iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VI **Month of publication:** June 2022

DOI: https://doi.org/10.22214/ijraset.2022.43959

Modelling and analysis of ventilated disc Brakes using Creo and FEA software

Dr. Swastik Pradhan[4], Santhosh M[1], Palepu Rithvik[2], Katkam Ravi Teja[3]
[1]*Assistant Professor, Department of Mechanical Engineering, Lovely Professional University, Jalandhar-144411, Punjab, India.*
[2, 3, 4]*Undergraduate Student*, Department of Mechanical Engineering, Lovely Professional University, Jalandhar-144411, Punjab, India.

Abstract: An important part of a car's safety system is the brakes. Brakes are easily worn, leading to unpredictable disasters. To avoid this, ventilated disc brakes are used, which helps the brakes to work well in stressful conditions and high temperatures. The materials used play an important role in determining performance. The main objective of this research work is to analyze the current design and conduct a suitable brake rotor analysis to improve its performance. Existing brake disc designs are modeled in Creo and analyzed with software. The material grades used in this study were performed on stainless steel, grey cast iron, structural steel, and titanium alloy brake discs using the same brake disc design to determine the best grade.
Keywords: ventilated disc brake, creo, thermal analysis, static analysis.

I. INTRODUCTION

A brake is a mechanical device that decelerates the car by converting mechanical energy to heat energy via friction. The main objective here is to dissipate the heat produced by the disc to the environment. The size and thickness of the brake plate play a major role in the deceleration of the car. As the piston of the brake caliper applies pressure on the disc, the vehicle comes to halt. The vehicle's brakes are frequently controlled by a pneumatic or hydraulic system. On large and heavy road vehicles, disc brakes are practically universally employed, although massive drum brakes were almost widespread. The goal is to evaluate and analyze the qualities of various types of materials used in existing disc brakes.

II. LITERATURE REVIEW

To endure an elevated degree of heat, any vehicle's slowing mechanism should be solid and dependable. Accordingly, various analysts certainly stand out enough to be noticed in this framework previously.

Deepak et al.**[1]** have studied different shapes of slots in various vehicles. They optimized the number of slots and shapes to enhance strong disc brake rotor thermal conductivity. They have carried out a thermal analysis on the geometrically modified disk brakes too and optimized the number of slots and shapes for the braking system for the Bajaj Pulsar.Dakhil et al. **[2]** Cast iron and stainless-steel materials were used to investigate the performance of disc brake systems. The temperature distribution was analyzed. stress and deformation in the instance of a disc brake utilizing finite element analysis element evaluation.Dhir**[3]** The temperature distribution I during braking was investigated using the finite element approach to determine disc durability. They finished by conducting durability tests using thermo-mechanical cycle loads to investigate the fatigue factor of safety. Phad et al.**[4]** This article looked into a brake calipers design for an ATV that would reduce weight and size without sacrificing strength, solidity, or cylinder drag. Creo 2.0 is being used to create a PC-supported brake calipers configuration model, which is then analyzed in ANSYS Workbench for pressure and misshaping. Vora et al. **[5]** had finished the investigation and the plan of a brake center utilized in an auto vehicle was researched in this paper. Whenever the vehicle is power-driven, the heap is passed from the center onto the rotor. The heap streamlining of the brake center is the principle objective of this paper, and the weight-upgraded segment was analyzed for primary investigation. The brake center feelings of anxiety were viewed as inside sensible cutoff points. Belhocine and Bouchetara **[6]** Using grey cast iron material, researchers investigated temperature and thermal stress disc brakes. ANSYS was used to investigate thermo-structural analysis and von Mises stresses in the disc. Das et al.**[7]** The reason for this paper "Underlying and Thermal Analysis of Disk Brake in Automobiles" was to analyze the temperature and underlying region of the strong plate break with four different materials for short and crisis frequencies. Bhat and Lee **[8]** have looked into improving the heat dissipation of the disc brake system. They employed the Taguchi method to calculate various ventilation characteristics such as rotor hole diameter, slot number, and the number of rotor holes.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

Dhir et al.**[9]** The point of this paper "Thermo-mechanical execution of auto disc brakes" was an increment in the temperature of a vehicle brake during the slowing down process and its effect on the sturdiness of utilizing the limited component investigation. Thilak et al.**[10]** The main goal of this Manuscript is to evaluate the utility of a vehicle's brake rotor during extreme braking situations to improve rotor design and inspection. A study has been performed on the use of novel materials to improve slowing down efficiency and vehicle stability. The product ANSYS was used to accomplish this investigation. The proper composite cross breed material was investigated in this paper, which is lighter than cast iron and has excellent "Youthful modulus, yield, and thickness, Composite Aluminum base metal grid, and Glass Fiber high strength composite" materials. Yevtushenko and Kuciej **[11]** A two-element model of a braking system consisting of a pad sliding with time-dependent velocity were investigated. The temperature and thermal stresses of a ceramic-metal strip were examined. Kubota et al.**[12]** A paper on the development of a lightweight disc brake rotor: a strategy for achieving the optimal temperature, vibration, and weight balance was presented. A parametric report based on a wind stream study through the ventilation openings, as well as a warm pressure research and vibration analysis when slowing down, is presented in this work. Gao and Lin.**[13]** Introduced The transient temperature field of a brake was investigated using a non-axisymmetric three-layered model. A scientific model for assuring contact temperature circulation on the working surface of a brake is described in this study. Garcia-Leon and Florez-Solano **[14]** The dynamics and kinematics of the disc brake system were studied to simulate using FEA. They concluded that by using geometry, they could optimize the system, which would be extremely beneficial to the automotive industry. Gijan **[15]** For heavier vehicles, a parametric assessment was used to research brake disc design. They investigated thermomechanical performance using a simulation approach to extend the bearing's fatigue life. Thom's.et.al**[16]** The disc brakes should retain all of the energy supplied by the motor as well as any additional energy delivered by the vehicle's movement to bring the vehicle to a complete stop. Thinking is currently ridiculous whenever energy is distributed. Contact is used by most vehicle disc brakes to capture energy, turn it to heated distribute it into the surrounding air. Limpert et.al**[17]** A vented and strong rotor performs better thermally at higher rotational velocities, where inward cooling may account for up to half or 60% of overall cooling. Work is still being done to improve the form of the vented rotor. Jungwirth et al. **[18]** Design brake discs and calipers were subjected to a thermo-mechanical coupled analysis. The deformations and fatigue strength of the simulation model were determined using a brake dynamometer. The focus of the research was on the mechanical interactions between the calipers and the brake disc, as well as the impact of heat power distribution on the brake disc. Sethupathi P et al. **[19]** The goal of this examination is to characterize warm execution on disc brake models Thermal execution is a key variable that is concentrated on involving the model in Finite Element Analysis reenactments. Design brake discs and callipers were subjected to a thermo-mechanical coupled analysis. The deformations and fatigue strength of the simulation model were determined using a brake dynamometer. The focus of the research was on the mechanical interactions between the callipers and the brake disc, as well as the impact of heat power distribution on the brake disc. Ameer Fareed and Ch Srinivas.**[20]** Thermal analysis of a race car's disk brake with and without a cross-drilled Rotar This study investigates the disc brake model used in a honda civic. on the disc brake, a combined field investigation (structural+thermal) is carried out. Cast iron is used in the construction. The evaluation is also carried out by altering the disc brake's plan. The true circle brake has no apertures; however, the plan is altered by providing openings in the disc brake to allow for improved heat distribution. Kim **[21]** proposed the investigation technique utilizing FE programming (ANSYS) to anticipate the temperature dissemination and warm deformity of a disc. Grzes **[22]** investigated the maximum temperature of the brake disc after repeated braking. They looked at braking systems utilizing friction and wear heat dynamics equations.

III. COMPONENTS OF DISC BRAKE

A circle brake comprises six unique parts. These parts cooperate to shape a useful to finish the stopping mechanism. These parts incorporate Caliper, Piston, Brake Pads, Rotor, Hub, and Wheel Studs (to associate or join the center with the rotor).

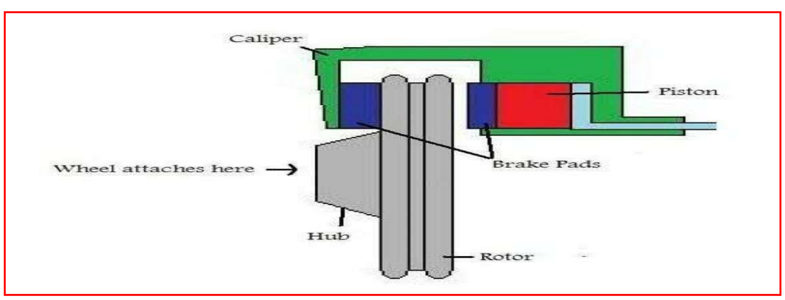


FIGURE:1 DISC BRAKE [24]

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

IV. DIMENSIONS OF DISC.

The disc brakes have the same components as a caliper, rotor, wheel pads, piston, wheel studs, and hub. But we are finding steady-state thermal analysis and static structural analysis of some components. To improve their performance in the system. We have increased the Disc plate thickness to bear the extra load acting on it after the modification.

Table:1 Dimensions of the rotor[23]

width	20.57(mm)
Diameter	325.15(mm)
Vane count	48(No.)
Weight	4.26(kg)
Rotor Bolt Circle	222.25
Rotor mount hole size	6.37
Lug ID	209.57(mm)
Far inside diameter	240.28(mm)

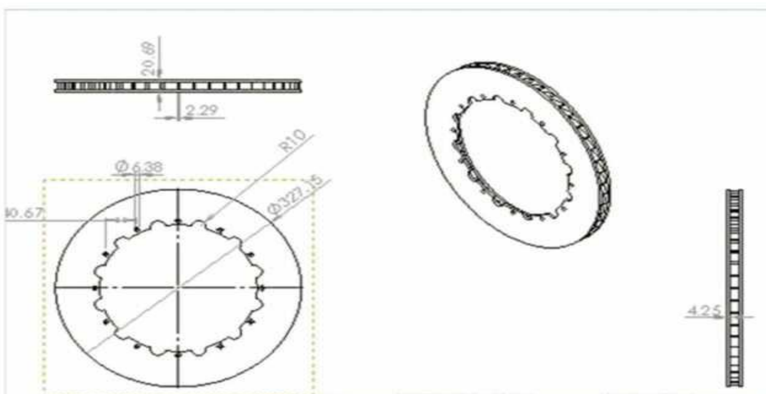


Figure:2 2D Drawing of rotor ventilated disc[23]

A. Material Properties For Disc Brake

Table: 2 Material properties

Material properties	Grey cast Iron	Stainless steel	Structural steel	Titanium alloy	Aluminum alloy	Copper alloy
Thermal conductivity (W m^-1c^1)	52	15.1	60.5	21.9		401
Density, (ρ)	7200	7750	7850	4620	2770	8300
Young's modulus, (pa)	1.1E+11	1.9E+11	2E+11	9.6E+10	7.1E+10	1.1E+11
Poisson's Ratio	0.28	0.31	0.3	0.36	0.33	0.34
Bulk modulus(Mpa)	833330	1.69E+11	1.6667E+11	1.1429E+11	6.9608E+10	1.1458E+11
Shear modulus(Mpa)	42969	7.3664E+11	7.6923E+10	3.529E+10	2.669E+10	4.1045E+10
Tensile yield strength(Mpa)	0	2.07E+08	2.5E+08	9.3E+08	2.8E+08	2.8E+08
Compressive yield strength(Mpa)	0	2.7E+08	2.5E+08	9.3E+08	2.8E+08	2.8E+08
Tensile ultimate strength(Mpa)	240	5.6E+08	4.6E+08	1.07E+09	3.1E+08	4.3E+08
Compressive ultimate strength(Mpa)	820	0	0	0	0	0

V. BOUNDARY CONDITIONS

The following data has been collected to perform analysis, for varies material the vehicle contains mass (m) of 1000kg, maximum velocity (u), and minimum velocity (v) it is considered in 100kh/h and 0km/h. the brake rotor inner diameter is 0.240m, the outer diameter is 0.327m coefficient of friction is 0.4, and the vehicle stops at 34m.the minimum frictional force is calculated using the formulae[23]

F = COEFFICIENT OF FRICTION * MASS* GRAVITY

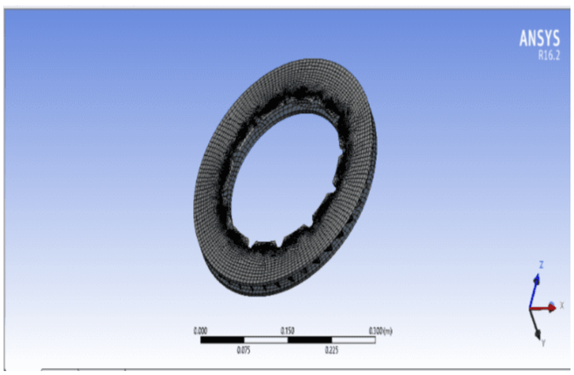
F=4316.4N

The temperature applied on the surface is (300 c)

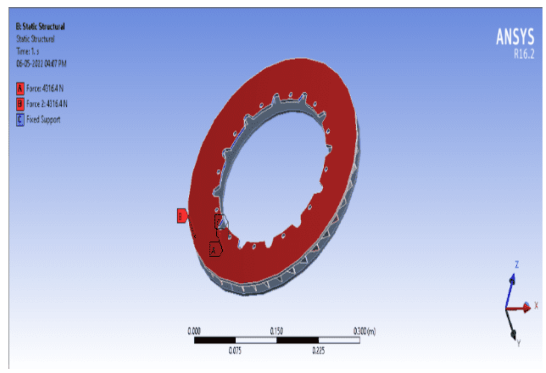
Fine mesh has been taken place to find out the output,

Table: 3 fine mesh

	FINE MESH
NO OF NODES	184503
NO OF ELEMENT	68148



(a)



(b)

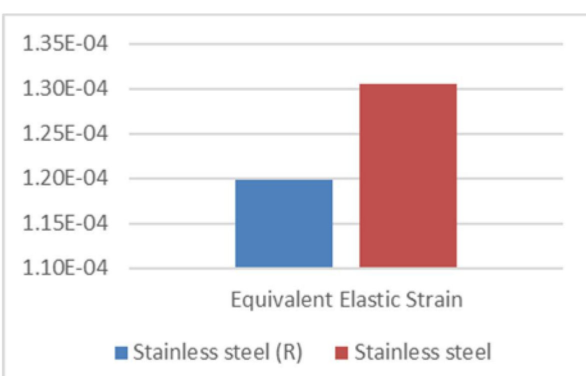
Figure:3 (a)Mesh of a geomentry and (b)Boundary condition

VI. ANALYSIS AND RESULT OF DISC BRAKE

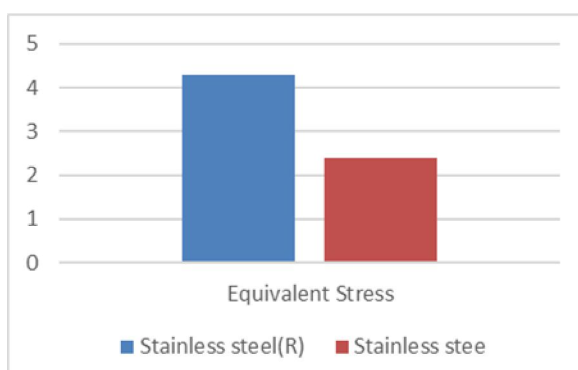
A. *Static Structural Output*

Table: 4 comparison of output response

Parameters	Stainless steel[35]	Stainless steel
Equivalent Elastic Strain	1.1986e-004	1.3052e-004
Equivalent Stress	2.3028e+007	2.4811e+007
Shear stress	6.11018e+006	6.477e+006

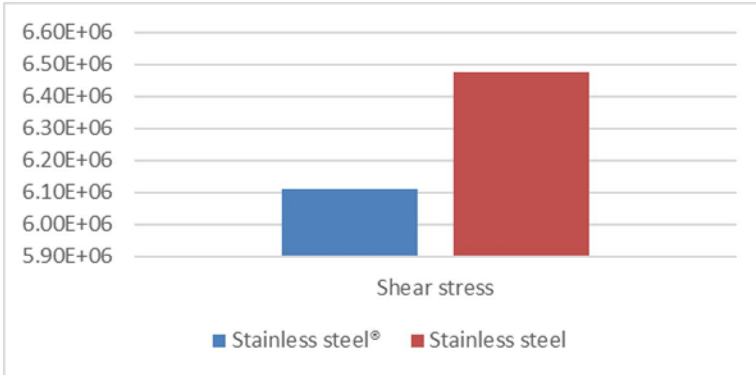


(a)



(b)

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com



(c)

Figure:4 Comparison of results of the stimulated model with reference

1) Error Formula

The percentage of error formula can be identified by the absolute value of the difference between the measured value and the actual value divided by the actual value and multiply by 100.

According to figure (a) actual value 1.1986e-004, expected value 1.3052e-004. As per the formula, the percent error is 9.2%

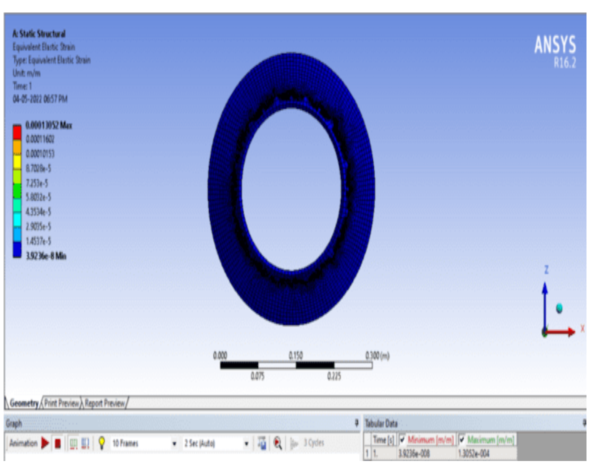
According to figure (b) actual value 2.3028e+007, expected value2.4811e+007 As per the formula, the percent error is 7.7%

According to figure (c) actual value 6.11018e+006 , expected value 6.477e+006. As per the formula, the percent error is 6%

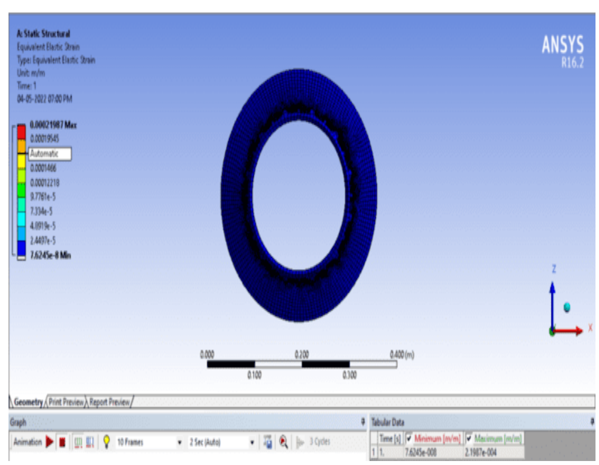
Table:5 Static structural results

Parameters	Stainless steel	Grey cast iron	Structural steel	Titanium alloy	Aluminum alloy	Copper alloy
Equivalent Elastic Strain	1.3052e-004	2.1987e-004	1.2339e-004	2.7353e-004	3.1712e-002	2.5595e-002
Equivalent Stress	2.4811e+007	2.3958e+007	2.411e+007	2.5445e+007	2.2515e+009	2.8155e+009
Shear stress	6.477e+006	6.5067e+006	6.4248+006	6.8125e+006	8.76e+008	1.0888e+009
Total Deformation	2.2285e-006	3.7224e-006	2.0321e-006	4.1377e-006	1.586e-003	1.3019e-003

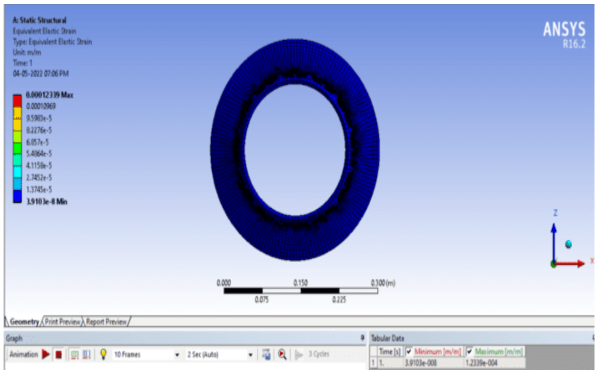
B. Equivalent Elastic Strain



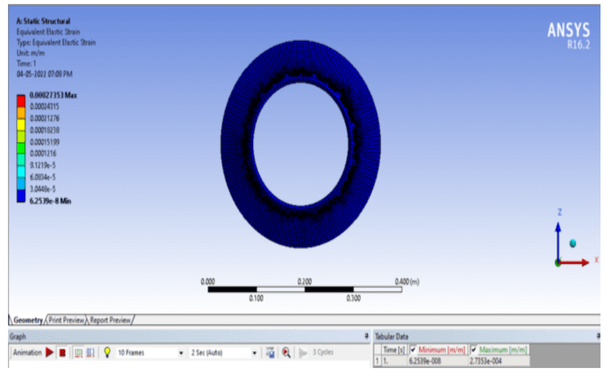
(a)



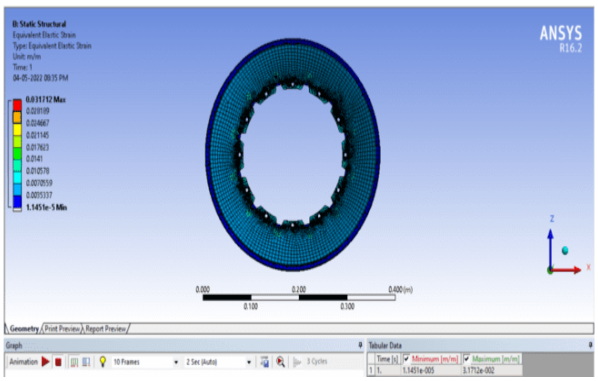
(b)



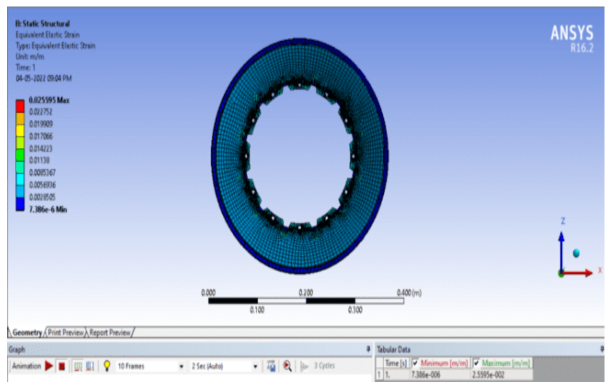
(c)



(d)



(e)



(f)

Figure:5

Equivalent Elastic Strain analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy.

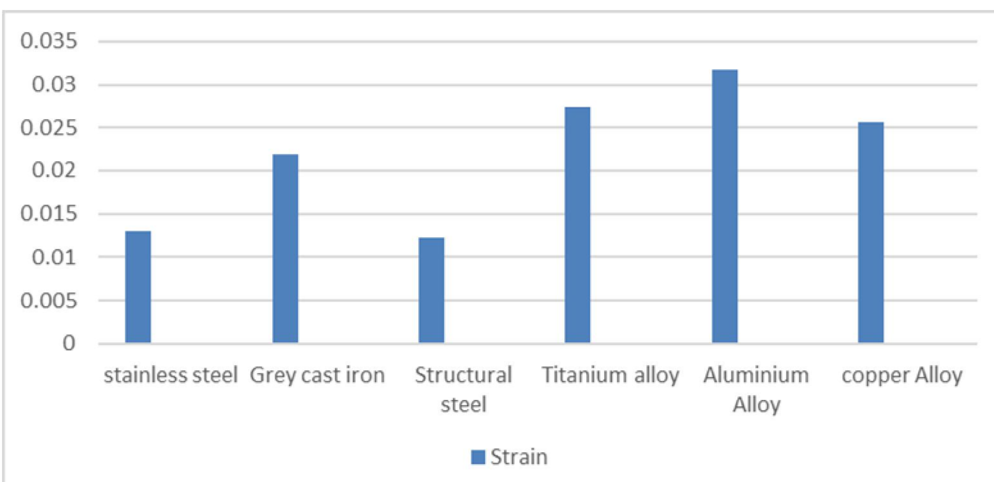


Figure:6

From Figure: 6 it can be seen that aluminum alloy has the highest equivalent elastic strain, after aluminum alloy titanium alloy has the highest strain copper alloy has a similar strain as titanium alloy. after titanium alloy grey cast iron has the highest strain.these value difference take place due the difference in their material properties.

C. Equivalent Stress

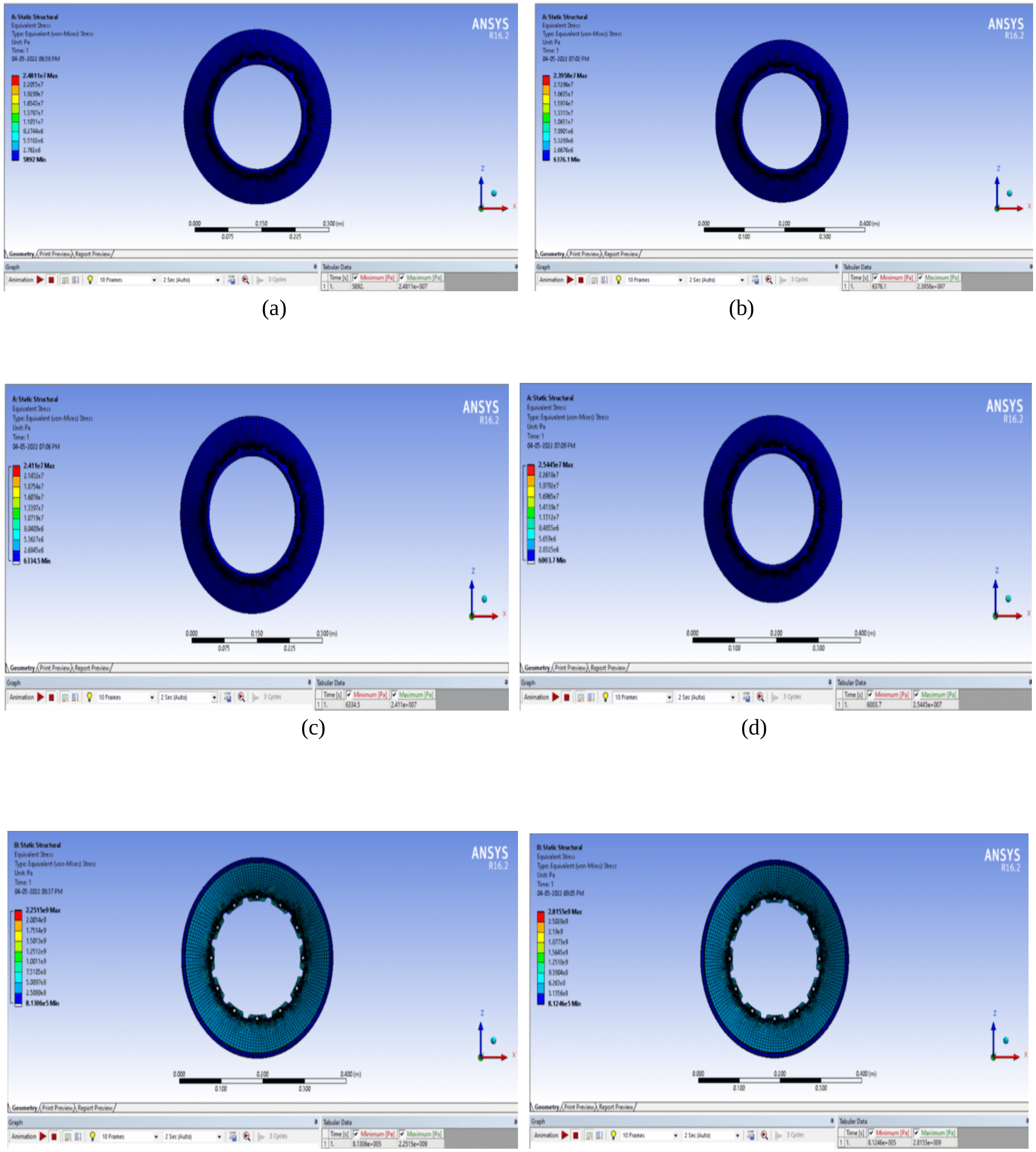


Figure: 7 Equivalent Stress analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminium alloy and (f)copper alloy.

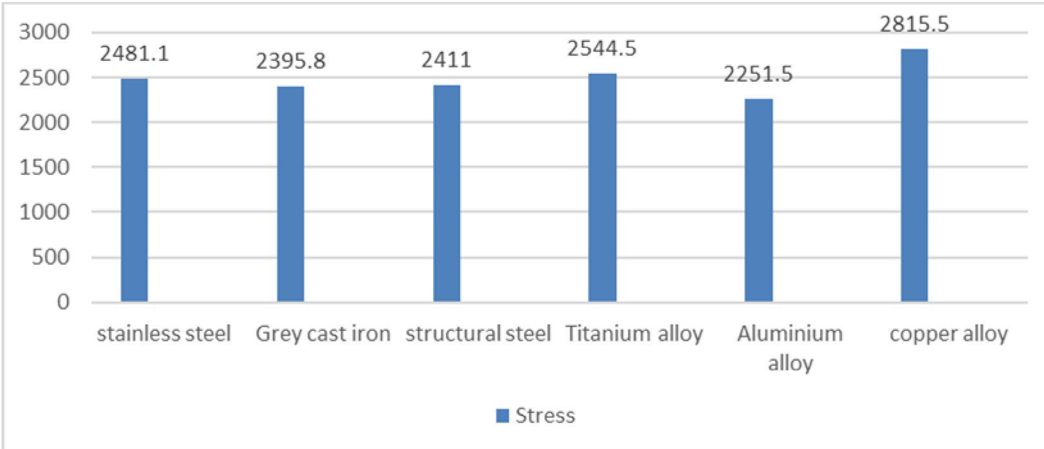
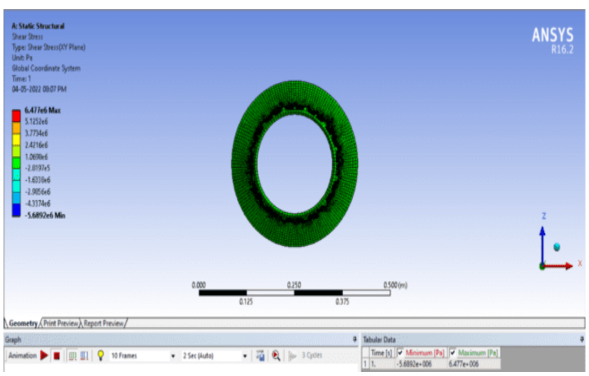


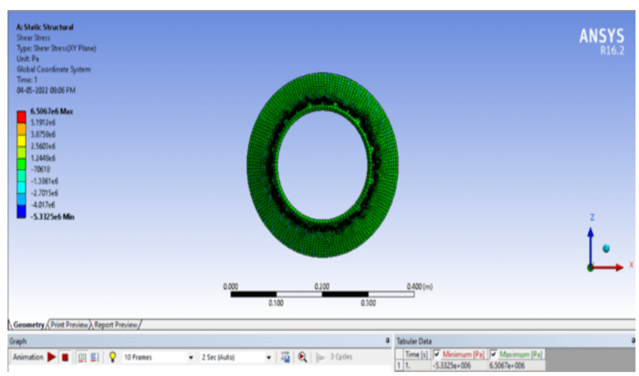
Figure: 8

Shows maximum stress is generated in the copper alloy which is 2815.5 mpa it is shortly followed by titanium alloy with 2544.5 mpa but aluminum has the lowest stress of 2251.5 mpa.

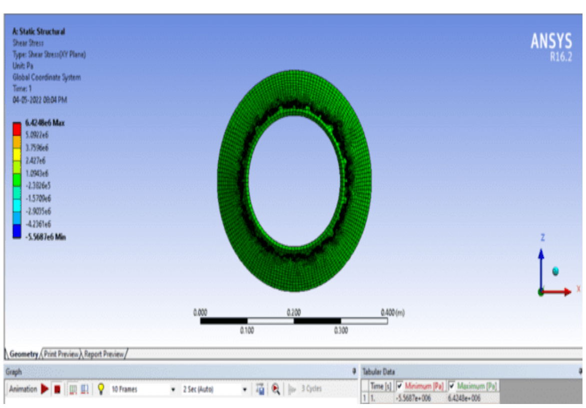
D. Shear Stress



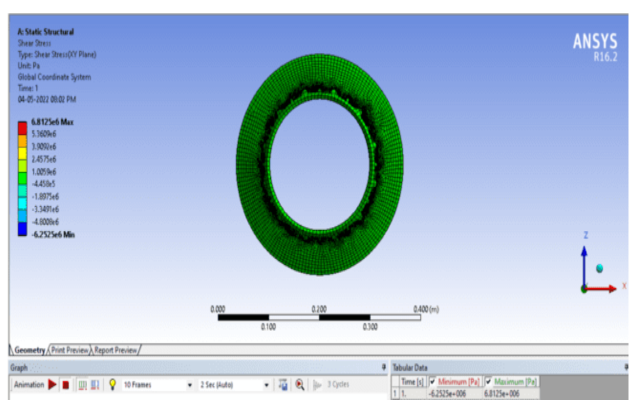
(a)



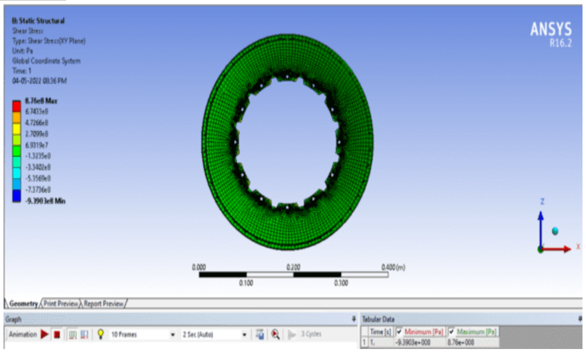
(b)



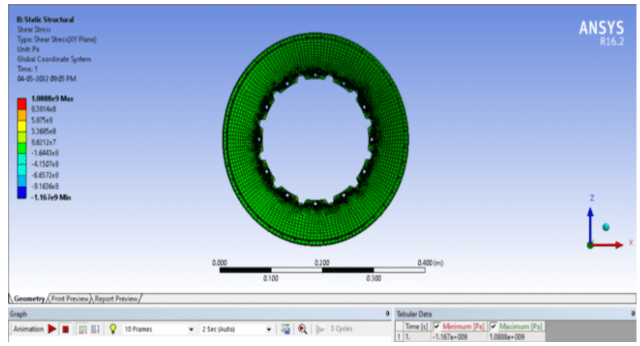
(c)



(d)



(e)



(f)

Figure: 9 Shear Stress analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy.

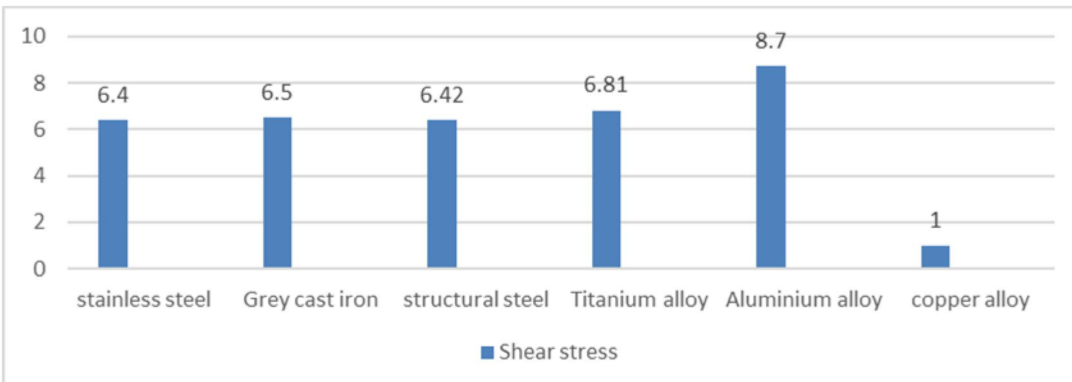
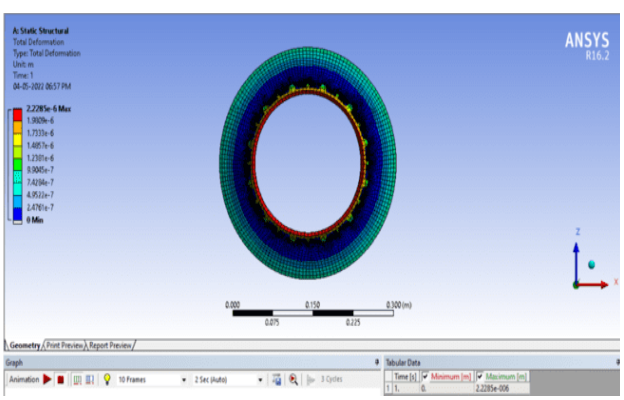


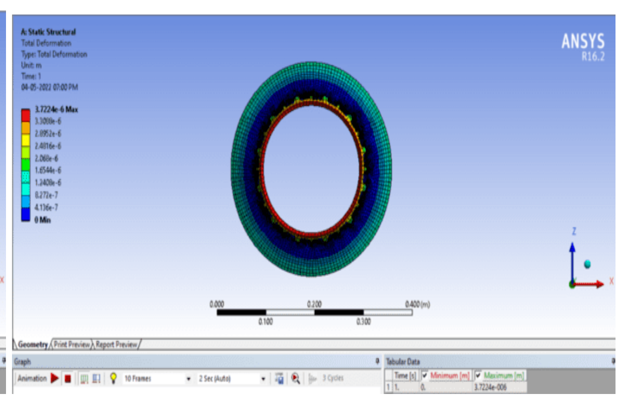
Figure: 10

Srear stress figure shoes aluminum alloy has the highest shear stress of 8.7 mpa then it gradually decreased 6.18 mpa for titanium alloy, structural steel, and stainless steel also follows the same trend of decreasing to 6.4 mpa but copper alloy have the lowest shear stress of 1 mpa. copper has less shear stress value but other material have in range of 6.4 to 6.8 as in average this is due to is variance in material properties.

E. Maximum Deformation

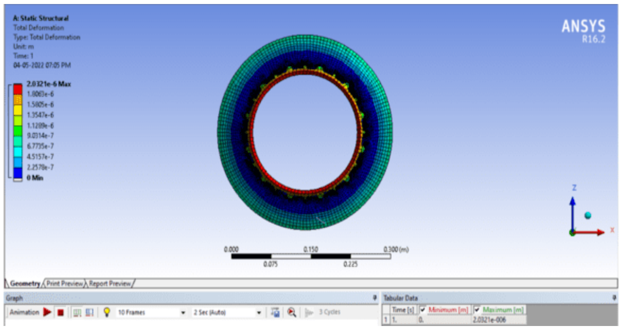


(a)

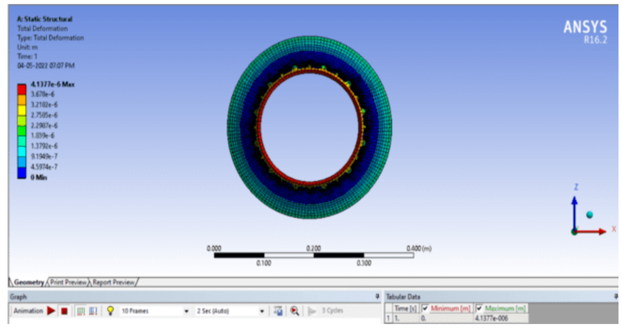


(b)

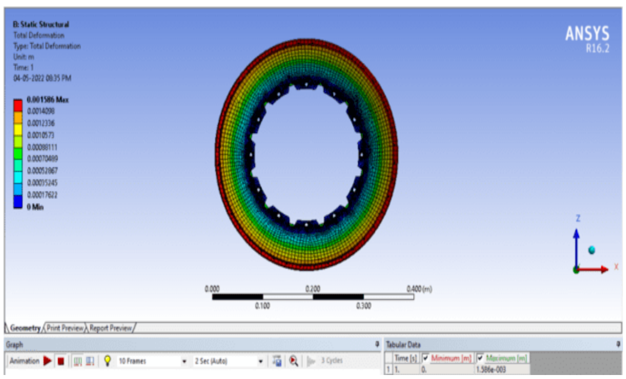
International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com



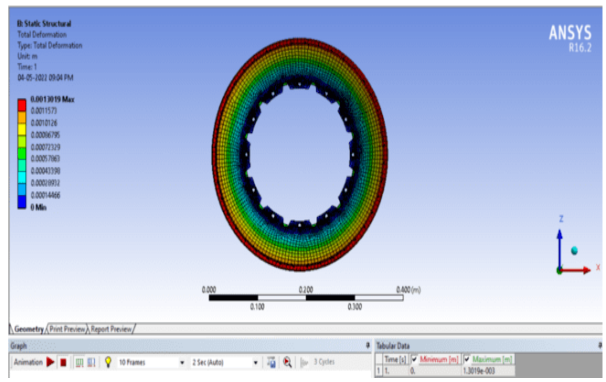
(c)



(d)



(e)



(f)

Figure: 11 Total deformation analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy

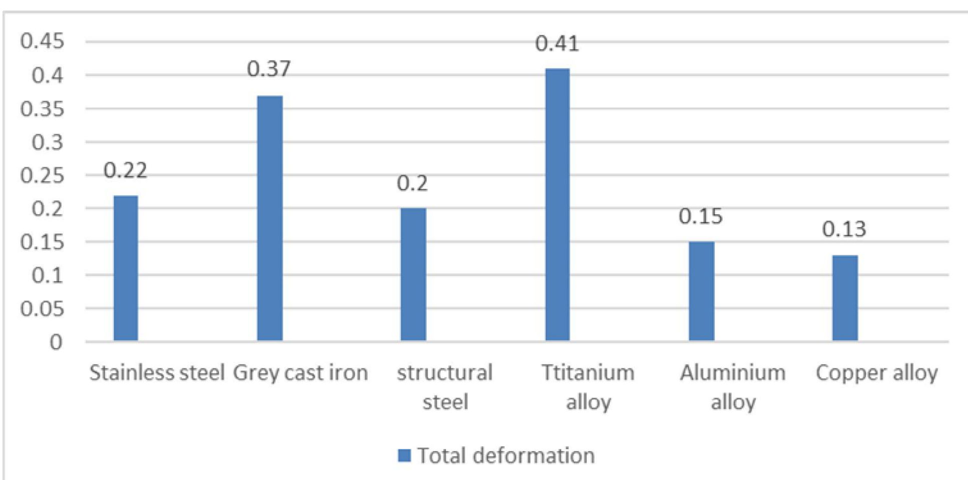


Figure:12

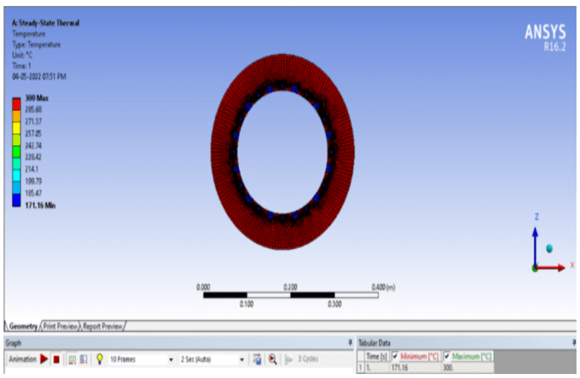
Figure: 12 shows titanium alloy has the maximum deformation of 0.41 mm and copper alloy have the lowest deformation of 0.13mm while aluminum is similar to this grey cast iron has a deformation of 0.37mm.Stainless steel and structural steel have similar deformation of 0.20mm.

F. Thermal Analysis

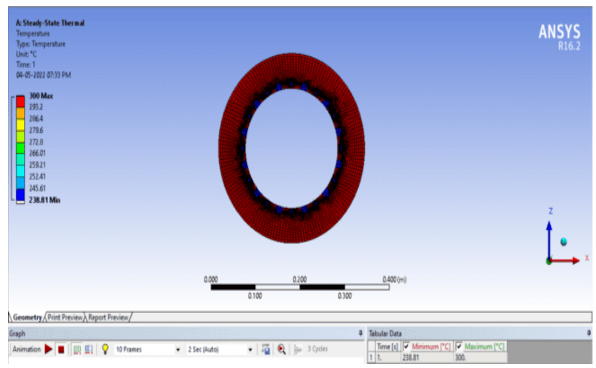
Table:6 Thermal analysis

parameters	stainless steel	grey cast iron	structural steel	titanium alloy	aluminum alloy	copper alloy
Temperature (c)	171.16	238.81	245.15	194.07	276.84	289.14
Total heat flux [w/m^2]	2.852e+005	4.2e+005	4.353e+005	3.2505e+005	5.1687e+005	5.50118e+005

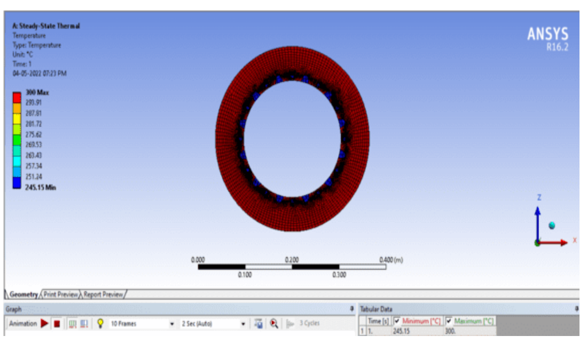
G. Temperature



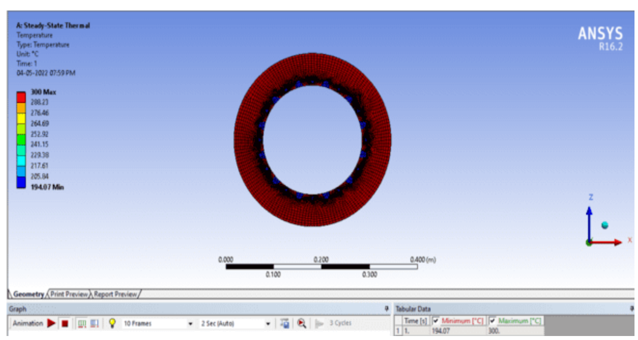
(a)



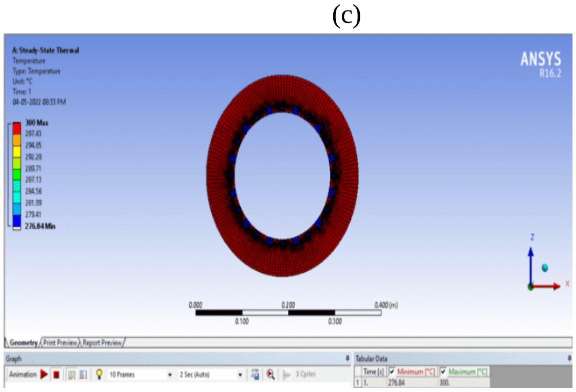
(b)



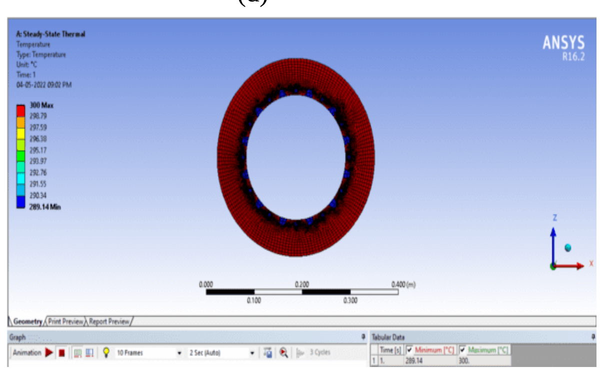
(c)



(d)



(e)



(f)

Temperature analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy

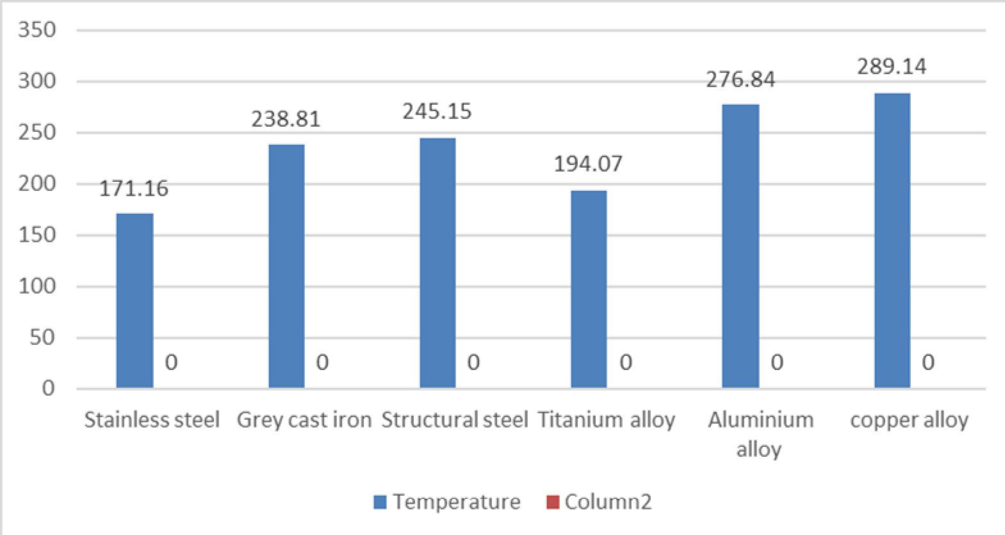
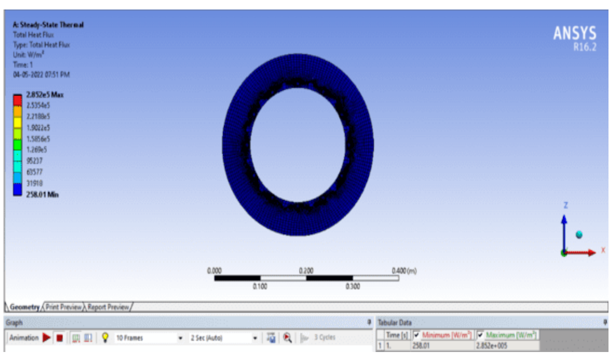


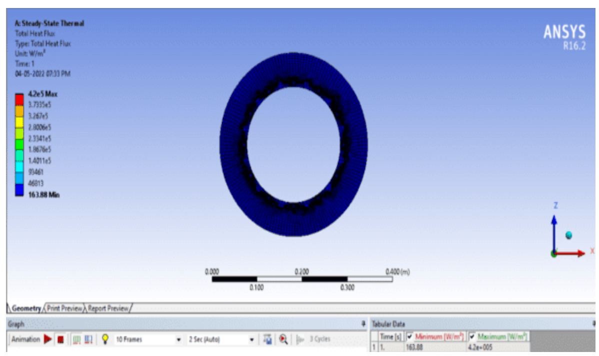
Figure:13
Temperature analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy

From Figure: 13 it can be seen that stainless steel dissipates more heat than all the other materials, stainless steel's final temperature is 171.16. when comparing it to other materials copper has the highest temperature of 289.14 which is followed by aluminum, structural steel, grey cast iron, and titanium

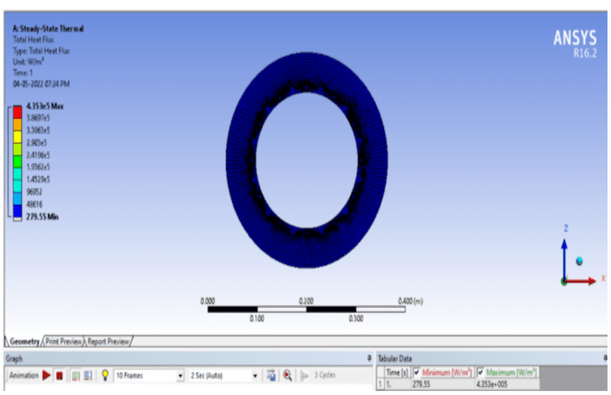
H. Total heat flux



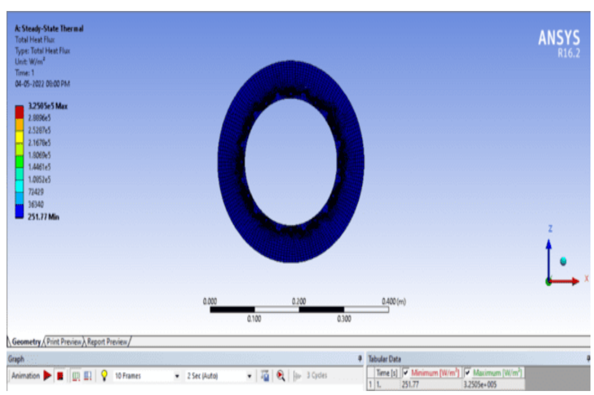
(a)



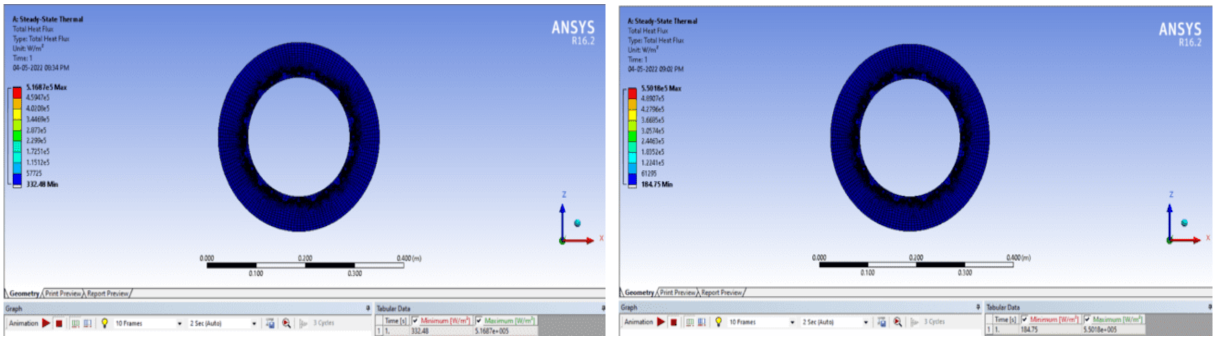
(b)



(c)



(d)



(e) (f)

Figure: 14

Total heat flux analysis for (a)stainless steel (b)grey cast iron (c)structural steel (d)titanium alloy (e)aluminum alloy and (f)copper alloy

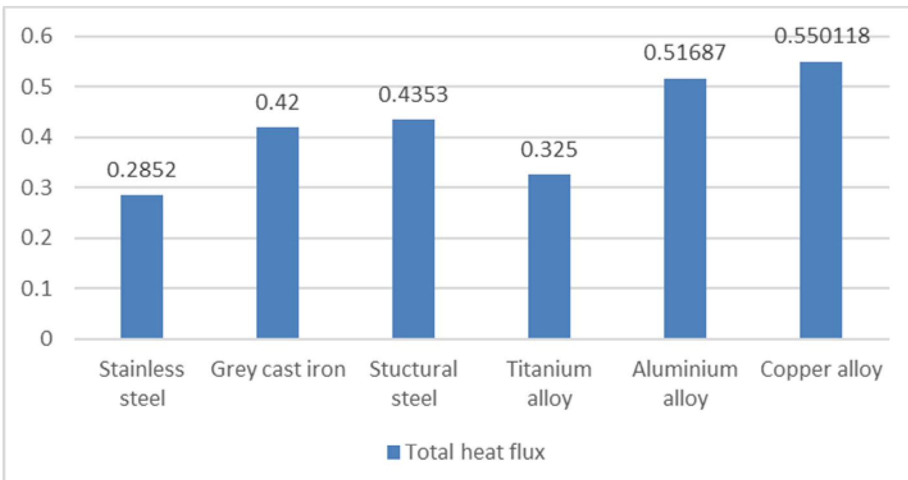
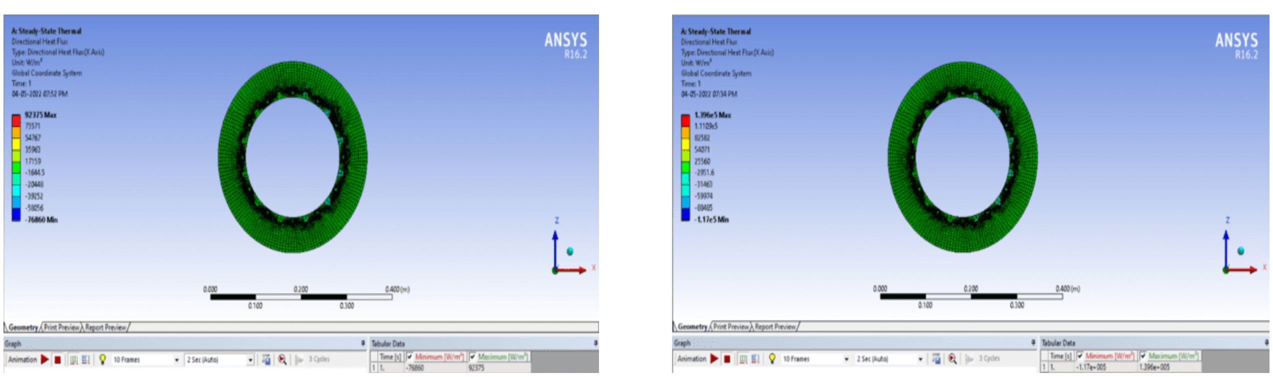


Figure:15

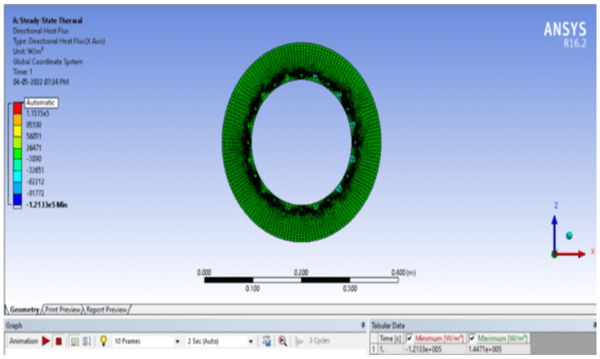
Total heat flux analysis for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy

The figure follows the same path as temperature, copper alloy has the highest heat flux of all while stainless steel has the lowest heat flux titanium has a value similar to it likewise grey cast iron and structural steel have a similar value of around 0.43 same applies to the aluminum and copper alloy and they have around 0.55.

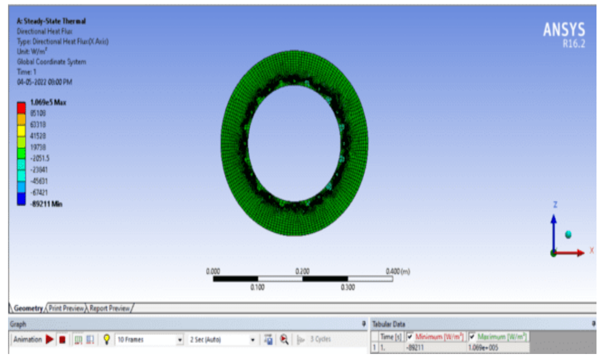
I. Directional Heat Flux



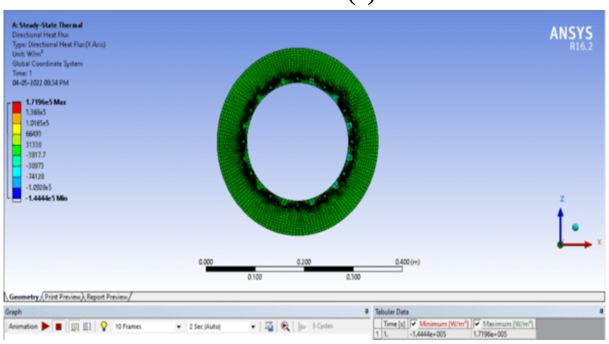
(a) (b)



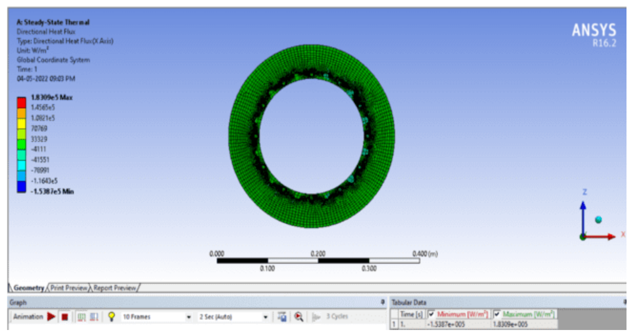
(c)



(d)



(e)



(f)

Figure: 16

Directional heat flux for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy

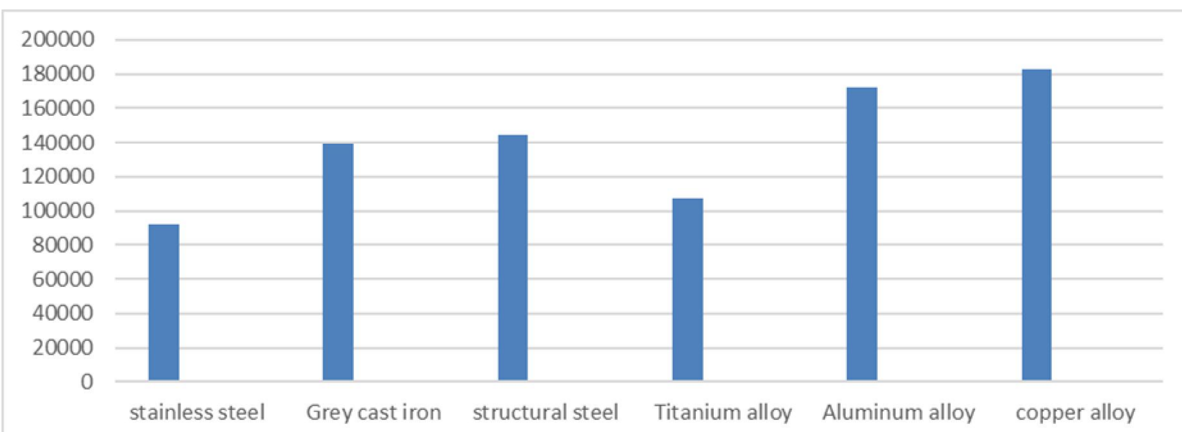


Figure:17

Directional heat flux for (a)stainless steel (b)Grey cast iron (c)structural steel (d)Titanium alloy (e)Aluminum alloy and (f)copper alloy

VII. CONCLUSION

The paper describes the design and analysis of the disc brake. The analysis has been done for various types of materials to find its static structural analysis which consists of strain, stress, shear stress, total deformation, thermal analysis temperatures, and total heat flux. From the above static structural results, we can conclude that structural steel has less strain compared to the remaining materials followed by stainless steel, grey cast iron, titanium, copper, and aluminum alloy. But were in stress aluminum alloy has less stress and then followed by grey cast iron and stainless steel.in shear stress, copper has less value. Even though in different conditions different material holds different values stainless steel and grey cast iron have maintained their average values in every analysis output. but stainless steel has higher corrosion properties.

REFERENCES

[1] D.S. Hugar, U.B. Kadabadi. Design and thermal analysis of disc brake for minimizing temperature. International Research Journal of Engineering and Technology (IRJET). 2017 Vol 4(07), pp: 3483-3487.

[2] M.H. Dakhil, A.K. Rai, P.R. Reddy, A.A.H. Jabbar, Design and structural analysis of disc brake in automobiles, Int. J. Mech. Product. Res. Dev. 4, 95–112 (2014).

[3] D.K. Dhir, Thermo-Mechanical performance of automotive disc brakes, Mater. Today Proc. 1, 1864–1871 (2018)

[4] M.H. Pendkar, P.S. Gaikwad, M.V. Kongari. Thermal analysis of 150 cc pulsar disc brake. International Journal of Application or Innovation in Engineering & Management, vol. 3, pp:63-67.

[5] D.K. Vora, R.K. Patil, V.H. Khatawate. Analysis of brake hub used in automobiles. In Proceedings of International Conference on Intelligent Manufacturing and Automation. 2020. pp. 849-859.

[6] A. Belhocine, M. Bouchetara, Temperature and thermal stresses of vehicles gray cast iron, J. Appl. Res. Technol. 11, 674–682

[7] D.A. Das, R. Christo, V. Raj, S. Preethy, R.G. Bharani. Structural and Thermal Analysis of Disc Brake in Automobiles. International Journal of Latest Trends in Engineering and Technology (IJLTET). Vol 2(3) 2013, pp: 18-25.

[8] R. Bhat, K.S. Lee, Optimization of brake parameters for a disc brake system to improve the heat dissipation using Taguchi method, Int. J. Mech. Eng. Technol. 8, 44–52

[9] D.K. Dhir. Thermo-mechanical performance of automotive disc brakes. Materials Today: Proceedings. 2018. Vol 5(1):1864- 1871.

[10] V. M. Thilak, R. Krishnaraj, M. Sakthivel, K. Kanthavel, M.D. Marudachalam, R.P. Gual. Transient thermal and structural analysis of the rotor disc of disc brake. International Journal of Scientific & Engineering Research. 2011. Vol 2(8), pp:1-4.

[11] A.A. Yevtushenko, M. Kuciej, Temperature and thermal stresses in a pad/disc during braking, Appl. Therm. Eng. 30, 354–373

[12] Masahiro Kubota., 2000. “Development of lightweight brake disc rotor: A design approach for achieving an optimum thermal, vibration and weight balance.” JASE review 21 (2000) 349-355

[13] Brakes and Dynamometer”-Theory of Machines by R.S. Khurmi & J.K. Gupta-732.

[14] R.A. Garcia-Leon, E. Florez-solana, Dynamic analysis of three autoventilated disc brakes, Ingenieria e investigacion 37, 102–114

[15] G.L. Gigan, Improvement in the brake disc design for heavy vehicles using parametric evaluation, Proc. Inst. Mech. Eng.

[16] Deichmann, T., & Lathwesen, H. (2012). Sheet cast disc-brake disc innovation through functional integration. Proceedings of the Eurobrake, 16-18.

[17] Koetniyon, S. (2000). Thermal stress analysis of automotive disc brakes

[18] Jungwirth, F. Dornheim, A. and Friedrich. C., “Coupled thermo-mechanical computation method for a virtual design processes of brake discs”, Proc. 11th World Congress on Computational Mechanics (WCCM XI), (2014), pp.1-10.

[19] Baskara Sethupathi P., Muthuvel A.,*, Prakash N., Stanly Wilson Louis Numerical Analysis of a Rotor Disc for Optimization of the Disc Materials, Journal of Mechanical Engineering and Automation 2015, 5(3B): 5-14 DOI: 10.5923/c.jmea.201502.02

[20] Ameer Fareed Basha Shaik, ch.lakshmi srinivas,structural and thermal analysis of disc brake with and without crossdrilled rotar of race car,international Journal of Advanced Engineering Research and Studies

[21] S. M. Kim, A study on thermal analysis in ventilated brake by FEM, Journal of the Korean Society of Machine ToolEngineers, 18 (5) (2009) 544-549

[22] P. Grzes, Maximum temperature of the disc during repeated braking applications, Adv. Mech. Eng.

[23] Anil Babu Seelam, Nabil Ahmed Zakir Hussain, Sachidanandha Hassan Krishanmurthy and design and analysis of disc brake system in high speed vehicles, Int. J. Simul. Multidisci. Des. Optim. 12 19 (2021)

[24] Mithlesh, S. & Tantray, Zubair & Bansal, Mohit & Kumar, Kotte & Kurakula, Varun & Singh, Manpreet. (2021). Improvement in performance of vented disc brake by geometrical modification of rotor. Materials Today: Proceedings. 47. 10.1016/j.matpr.2021.05.006.