International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

Structural Effects of Fins Inclination Angles on Vented Brake Disc

Sunday Bako[1*], Muhammed Bello Umar[2], Paul Oscar Yahaya[3], Nuhu Mba Gora[4], Yusuf Saad[5]

[1,2,3,4,5]Department of Mechanical Engineering, Nuhu Bamalli Polytechnic, Zaria, Nigeria.*

Email: [2]mbumar18@gmail.com, [3]pauloy1ng@yahoo.com, [4]neatman76@gmail.com, [5]yusufsaad210@gmail.com
Corresponding Email: [1]s2bako@yahoo.com*

Received: 06 April 2023 **Accepted:** 22 June 2023 **Published:** 10 August 2023

Abstract: An automobile brake disc is speed control mechanism used in most vehicles. The component is subjected to high mechanical stress, because it converts the kinetic energy of a moving vehicle into thermal energy. Therefore the component is prone to damages which can leads to brake failure resulting to lost of lives and properties. However, most researchers are more concern with methods to improve the heat dissipation of the vented brake disc, without giving much emphasis to the angle of inclination of the vents which can leads to some structural problem. Therefore, this paper aimed at investigating the effects of the internal fins inclination angles on the vented brake disc. A static state structural analysis was performed using Solidworks Simulation software on three brake disc models, with fins at 90^o, 60^o, and 30^o inclination. The results shows that the model with fins at 90^o inclination has the lowest von misses stress (714,044.9N/m^2), deformation (1.7x10^{-4}mm) and strain (9.135x10^{-6})which leads to its high Factor of Safety than the two models. It is hereby recommends that, the length of the fins or vents should be position along R, R_1 and R_2 in order to reduce stress generation on the brake disc. However, further research work should be done to investigate the thermal performance of these three models. However, another work should be carryout by elongating the length of these fins to be position along R, $R_1$and R_2.

Keywords: Vented Brake Disc Design, Modeling and Simulation.

1. INTRODUCTION

The most important safety and control feature of any automobile is its braking system. One of the Fundamental functions of the system is to decelerate the vehicle at different driving condition [1,2]. Brake application is a form of energy balance and conversion system. Its aim is to transform mechanical energy of moving wheel into other form of energy, thereby

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

decelerating motion of a moving vehicle. In this process, the kinetic energy of the vehicle is transformed into the heat energy, through friction and, after which it is dissipated to the wheels surroundings [3].

Unlike drum brake, disc brake has a metal disc in place of a drum in the drum brake system. Disc brake has a brake pad situated at the brake caliper [4]. Unlike the drum brake, the disc brake is a external contracting system where the brake pads contact the brake disc in order to cause braking. Figure 1 show the schematic diagram of the automobile disc brake.

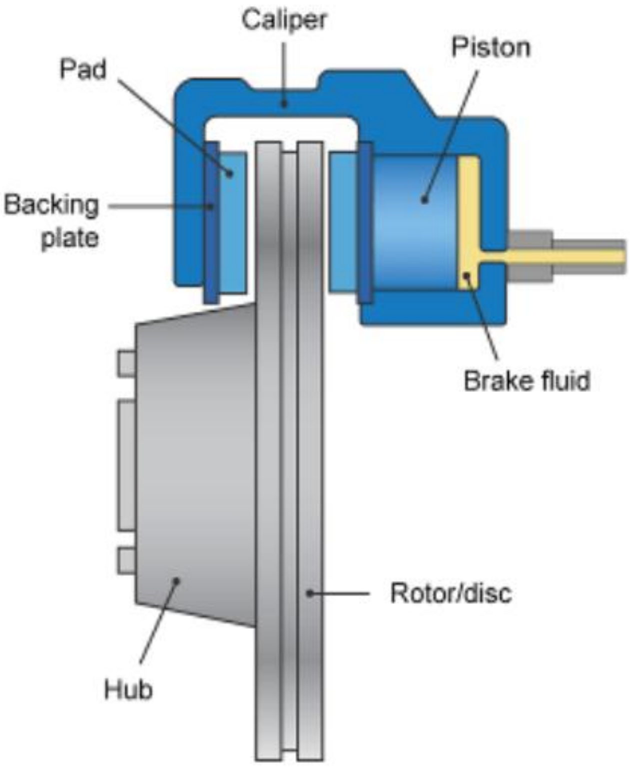


Fig. 1 Schematic Diagram of Automobile Disc Brake

During braking, the kinetic and potential energy of the vehicle are converted into thermal energy. This energy is absorbed by the brake disc and is transferred to the surrounding. The brake disc can be vented or non-vented. The vented disc has two sets of discs connected together by internal fins. The vented disc has a larger surface area, while non-vented disc brake has a single disc with a relatively smaller surface area. [5,6]. The vented disc are lighter with additional convective heat transfer. Therefore, the vented disc can minimize thermal problems such as the variation of the pad friction coefficient, brake fade and vapor lock [7, 8]. However, this vents can reduce the strength of the brake disc if they are not properly positioned.

The disc brake fails during extreme braking application which can reduced the efficiency and performance of the system [9]. This can lead to brake failure and road clashes. Brake discs without vents dissipate heat at a lower rate. The vented discs are used to enhance brake disc

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

cooling [10]. The heat generated during brake application can cause problems on the brake assembly such as brake fade, premature wear, thermal cracks and Disc Thickness Variation [2]. Due to different brake disc geometry, each disc has different geometrical constraints for the thermal expansion. The frictional heat generated during braking application can cause numerous problems to the brake disc such as, brake fade, thermal cracks, wear, permanent damage, breakage in brake disc due to high compressive stress, variation of disc thickness, hot spots formation and macroscopic cracks [11-17]. This problems are disastrous and can lead to lost of lives and properties.

Stress generation and heat dissipation rate are two critical factors in design of automobile brake disc. If the disc is simply solid without vents, the stress concentration will be minimum, but the heat dissipation rate will be minimum. Also, if holes are created into the disc, the stress concentration will also increase while the heat dissipation rate will also increase [3]. Therefore, these two important parameters needs to balance in order o ensure brake safety. However, many researchers [18-28] have carried out researches on brake disc without giving much emphasis to fins or vent inclination angles. This brought the concept this research. Meanwhile, Bako et.al., [29-32],uses fins to improve the strength and heat dissipation of an automobile brake drum and of two stroke spark ignition engine block. Therefore, this paper aimed at altering the internal fins inclination angles pf the vented brake disc as to determine the brake disc model with low stress concentration, deformation and strain.

2. MATERIALS AND METHODS

The main materials used in the analysis are, a model of a vented brake disc, AutoCAD 2018 for the conceptual presentation and a Solidworks 2013 software for modeling and simulation of the vented brake disc. Three solid models of an automobile brake disc were developed with internal fins at 90^o, 60^o and 30^o inclination using the Solidworks 2013 software. A steady state structural analysis was carried out on the three models under the same boundary condition to ascertain their structural behaviors. The simulation results for the three models were compared to ascertain the effects on the fins inclination angle on their structural performance.

2.1 Design

The design of an automobile brake disc is greatly influenced by space available, while the type of wheel defines the space limitation for brake disc [1]. The usual procedure for development of brake disc is to copy the design from a similar model or to replicate the previous design with little modifications, and such designs are implemented if they are proved to be satisfactory [9].
The diameter of brake disc is determined by considering maximum amount of braking torque required to be applied on the brake disc. The area of application of the clamping force by the caliper and the frictional force on the brake disc are the major factors in design of the brake disc [1]. Figure 2 shows the structural parts of a vented brake disc used in this analysis. While Table 1 shows the dimensions of the brake disc. The cross section length and width of the fins (n) are 7mm and 5mm respectively. The fins were inclined at 90^o, 60^o and 30^o to generate three models of brake disc required for this analysis

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

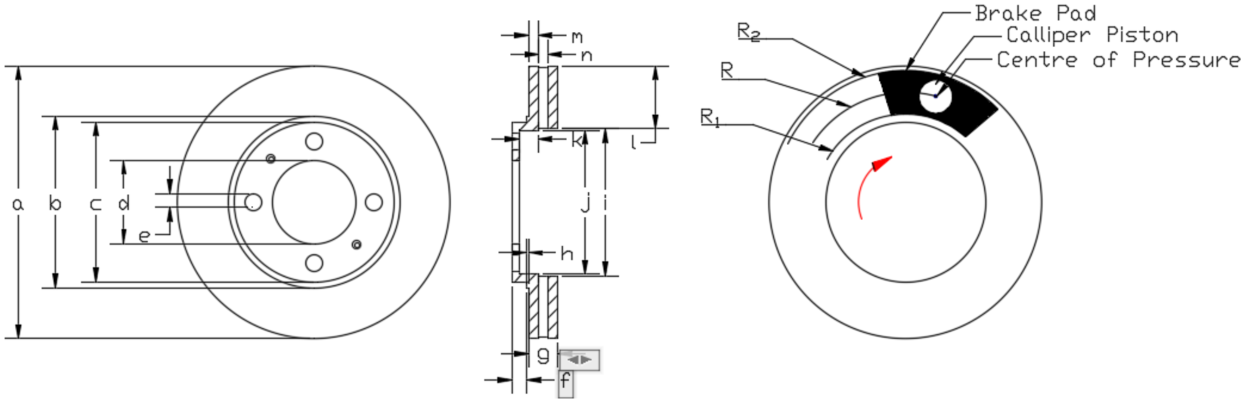


Fig. 2 Structural Parts of Automobile Brake Disc

The normal clamping force N on each side of the brake disc produces a frictional force ($F = \mu N$). If the resultant frictional force pass through the centre of the brake pad R (centre of Pressure) [32], then the mean distance between the centre of the pad pressure and the centre of the brakedisc becomes;

$$R = \frac{R_2 + R_1}{2} \tag{1}$$

But,

$$F = \mu N \tag{2}$$

The frictional braking torque is double due to the action of the frictional force N on both sides of the brake disc, and depends on the distance the pads are located from the centre of the wheel rotation. Therefore,

$$T_b = 2\mu N \left(\frac{R_2 + R_1}{2}\right) = 2\mu N R \tag{3}$$

The Braking TorqueT_b,

$$T_b = 2\mu N \left(\frac{R_2 + R_1}{2}\right) = 2\mu N R \tag{4}$$

Therefore, the Clamping Force N,

$$N = \frac{T_b}{\mu(R_2 - R_1)} = \frac{T_b}{2\mu R} \tag{5}$$

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

Table 1. Parts of Automobile Brake Disc

S/N	Nomenclature	Dimension (mm)
1	a	259.80
2	b	138.70
3	c	135.70
4	d	60.05
5	e	13.50
6	f	7.00
7	g	37.00
8	h	5.20
9	i	124.90
10	j	138.70
11	k	22.50
12	l	53.75
13	m	7.50
14	n	7.00

2.2 Modeling

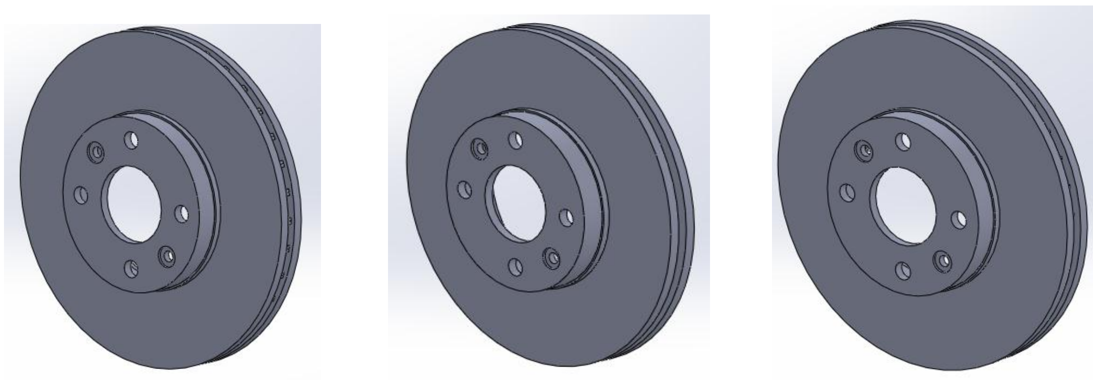
To model a complex geometry, some simplifications are always necessary, keeping in view the difficulties involved in the theoretical calculation, and usually ignoring values of less importance and impact on the analysis. While assumptions are always made depending upon the details and accuracy required in the modeling [34]. There are many parameters involved in design of a brake disc, and sometimes it is difficult to obtain mathematical equations for such processes. This makes, Finite Element Method to serves as an optimization method for brake disc design [1]. Therefore, in this research, Finite Element Software known as Solidworks 2013 was used in the modeling of the brake disc with fins at 90^{o} 60^{o} and 30^{o} inclination, after which a simulation analysis was conducted using the same software.

A static steady state structural analysis was performed on the three brake disc models using the same boundary condition. The static analysis are performed on a given structure when the loads and boundary conditions kept stationary and do not change with time [31]. During this simulation process, the three models were treated under the same boundary conditions to ascertain their structural behaviors.

Igbax et. al., [36] emphasized on the need for engineering materials to have a desirable properties in order to prevent failure. Because wearing of the metal surfaces of the braking

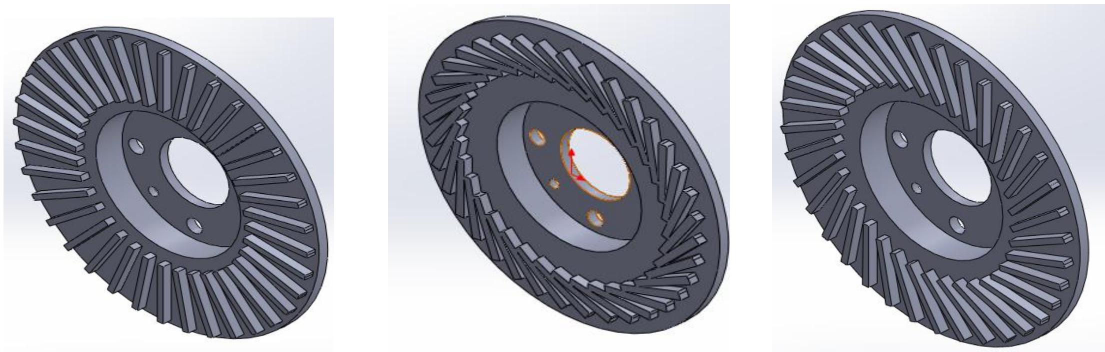
International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

system can interfere with the proper operation of its components, leading to a diminished margin of safety of the system [37]. The brake discs are made of gray cast iron material [10] due to their strength. They are designed to withstand high clamping force and temperature. Therefore, a gray cast iron material was selected during the simulation analysis, while a clamping force of 4000N was used on each model as the initial boundary condition. In order to unify the analysis, all the three models were simulated under the same boundary condition (400N). While in order to simplify the analysis it was assumed that, the clamping force of the caliper piston is acting on the entire braking surface of the brake disc. Also in order to ensure consistency in the Finite Element simulation, an element size of 4mm was used for the three models during the meshing process. The meshing process is a Finite Element process for dividing the models into elements and nodal points for further computation. Figure 3 shows the solid models, while Figure 4 shows the internal structures of each of the models of the brake disc respectively.



a) (b) (c)

Fig. 3 Solid of the Brake Disc Models (a) Model at 90^o (b) Model at 60^o (c) Model at 30^o



(c) (d) (e)

Fig. 4 Internal Structure of the Brake Disc Models (a) 90^o Inclination (b) 60^o Inclination (c) 30^o Inclination

3. RESULTS AND DISCUSSIONS

The Table 2 shows the meshing result, while Figure 5 shows the meshed models after meshing

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

process. The result shows that, no elements of the three models were damaged as the result of distortion; because this could affect the simulation results. The result shows that, the three models have the same Jocobian point (4), % distortion (0), element size (4mm), and element tolerance (0.2mm). This justified that, the three models were treated under the same boundary conditions. While the model with fins at 60^o inclination shows a high number of elements (97968) and nodal points (158706) than that of the model with fins at 90^o inclination (91905 and 151327), and 30^o inclination (152629 and 152629) respectively. This shows that, the brake disc with fins at 60^o inclination has large surface area than the other models. This is because the fins are connected at their lower ends due to their inclination. This would prevent proper ventilation of the brake disc thereby creating some thermal problem to the braking system. This also implied that, the model with 60^o inclination would take a longer time to complete the simulation process due to its high number of nodal points and elements.

Table 2. Mesh Results

S/N	Mesh Parameters	Brake Disic Models		
		Fins at 90^o	**Fins at 60^o**	**Fins at 30^o**
1	Mesh type	Solid Mesh	Solid Mesh	Solid Mesh
2	Mesher Used	Standard mesh	Standard mesh	Standard mesh
3	Jacobian points	4.0000	4.0000	4.0000
4	Element size (mm)	4.0000	4.0000	4.0000
5	Tolerance (mm)	0.2000	0.2000	0.2000
6	Mesh quality	High	High	High
7	Total nodes	151327	158706	152629
8	Total elements	91905.0	97968	92779
9	% of distorted elements (Jacobian)	0.00000	0.00000	0.00000

Figure 6 (a) and (b) shows a von mises stress distribution for the brake disc model at 90^o fins inclination. The plots indicate a low stress distribution than that of the model at 30^o and 60^o fins inclination. This is due to the fact that the fins tips are positioned along the braking surface with both ends at R_1 and R_2 respectively. This provides much support to absorb more stress than the other brake disc models. This low stress exhibited by this model make the model to have low displacement (deformation) than the two models as indicated by Figure 6 (c) and (d).

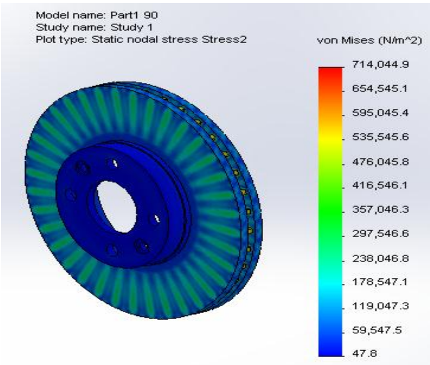
Strain is the measure of deformation in a material when subjected to mechanical stress. The brake disc model at 90^o inclination shows a low static strain, strain energy, and strain intensity than the two models. This is due to the structural arrangement of the fins as shown in Figure 4. This leads to low stress and displacement of the model. The Results of this analysis implies that the brake disc model at 90^o inclination would have high tendency to absorb more compressive stress resulting from the clamping force of the caliper pistons.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

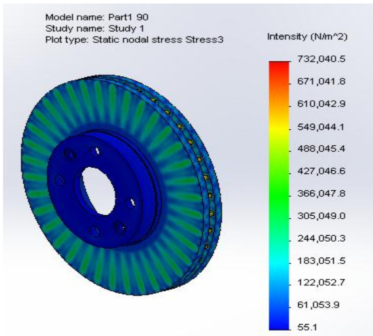
(a) (b) (c)

Fig. 5 Mesh Model (a) 90° inclination (b) 60° inclination (c) 30° inclination

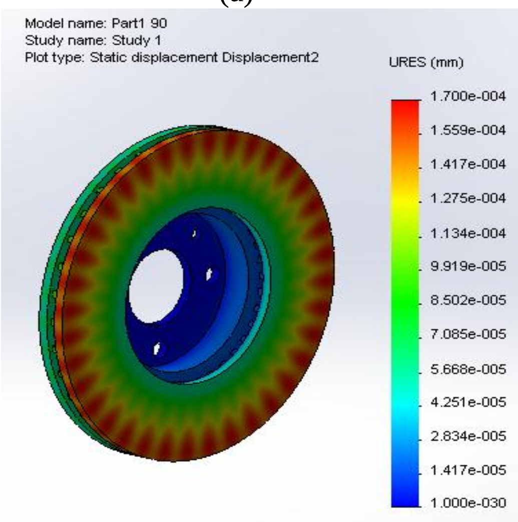
The analysis results (Figure 6 (h)) shows that the brake disc at 90° inclination indicates a high Factor of Safety (FOS) than that of the two models. This is due to the position of the fins along R_1 and R_2. This makes the model to have low stress, displacement, strain, but high FOS.



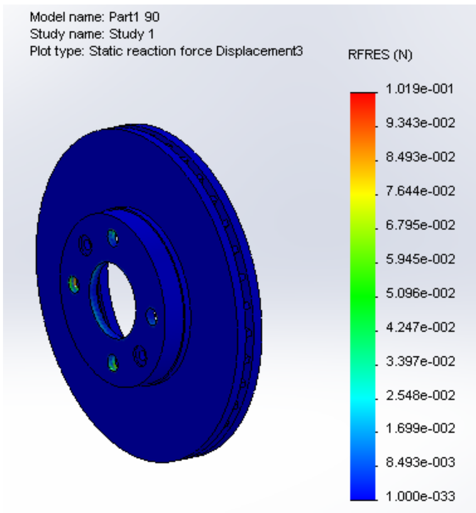
(a)



(b)

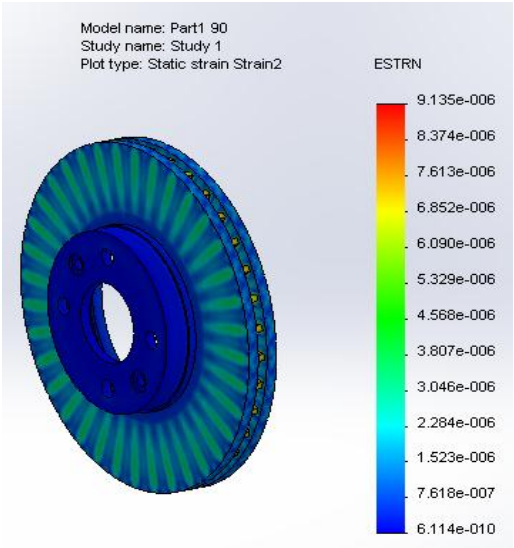


(c)

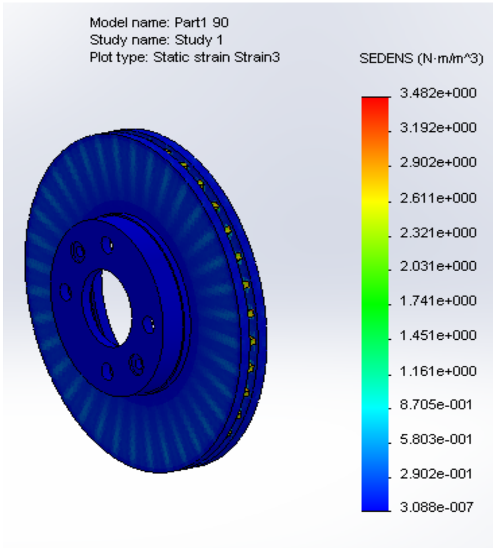


(d)

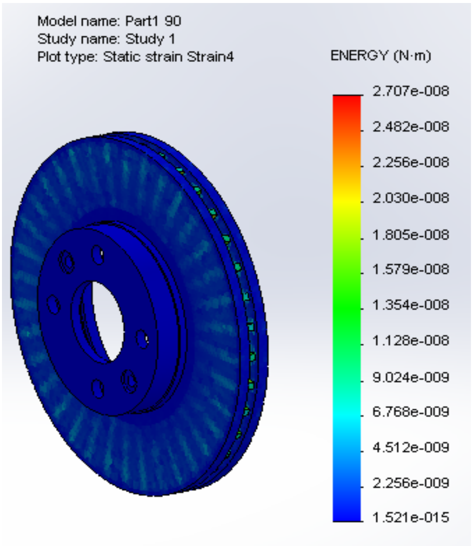
International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43



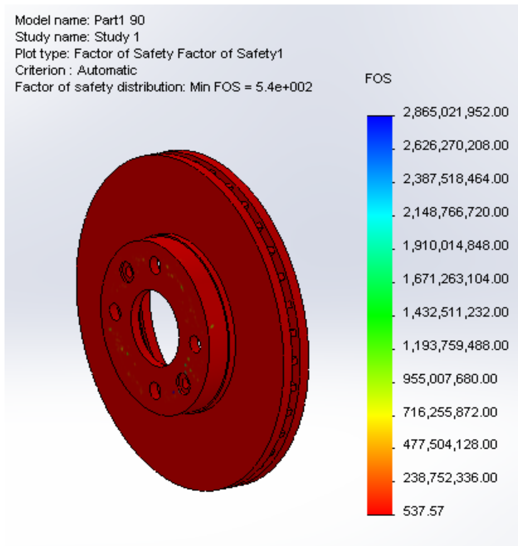
(e)



(f)



(g)

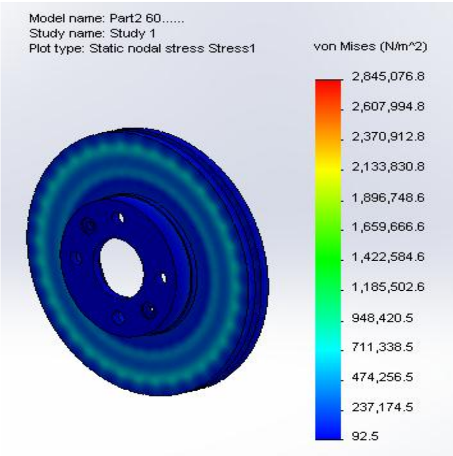


(h)

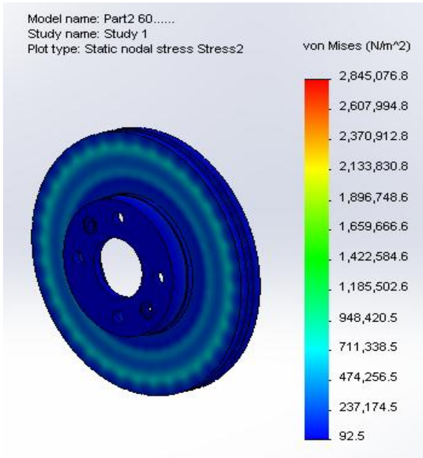
Fig. 6 Model with Fins at 90º Inclination (a). Von Mises (b) Stress Intensity (c) Resultant Displacement (d) Resultant Reaction Force (e) equivalent Strain Energy (f)Strain Energy Density (g) Total Strain Energy (h) Factor of Safety

The von misses stress distribution for the model at 60º inclination is higher than of 90º and 30º inclination. This is because when the fins were incline at 60º from the brake disc centre of pressure (R), the tips of the fins are not positioned at R_1 and R_2 because its length has shorten due to its inclination. Therefore, this creates an avenue to absorb for more stress; leading to higher displacement (deformation) and strain, and lower FOS as indicated in Figure 7 below.

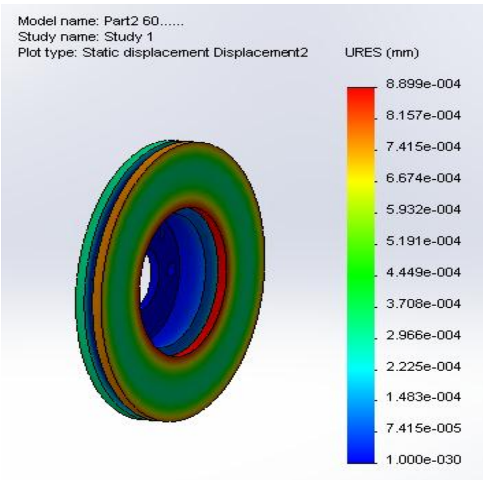
International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43



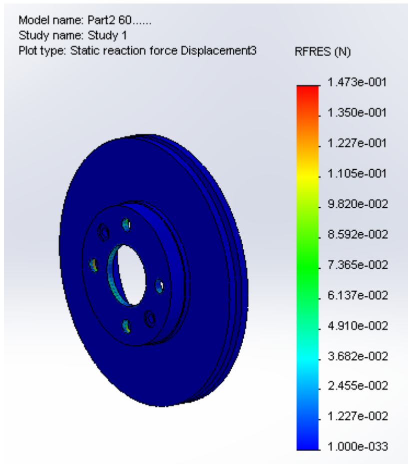
(a)



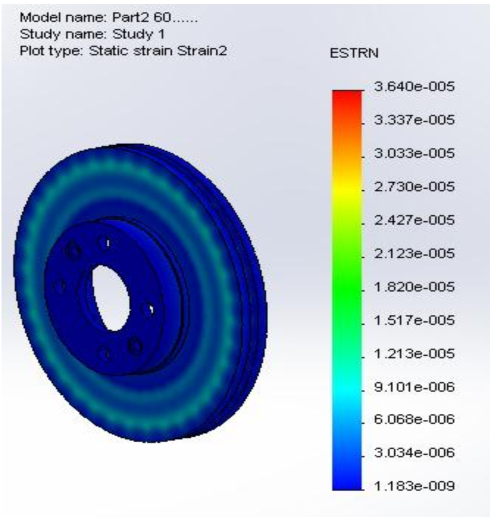
(b)



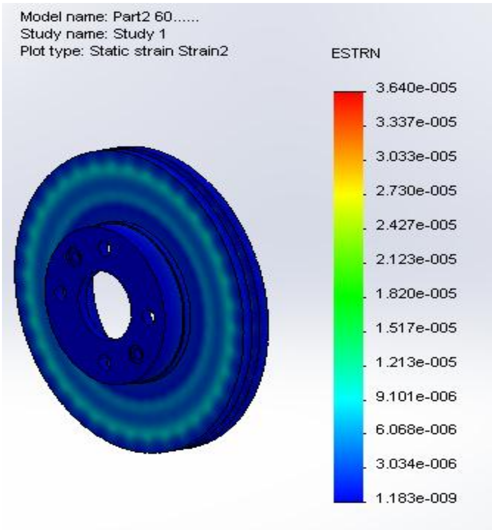
(c)



(d)

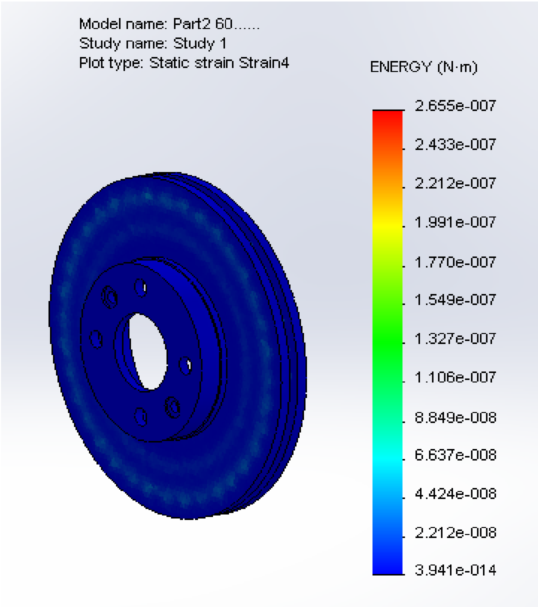


(e)

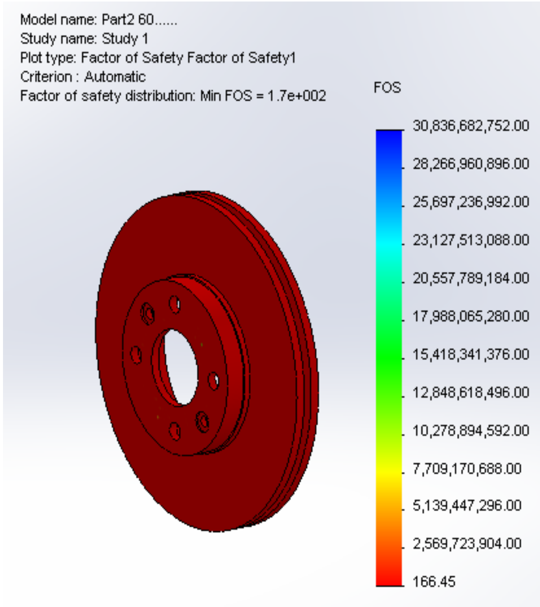


(f)

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43



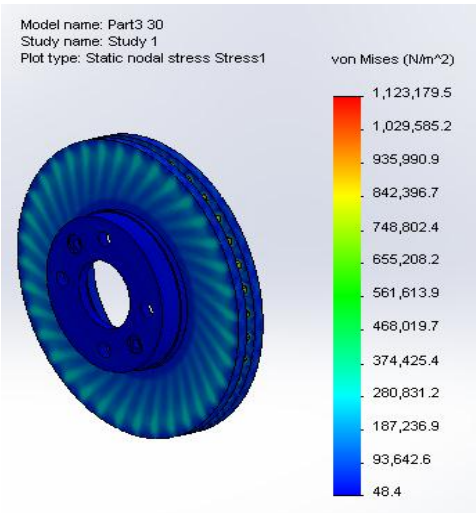
(g)



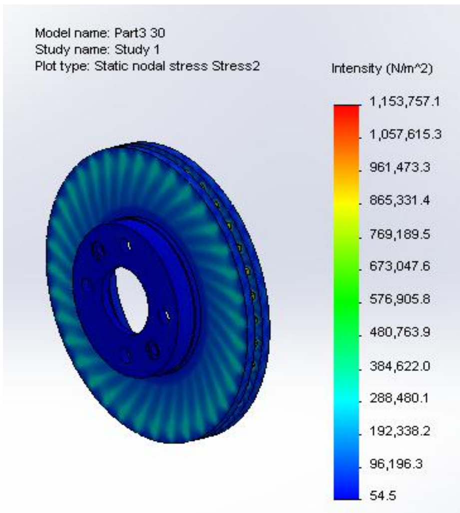
(h)

Fig. 7 Model with Fins at 60^{o} Inclination (a). Von Mises (b) Stress Intensity (c) Resultant Displacement (d) Resultant Reaction Force (e) equivalent Strain Energy (f)Strain energy density (g) Total Strain Energy (h) Factor of Safety

The inclination of the third model is at 30^{o}. Therefore unlike the model at 60^{o} inclination, this model has lower angle of inclination from the centre of pressure of the clamping force. This makes the tips of the fins to be closer to R_1 and R_2, than the model at 60^{o} inclination. This makes the model to have high von mises stress than the model at 90^{o} inclination, and lower displacement and high Factor of Safety than the model at 60^{o} inclination as indicated by the Figure 8.



(a)



(b)

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

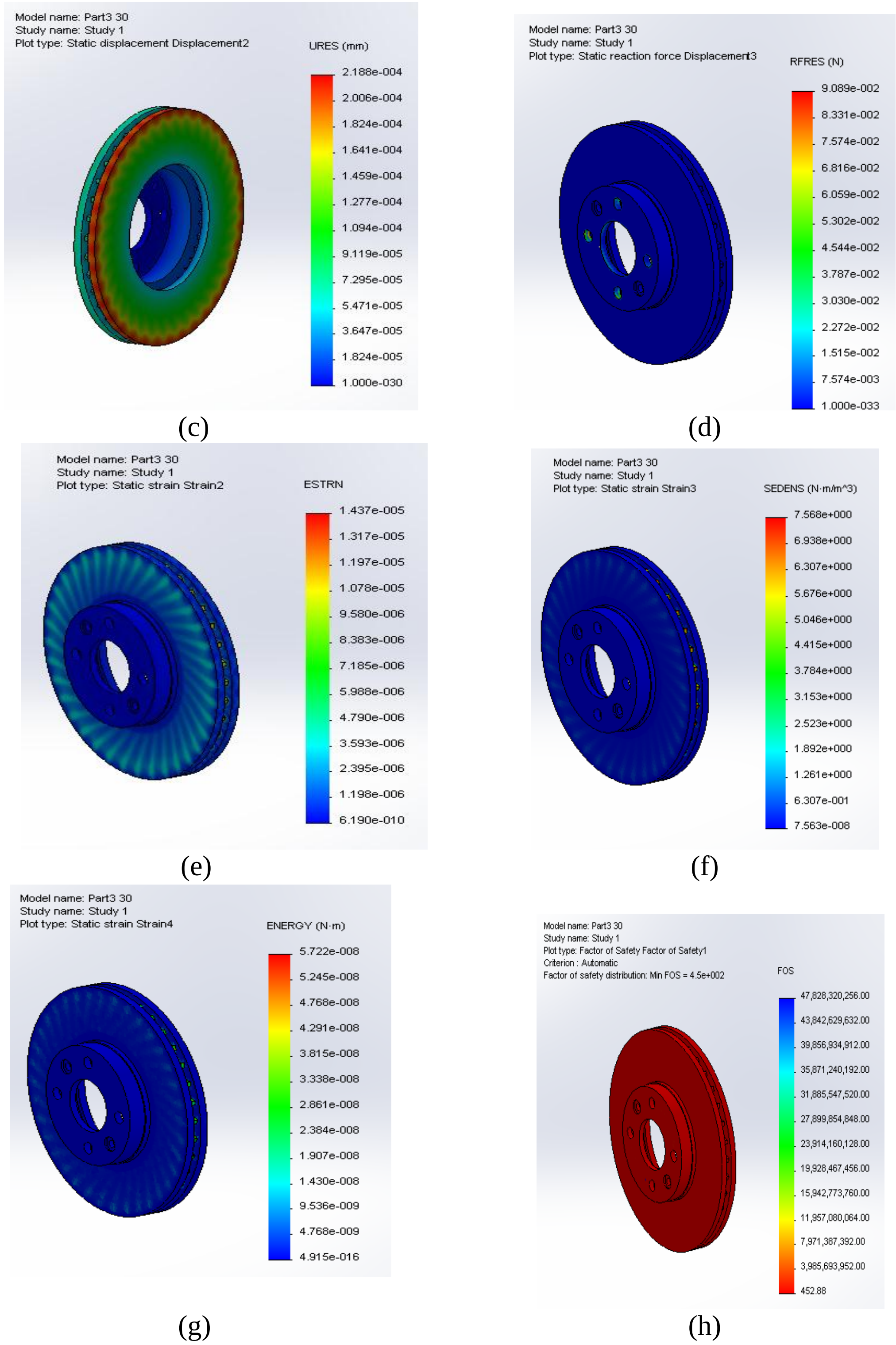


Fig. 8 Model with Fins at 30° Inclination (a). Von Mises (b) Stress Intensity (c) Resultant Displacement (d) Resultant Reaction Force (e) equivalent Strain Energy (f)Strain energy density (g) Total Strain Energy (h) Factor of Safety

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

In this analysis, the behavior of the brake disc in steady state boundary conditions was analyzed. The clamping force from the brake caliper piston was used as the input boundary condition. The resulting output includes von mises stress, displacement, strain and Factor of Safety. The analysis shows that as the fins inclination increases, the fins length decreases and needs to be elongated in order to reach the circumference of R_1 and R_2. The shortening of the fins length as the result of the inclination creates more stress to the brake disc and provides more avenues for displacement and strains on the brake disc, thereby reducing the brake disc FOS and service life. A Literature [2] clearly states that during hard brake application, high compressive stresses are generated at the circumference of the brake disc which creates plastic yielding. This implies that, the R, R_1 and R_2 are important parameters that need critical consideration during vented brake disc design, or else the brake disc will be subjected high stress distribution, thereby leading to brake disc and brake pads damage.

4. CONCLUSION

This steady state structural analysis of the brake disc was performed to analyze the strength of the brake disc at the same braking force and under different fins inclination in the brake disc. The analysis shows that the values of R, R_1, R_2 and the vents inclinations angles are important parameters that needs critical consideration during ventilated brake disc design, because they can influence the performance and servicing life of the brake disc. However, the position and inclination of the fins and vents should be done with caution in order to improve the brake disc heat dissipation.

This paper recommends that the length of the fins or vents should be position along value of R R_1 and R_2 in order to ensure uniform distribution of the clamping force on the brake disc. However, further research work should be carryout to investigate the thermal performance of these three brake disc models. And also another research should be done by elongating the length of these fins to be position along R, $R_1$and R_2.

5. REFERENCE

1. Vivek S. N., Amit D., Nayan D. (2018). Design of Brake Disc for Hydraulic Brakes International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05(01)
2. Sagar B. P. (2017). Design, Analysis And Optimization Of Brake Disc Made Of Composite Material For A Motor Cycle. International Journal of Research Publications in Engineering and Technology [IJRPET] ISSN: 3(3),
3. Alok K. (2018). Design and Analysis of Disc Brake with different drill pattern, drill size, drill angle and varying thickness using Autodesk Inventor Professional. International Journal of Applied Engineering Research. 13(6),. 66-72.
4. Sainath C., Anoop K. (2017). Design, Analysis And Fabrication Of Disc Brake Using Different Pattern Of Holes. International Journal Of Current Engineering And Scientific Research. 4(11),

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

5. Vishlawath R., Pranathi G, (2017). Design and Analysis of Disc Brake. International Journal of Magazine of Engineering. 4 (1),.
6. Manjunath T.V., Suresh P. M. (2013). Structural and Thermal Analysis of Rotor Disc of Disc Brake, International Journal of Innovative Research in Science, Engineering and Technology 2(12),
7. Choi, B. K., Park, J. H., Kim, M. R. (2008). Simulation of the braking condition of vehicle for evaluating thermal performance of disc brake, Proceedings of KSAE Autumn Conference, 2008, 1 265–1 274.
8. Jacobsson, H., (2003). Aspects of disc brake judder, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 217 (6), 419–430.
9. Chetan K., Ganesh K. (2019). Design And Analysis Of Disc Brake. IJRTI1905024 International Journal for Research Trends and Innovation. 4(5),
10. Pevec M., Potrc ., . Bombek G., Vranesevic D. (2012). Prediction of the Cooling Factors of a Vehicle Brake Disc and its Influence on the Results of a Thermal Numerical Simulation. International Journal of Automotive Technology, 13, (5), 725−733.
11. Swapnil R., Abhang, D., Bhaskar P. (2014). Design and Analysis of Disc Brake, 165-167
12. Karthik R. K. M, Qaiser B., Rizwan A. D., Yasir M. R. (2014). Experimental Test Rig for Surface Temperature Measurements in Disc Brakes. 191-195.
13. Borchate S. S., Hanamapure N. S., Swapnil S. K. (2014). Design, Analysis And Performance Optimization Of Disc Brake. 25-27
14. Murali D., Mohan R., Prasad C.L, Ramakrishna T. (2013). Experimental and Simulated Studies on Temperature Distribution for Various Disc Brakes, 34-40
15. Jiguang C., Fei G, (2013). Thermo-Mechanical Simulation of Brake Disc Frictional Character by Moment of Inertial. 227-232
16. Hosseini T. P., Talebi M. (2012). “Stress And Temperature Distribution Study in a Functionally Graded Brake Disc”, International Journal of Automobile Engineering, 172-179
17. Adebisi A. A., Maleque M.A., Rahman M. M. (2011). Metal Matrix Composite Brake Rotor: Historical Development and Product Life Cycle Analysis. 471- 480.
18. Dheeraj V. (2016). Design and thermal Analysis of Disc Brake using Ansys, International Research Journal of Engineering and Technology, 3(11), 872-876
19. Swapnil R., Abhang D. P. (2014). Design and analysis of Disc Brake. International Journal of Engineering Trends and Technology. 8(4): 165–7.
20. Parthasarathy. C (2020). Design and Analysis of Disc Brake rotor using different profiles, International Journal of Engineering Applied Sciences and Technology, 4(9), 286-293
21. Ganesh K. (2019). Design and Analysis of Disc Brake, rotor using different profiles, International Journal for Research Trends and Innovation. 4, (5), 98-101
22. Ganesh K. (2018). Design and Analysis of Disc Brake Rotor of Car, International Journal of Creative Research Thoughts, 5(1), 244-250
23. Manjunath T. V., Suresh P. M. (3013). Structural and Thermal Analysis of Rotor Disc of Disc Brake. International Journal of Innovative Research in Science, Engineering and Technology. 2(12):7741–9.
24. Nikit G., Mohit B., & Basant S. S. (2017). Modelling and Simulation of Brake Disc for Thermal Analysis, Indian Journal of Science and Technology, 10(17), 1-5

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 05, Aug-Sept 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.35.29.43

25. Parosh G. (2017). Design and Structural Analysis of Disc Brake by using Catia and Ansys Workbench, International Research Journal of Engineering and Technology. 4, (9), 70-75
26. Jean G. B., Patric D. N., Ney F. F. (2010). Analysis of the influence of temperature on the friction coefficient of friction. ABCM Symposium Series in Mechatronics. 4:898–906.
27. Vidhya V.S.. (2017). Modelling and Simulation of Automobile Braking System, International Research Journal of Engineering and Technology, 5(4), 7084-7089
28. Seshagiri R., Anand K. (2016). Design and thermal Analysis of Disc Brake using Ansys, International Journal Of Engineering, Education And Technology, 4(4), 1-10
29. Bako S., Borı I., Musa N., Nasır A. (2018). Improvement of Heat Dissipation Rate of An Automobile Brake Drum Using Fins Incorporation. Bartın University International Journal of Natural and Applied Sciences 1(2): 117-127 31
30. Bako S., Usman A,, Paul O. Y., , Mohammed B. N. (2015). Development and Analysis of Finned Brake Drum Model Using Solidworks Simulation International Journal of Innovative Research in Science, Engineering and Technology, 4(5).
31. Bako, S., Dogo, J. N., Umar, M. B., & Bori, I. (2021). Thermal and Computational Fluid Dynamics Analysis of a Modified Two Stroke Spark Ignition Engine Block. GU J Sci, 8(4), 482-493
32. Bako S., Dogo N. J., Umar. M. B., Jesuloluwa S. I (2021). Development And Structural Analysis of A Modified Two Stroke Spark Ignition Engine Block. The 6th Conference (Hybrid) of Nigerian Institution of Mechanical Engineers, Minna Chapter, Niger state, Nigeria (NIMechE-MC 2021) was successfully held on 14th August 2021.
33. Giri, N. K. (2012). Automobile Technology (6th ed). Delhi. Khanna Publisher
34. Belhocinea A., Chob C.D., , Noubyc M.,, Yid Y.B., Bakare A.R. (2014). Thermal Analysis of both Ventilated and full Disc Brake Rotors with Frictional Heat Generation. Applied and Computational Mechanics 8 (2014) 5–24
35. Praharsha G., Shravan A. K., Vinod K. G. (2019). Design and Analysis of Vented Disc Brake Rotor International Journal of Applied Engineering Research. 14(9), 2228-2233 © Research India Publications. http://www.ripublication.com.
36. Igbax S. I., Ogwu E. A., & Atiku L.I. (2016). Caouses of Failure inStprage Facilitiesand their Supports. The International Journal of Engineering and Science (IJES), 5(5). 14. 18,
37. Bako S., Usman T., Ezra P. M., & Igbax S. I., (2019): An Overview of Hydraulic Brake Fluid Contamination. Proceedings of the 15th iSTEAMS Research Nexus Conference, Chrisland University, Abeokuta, Nigeria, 16th – 18th April, 2019. Pp 47-56. Available online at www.isteams.net . DOI Affix - https://doi.org/ 10.22624/AIMS/iSTEAMS-2019/V15N1P5

