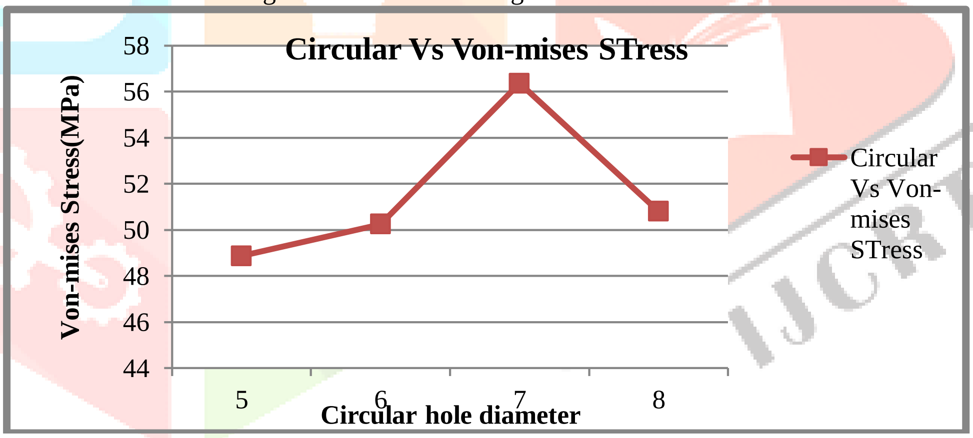


Fig 5.35 Comparison of rotors disc holes with different circular diameters

The fig 5.36 shows the comparison of von-mises stress developed in the rotors with different angular positioned holes. The fig reveals that the stress increases with increase in angular distance of holes. But beyond 40^0, though there is increase in stress, the rate of increase is found to be very small.

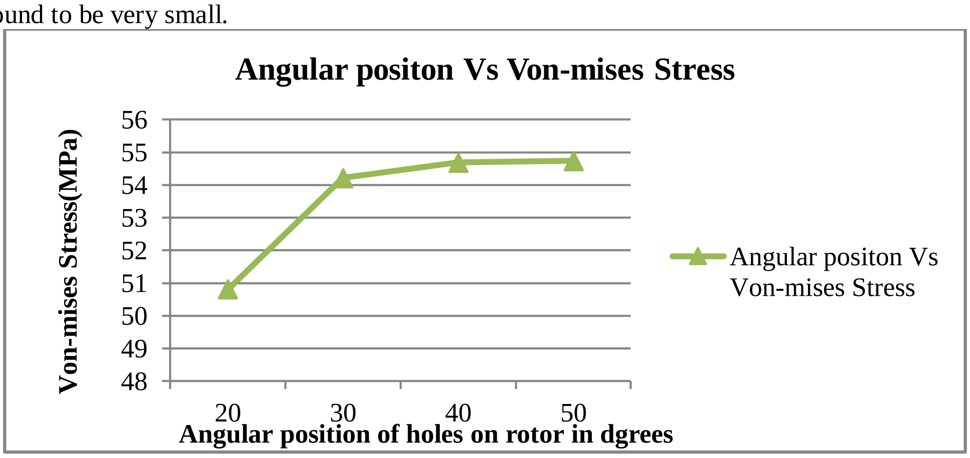


Fig 5.36 Comparison of rotors disc different angular positioned holes (circular).

VI. CONCLUSIONS

The following conclusions were drawn by conducting structural analysis tests on series of disc brake rotor by varying shape, size and position of the holes.

- Both von-mises and shear stress on disc brake rotor with elliptical shape holes is minimum in model-2 (6X10 ellipse), which are 35.2% and 32.7% lower than the highest stress model-1.
- The deformation on disc brake rotor with elliptical shape holes in the optimum model-2 (6X10 ellipse) is 0.020057mm, which is 6.6% lower than the highest deformed model-4.
- The model-2 (6X10 ellipse) is the optimum among all the analyzed models with elliptical holes, which result in highest safety factor.
- Both von-mises and shear stress on disc brake rotor with circular shape holes is minimum in model-5 (5mm diameter), which are 13.2% and 13.8% lower than the highest stress model-7.
- The deformation on disc brake rotor with circular holes in the optimum model-5 (5mm diameter) is 0.0195mm, which is 8.9% lower than the highest deformed model-8.
- The model-5 (5mm diameter hole) is the optimum among all the analyzed models with circular holes, which result in safety factor of 5.11
- Comparing the von-mises stress, shear stress and deformation among all the tested models with different angular positions of holes on the disc brake rotor, the model-8 with 20^0 angular positioned holes is optimum.

Thus concluding with comparing all the 11 models, the model-2 with 6X10mm elliptical hole is found to be optimum with lower stress and deformation development, giving a highest safety factor of 7.0721.

REFERENCES

[1] S. R. Abhang and D.P.Bhaskar, Design and Analysis of Disc Brake, International Journal of Engineering Trends and Technology, 8, (4), 165-167, 2014.

[2] Y.H. Mishra, V.R. Deulgaonkar and P.A. Makasre, Design and Optimisation of Disc Brake Rotor (For Two Wheeler), International Engineering Research Journal, 288-300, 2016.

[3] Vanam B. C. L, Rajyalakshmi M. and Inala R, (2012).Static Analysis of an Isotropic Rectangular Plate Using Finite Element Analysis (FEA).Journal of Mechanical Engineering Research, V.4 (4), pp. 148-16..

[4] T. D. Gillespie, Fundamentals of Vehicle Dynamics, Society of Automotive Engineers, Inc., 400 Commomwealth drive Warrendele 45-76, 1992.

[5] P. kllungchang, P. Deshattiwar, K. Menjo, Ruikar, S. Kumar, R. K. Shrivastava, Thermal Analysis of Brake Disc, SlideShare/Engineering, 2016.

[6] M.A. Maleque, S.Dyuti and M.M. Rahman, Material Selection Method in Design of Automotive Brake Disc, Proceedings of the World Congress on Engineering, 3, 2010 (ISBN: 978-988-18210-8-9).

[7] V. Chengal Reddy, M. Gunasekhar Reddy and Dr. G. HarinathGowd (2013), Modeling and Analysis of FSAE Car Disc Brake Using FEM. International Journal of Emerging Technology and Advanced Engineering.

[8] J. Rakesh, A. Raj, K. Anush, D. Debayan, J. Pawan, R. Saurav, Structural and Thermal Analysis of Disc Brake using Solidworks and Ansys, International Journal of Mechanical Engineering and Technology, 7, (1), 66-77, 2016

[9] Guru Murthy Nathi1, T N Charyulu ,K.Gowtham and P Satish Reddy,(2012), Coupled Structual Thermal Analysis Of Disc Brake , ISSN: 2319 – 1163 Volume: 1 Issue: 4

[10] Palmer, Edward, Mishra, Rakesh and J. D. Fieldhouse,A computational fluid dynamic analysis on the effect of front row pin geometry on the aerothermodynamic properties of a pin-vented brake disc, Proceedings of the Institution of Mechanical Engineering Part D of Automobile Engineering 22, (7), 1231–1245, 2008.

[11] S. Sarkar, P. Rathod, A. J. Modi, Research Paper on Modeling and Simulation of Disc Brake to Analyse Temperature Distribution using FEA, International Journal for Scientific Research & Development, 2, (3), 492-494, 2014.