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MODELLING AND STRUCTURAL ANALYSIS OF DISC ROTOR USING VARIOUS MATERIALS

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ABSTRACT

Brakes are one of the most significant safety systems in an automobile. In the braking process, the rotor will be exposed to large stresses which result in surface cracking, overheating of brake fluid, seals and other components. Therefore one of the main tasks of the braking system is to reduce the surface temperature of the brake rotor. Failure of brakes especially in two-wheelers has been one of the major causes for many accidents. The forced stresses acting on the disc rotor due to forced braking damages the disc and eventually it breaks. This shows that no proper material and design has been chosen while analyzing the disc at different conditions. The study describes the various designs like Normal disc rotor and slotted disc with holes brake rotor. The main objective of this project is to propose a new automotive brake disc rotor design for BAJAJ PULSAR 150 which will reduce the total deformation and increase the maximum heat dissipation. Ventilated disc (Existing design) and Slotted with normal holes (Proposed design) is designed using SOLIDWORKS software. The static structural analysis and thermal analysis of brake disc rotor is done using ANSYS 18.0 using various materials Grey cast iron, ALSIC, Ti6AL4V, AISI 6150, EN8, which is a dedicated finite element package used for determining the von - misses stresses, shear stress, strain, deformation, total heat flux. Across the disc brake profile. The best of the designed and material of brake disc rotor is to be suggested based on the magnitude of von - misses stresses, shear stress, strain deformation, total heat flux.

I. INTRODUCTION OF DISC BRAKES

A brake is a mechanical device that uses frictional resistance to retard a motion by absorbing kinetic energy from and convert it into heat energy. The disc brake is a type of braking system that uses a disc rotor is connected to the axle of wheel and a set of friction material called as brake pads (mounted on a component called brake caliper) is forced usually by hydraulic pressure against both sides of disc which causes it to stop with the help of friction.

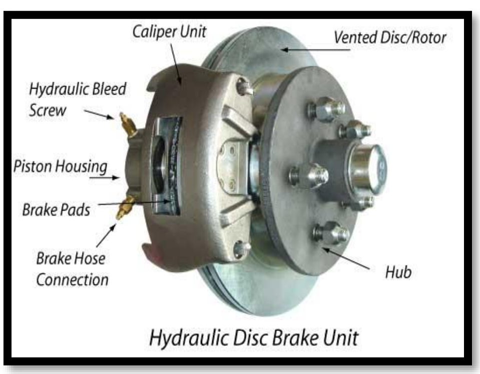

Figure 1 hydraulic disc brakes

A proper braking system should have following properties:

• The stopping distance of the vehicle should be minimum.

• All the wheels should be locked at the time of hard braking.

• The system must be leak proof.

• Braking properties must not fade with constant prolonged application.

• The weight of system should be low

COMPONENTS OF DISC BRAKE SYSTEM:

- Caliper Bracket
- Slider Pins
- Dust boots/ Rubber Bellows
- Inner brake pads
- Outer Brake Pad
- Caliper Frame
- Piston
- Wheel

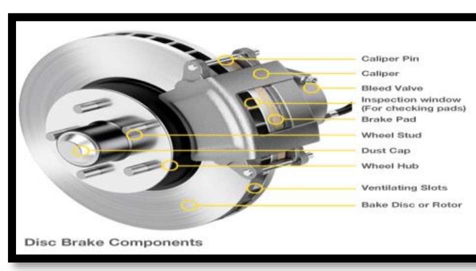

Figure 2disc brake components

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II. LITERATURE REVIEW

T. D. GILLESPIE a book of Fundamentals of Vehicle Dynamics an overall guide to design a automobile used for the better understanding of braking system, its performance improvements and for braking calculation. It covers from the very basic coordinating system, acceleration performance system, braking performance, road loads, ride, suspension, tires.

R. LIMPERT,A book of Brake Design and Safety purely guide of brake fundamentals, braking systems, automatic brake control, analysis design and analysis of friction brakes helps us to revise our concepts and correct our mistakes. Calculation of braking system was done on the basis of the book.

BAJA SAEINDIA RULEBOOK 2018,as it mentioned a disc rotor developed fully from the zero bases using the product development steps, disc was tested as a part of BAJA ATV- All terrain vehicle braking system under critical limits and achieved the target constraints. Rulebook, a set of every minute data being used to design the whole vehicle and guides thoroughly.

S. R. ABHANG AND D. P. BHASKAR,Associate Professor Department of Mechanical Engineering, SRES College of Engineering, Pune University, Kopargaon, India, discusses the problems occurs in brake system during braking like Squealing, scarring, excessive rusting, cracking. It helps us to give a whole of braking calculation with the proper assembly of braking system and assumed data makes a calculation of forces generated torque at pads, net heat flux and other parameters. Use of ANSYS was also done to mesh the disc and thermal analysis was performed to get the real time view of disc under circumstances.

Y.H. MISHRA, V. R. DEULGAONKAR AND P. A. MAKASRE WORKS AT JCOE KURAN, starts with a overview how technology changing the world today and brief about disc brake rotor system assembly and describes about material selection for disc brake rotor among comparison of steel, aluminums and its alloy like magnesium, titanium. It helps us to choose us the best suitable material under current scenario considering our object of work. An assumed data was used to calculate working force, stress, and torque generated, break distance and its calculation. Use of wide ranging calculation was done to understand the braking phenomenon and for comparison.

A. MALEQUE, S. DYUTI AND M. M. RAHMANfrom Department of Manufacturing and Materials Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia has a wide research on material selection through exhaustive method and comparative analysis starts with steps of material selection chooses six materials into consideration and provides using Digital Logic Method (DLM) assigns numbers using product-process matrix.

P. KLLUNGCHANG, P. DESHATTIWAR, K. MENJO, RUIKAR, S. KUMAR, R. K. SHRIVASTAVA from department of mechanical engineering presents a thermal analysis of brake disc comparatively same work as ours. Design aspects used for braking calculation and also to better understand finite element analysis and ANSYS. It describes about material selection, FEA limitations and advantages and thermal analysis of brake disc through iterations.

J. RAKESH, A. RAJ, K. ANUSH, D. DEBAYAN, J. PAWAN, R. SAURAV from Department of Mechanical Engineering, NIT Durgapur presents Structural and Thermal Analysis of Disc Brake using Solid works with a objective of calculating values of shear stress, total deformation, convective heat transfer coefficient and temperature distribution on disc brake. It presents structural and thermal analysis of disc brake rotor using FEA, CAD and ANSYS and shows the variation of time with respect of time. A proper calculation has been done using available data.

PALMER, EDWARD, MISHRA, RAKESH AND FIELD HOUSEFROM UNIVERSITY OF HUDDERSFIELD, presents a computational fluid dynamic analysis on the effect of front row pin geometry on the aero-thermodynamic properties of a pin-vented brake disc This work has very clearly demonstrated that the mass distribution of the disc affects heat transfer through the brake disc considerably. From the discussion it is clear that, as hypothesized in previous work the first row of pins has the most significant effect on the flow field through the disc (as shown by the change in static pressure through the rotor) and hence the mass flow rate and the heat transfer rate from the disc. The second row has the next-largest effect and the third row only a small effect on the thermo-aerodynamic performance of the disc.

S. SARKAR, P. RATHOD, A. J. MODIfrom different institutes internationally presents a Research Paper on modeling and Simulation of Disc Brake to Analyze Temperature Distribution using FEA. It tests the brake discs at different speeds and gives conclusion through different graphs and curves. Disc has its standard dimensions.

GAO AND LIN (2002)presented Transient temperature field analysis of a brake in a non-ax symmetric three-dimensional model. The disk-pad brake used in an automobile is divided into two parts: the disk, geometrically ax symmetric; and the pad, of which the geometry is three-dimensional. Using a two-dimensional model for thermal analysis implies that the contact conditions and frictional heat flux transfer are independent of y. This may lead to false thermal elastic distortions and unrealistic contact conditions. An analytical model is presented in this paper for the determination of the contact temperature distribution on the working surface of a brake. To consider the effects of the moving heat source (the pad) with relative sliding speed variation, a transient finite element technique is used to characterize the temperature fields of the solid rotor with appropriate thermal boundary conditions. Numerical results shows that the operating characteristics of the brake exert an essentially influence on the surface temperature distribution and the maximal contact temperature.

VOLLER, ET AL.(2003)perform an Analysis of automotive disc brake cooling characteristics . The aim of this investigation was to study automotive disc brake cooling characteristics experimentally using a specially developed spin rig and Singh and Sherrill 85 numerically using finite element (FE) and computational fluid dynamics (CFD) methods. All three modes of heat transfer (conduction, convection and radiation) have been analyzed along with the design features of the brake assembly and their interfaces. The influence of brake cooling parameters on the disc temperature has been investigated by FE modeling of a long drag brake application. The thermal power dissipated during the drag brake application has been analyzed to reveal the contribution of each mode of heat transfer.

OVER VIEW OF THE PROJECT

1. Have sufficient mechanical strength and stiffness of Rotor disc.

2. Can effectively block the heat reached the rotor disc.

3. Select High temperature corrosion resistance Material and design

4. Dimensions as compact as possible, in order to reduce the weight of the piston.

5. Perform the static and thermal analysis of rotor disc.

6. Study the stress distribution, strain, deformation, shear stress, Total heat flux.

OBJECTIVE OF THE PROJECT:

As a step toward gaining a better understanding of the construction of the DISC ROTOR. This study was designed to analyze the structural and thermal analysis of disc rotor for different designs and different materials. The study investigates the best suitable material for the material and design construction by examining the stress, deformation, strain, shear stress, Total heat flux developed due to loading conditions

- To Model the 2 Existing and proposed design of disc rotor using SOLIDWORKS software and analysis using the ANSYS 18.
- Create the Normal disc and slotted with holes disc.
- To perform structural analysis for examining the stresses, deflections, shear stress, strain and Thermal analysis under specified load conditions.
- To reduce the weight of the structure using optimization process using with different design and materials.
- Finally concluded the suitable materials of the disc rotor in these materials **Grey cast iron, ALSIC, Ti6AL4V, AISI 6150, EN8**

III. METHODOLOGY

The aim is to compare the structural and thermal properties of rotor disc during braking, of standard motorcycle "BAJAJ PULSAR 150" with a

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nonstandard rotor disc and to find out the difference in structural and thermal properties.

The analysis of disc rotor will be observing the different materials. The disc rotor by applying a force during the apply braking force under structural analysis in ANSYS 18. Then the total deformation, Vonmisses stress, shear stress and strain, Total heat flux were calculated for different alloys after applying the boundary conditions.

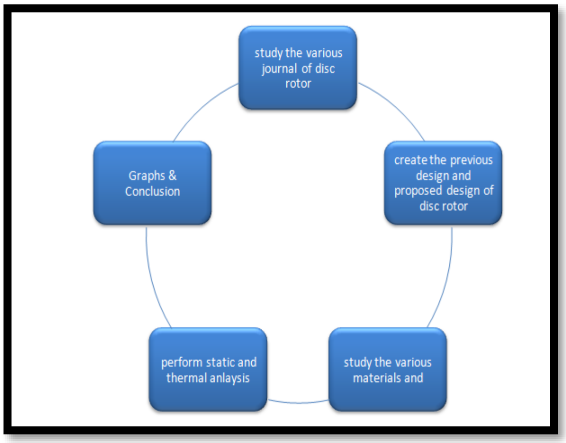

Figure 3 methodology

INITIAL CONDITIONS AND ASSUMPTIONS

To make the calculation perfect the initial condition are taken from dealer site and the relevant assumptions are made as follows

- The total weight of the vehicle is assumed to be 300 Kg.
- The vehicle is assumed to travel at a maximum speed of 100kmph, i.e. = 27.77m/s
- The axial weight distribution is taken as 0.5
- The coefficient of friction is assumed to be 0.5
- The effective radius is taken as, R eff = 0.12 m
- The Kinetic energy to absorbed is taken as 0.9
- The standard hydraulic pressure is taken as 1 Mpa
- The coefficient of friction is same for brake pad and rotor, i.e., $\mu I = \mu O$.
- The ambient temperature is taken as 23 °c
- The vehicle is said to stop using 1 brake caliper, i.e., the stopping distance is taken as 50 m
- The brake pad's total coverage angle is measured to be 42.5°
- The vehicle has varying leverage and actuation based on driving condition so, a FOS of 2.5 is taken into consideration for single stop surface temperature rise.
- The tangential clamping force between the brake pad and rotor on inside is equal to outside, i.e., FTRI = FTRO, FRI = FRO

CALCULATION

Structural calculations Brk pad cont area,

$A = (\pi(r1)^2 - \pi(r2)^2) * \theta/360$

$= (\pi (120)^2 - \pi (95)^2) * 42.5/360$

$= 1993.49 \approx 2000\ mm^2 = 0.002\ m^2$

Norm force on inn side, FRI = ((P max/ 2) x A)

$= ((1 * 10^6)/2 * 0.002)$

$= ((1000000)/2 * 0.002)$

$= (500000 * 0.002)$

= 1000 N

Tang react force on inn side, FTRI

$= \mu I \times FRI = (0.5 * 1000)$

= 500N

Tang react force on outside, FTRO = $\mu O \times FRO$

$= (0.5 * 1000)$

= 500N

Tang clamping force, FT = FTRI + FTRO = 500 + 500 = 1000 N

Brake torque, TB = FT * Reff = 1000* 0.12 = 120 N-m

Thermal calculations

Braking time, d = (u + v) /2 * t

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50 = (0+27.77)/2 * t

13.885 t = 50

t = 3.6 s

Kinetic energy,

K.E = γ k * (m (u-v)^2) / 2

= (0.5) (0.9) * ((300)(0-27.77)^2) /2

= (0.5) (0.9)*(115675.5)

= 52053.98 J

Braking power, Pb = K.E / t

= 52053.98 / 3.6

= 14459.44 W

Max. Contact area, A1 = π(r1)^2

= π * (120)^2

= 45238.93 mm^2

Min. contact area, A2 = π(r2)^2

= π * (95)^2

= 28352.87 mm^2

Net disc contact area, A = A1- A2

= 45238.93 - 28352.87

= 16886.06 mm^2

= 0.01688 m^2

Heat flux,

q = Pb/A = 14459.44 / 0.01688

= 856601.89 W/m^2

Max temperature, $Tmax = \frac{0.527 * q * \sqrt{t}}{\sqrt{(\rho * c * k)}} + Tamb$

$$= \frac{0.527 * 856601.89 * \sqrt{3.6}}{\sqrt{(6600 * 460 * 50)}} + 296$$

$$= \frac{0.527 * 856601.89 * 1.897}{\sqrt{151800000}} + 296$$

$$= \frac{856361.18}{12320.71} + 296$$

$$= 69.505 + 296 = 365.505\ K$$

$$= 92.505\ ^\circ c \approx 93\ ^\circ c$$

Considering, FOS = 2.5

= 2.5 * 93

= 232.5 ≈ 250 °c T max = 250°c

MATERIAL PROPERTIES

MATERIAL PROPERTIES	Density(g/cm3)	Possions ratio(μ)	Young's modulus (Mpa)	Tensile strength (Mpa)	Thermal conductivity (W/M-K)	Specific heat j/kg-k
GREY CAST IRON	6.9	0.25	105	250	40	265
ALSIC	2.7	0.29	195	220	150	740
AISI 6150	6.11	0.29	190	1100	46	470
TI64ALV	4.429	0.31	110	862	7.1	553
EN 8	7.85	0.28	210	620	51.9	510

SPECIFICATIONS OF THE DISC BRAKE ROTOR

The Disc Brake details are as follows:

Outer Diameter: 240 mm

Inner Diameter: 175 mm

Thickness: 5 mm Mean

Contact Radius: 107.5 mm

HoleDiameter: 7 mm

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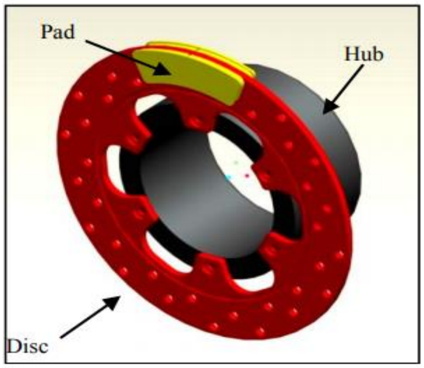

Figure 4specifications of the disc brake rotor

DESIGN PROCEDURE OF DISC ROTOR IN SOLIDWORKS WORKBENCH:

Go to the sketch create the outer circle diameter as per the dimensions 240mm and 175mm after create the inner circle now create the circle bolt holes apply circular pattern after go to the part design work bench apply pad 4mm now go to the sketcher work bench create the small holes as per the dimensions as shown below figures

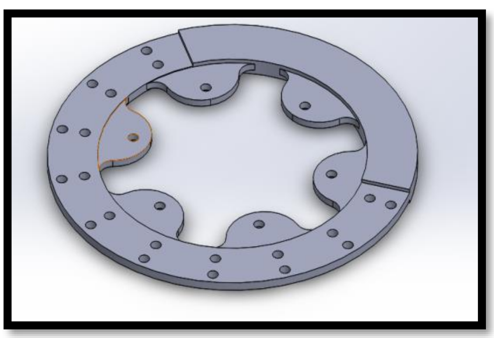

Figure 5 final view of existing disc rotor

PROPOSED DESIGN OF DISC ROTOR IN SOLIDWORKS WORK BENCH:

Go to the sketcher workbench create the outer circle diameter as per the dimensions 240mm after create the inner circle now create the circle bolt holes apply circular pattern after go to the part design work bench apply pad 4mm now go to the sketcher work bench create the slotted holes as per the dimensions again apply pocket as shown below figures.

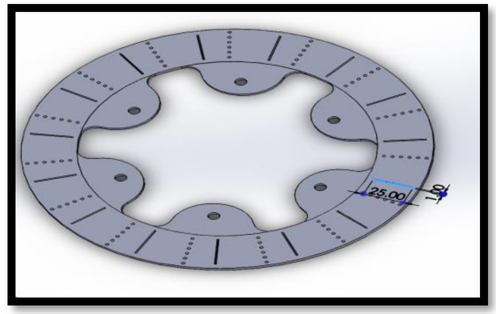

Figure 6 proposed disc rotor with slotted holes

MESH AND BOUNDARY CONDITIONS:

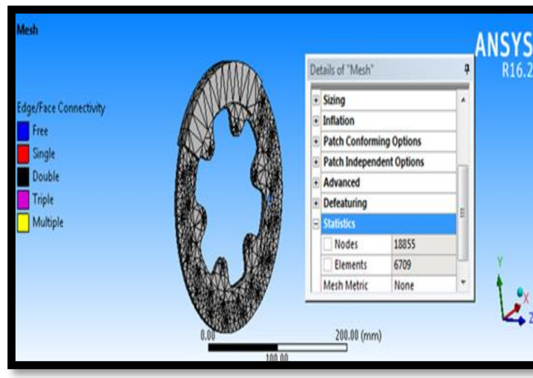

Figure 7 meshing

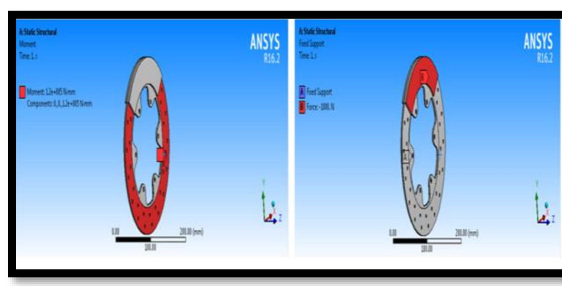

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Figure 8 moments applied in static analysis

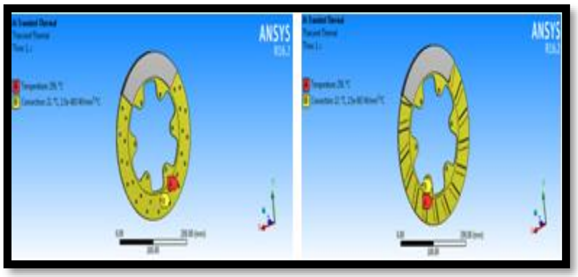

Figure 9 thermal boundary condition of normal disc rotor existing

IV. RESULTS AND DISCUSSIONS

Perform the static and thermal analysis with two design and various materials Grey cast iron, Al-Si-C, Ti6AL4V, AISI 6150, EN8 After formulation of the heat flux thermal boundary conditions they are applied on the FE model to obtain an estimate of the temperature distribution in the disc rotor. The thermal boundary conditions on the rotor are as follows Initial temperature on the rotor is set to 250C.Convection is applied on those surfaces of rotor which is not in contact with the pad, with the film coefficient of 0.0025w/mm2 Heat flux at each second time steps is applied on the respective contact region. The pressure values are applied for the disc / rotor is 1000N. The hub region of the rotor is constrained in all degree of freedom. Consider the moment is 120N-m, Clock wise direction.

7.1 EXISTING DESIGN OF NORMAL DISC ROTOR

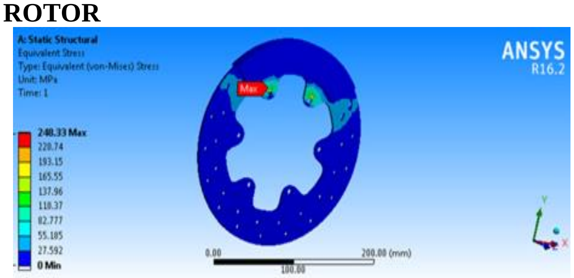

Figure 10von-misses stress of AISI 6150 material

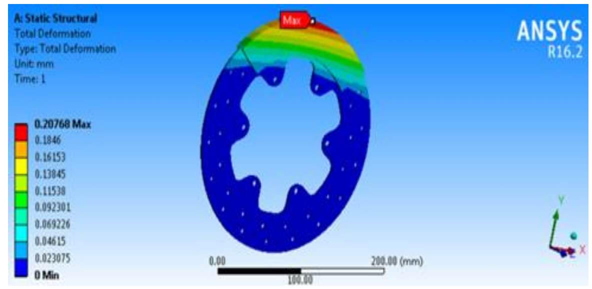

Figure 11total deformation of AISI 6150 material

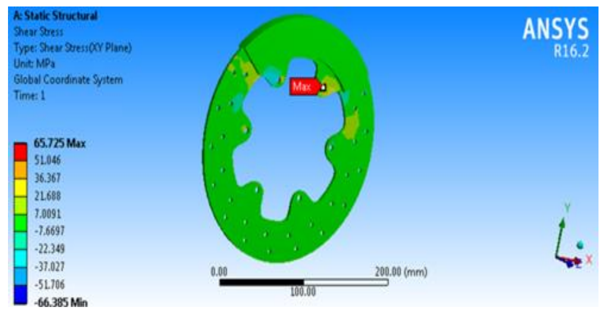

Figure 12shear stress of AISI 6150 material

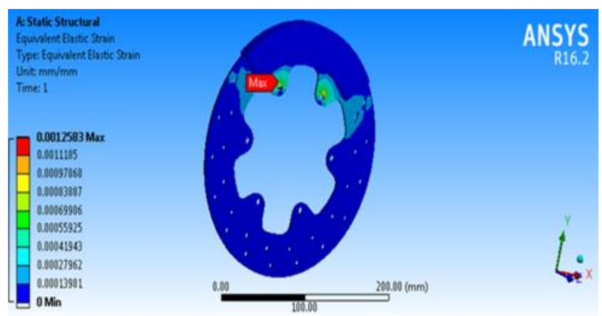

Figure 13strain of AISI 6150 material

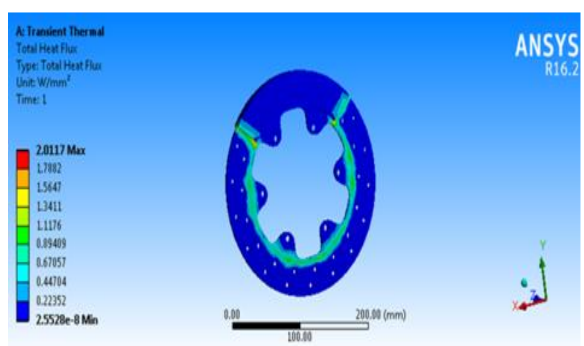

Figure 14total heat flux of AISI 6150 material

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SLOTTED VENTILATED DISC ROTOR PROPOSED DESIGN:

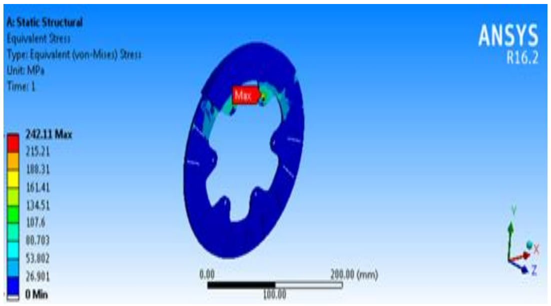


Figure 15von-misses stress of AISI 6150 material

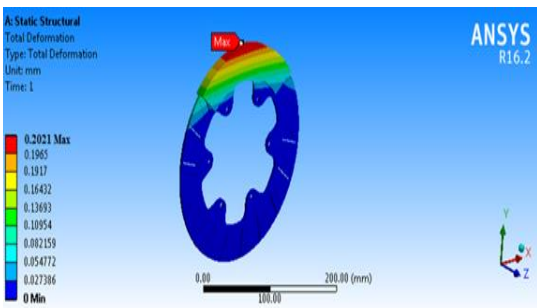


Figure 16total deformation of AISI 6150 material

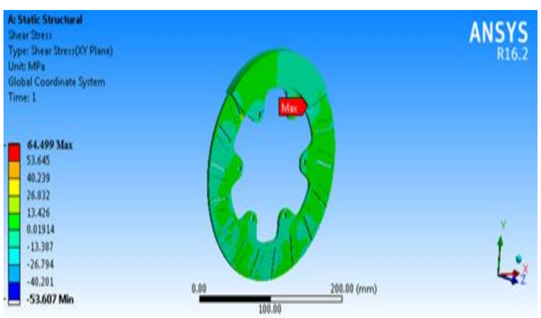


Figure 17shear stress of AISI 6150 material

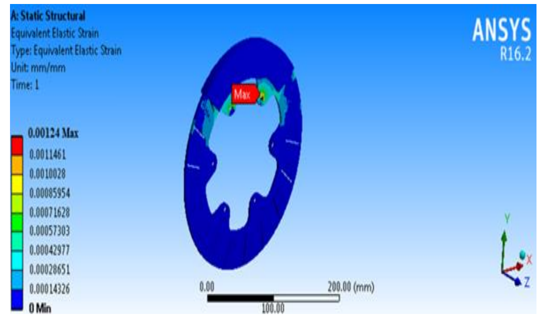


Figure 18strain of AISI 6150 material

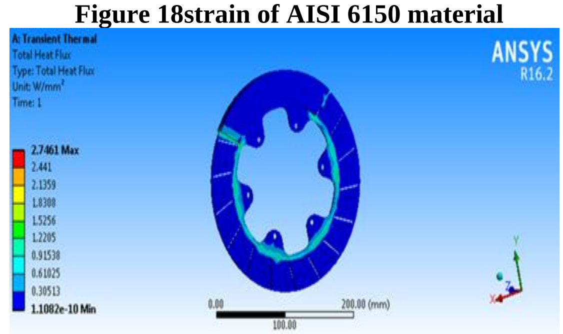


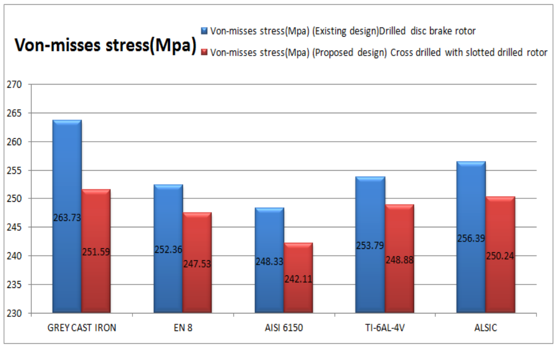
Figure 19 total heat flux of AISI 6150 material

GRAPHS

The static and thermal analysis of Grey cast iron, AlSiC, Ti6AL4V, AISI 6150, EN8 are done we are taking load conditions are Fixed at holes and apply load at disc pad and results are obtained for Equivalent (Von-Misses) stress, shear stress, strain total deformation and Heat flux These results are plotted graphically and a comparison is made between these results.

VON-MISSES STRESS:

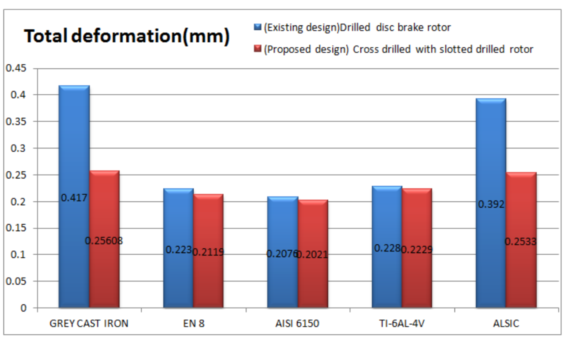
we can observe that in case of equivalent (von-misses) stress, disc rotor made of Two designs and various materials **Grey cast iron, Alsic, Ti6AL4V, AISI 6150, EN8 finally AISI 6150** is found to have least stress of 242.11as shown below figure.



Graph 1von-misses stresses

TOTAL DEFORMATION GRAPH:

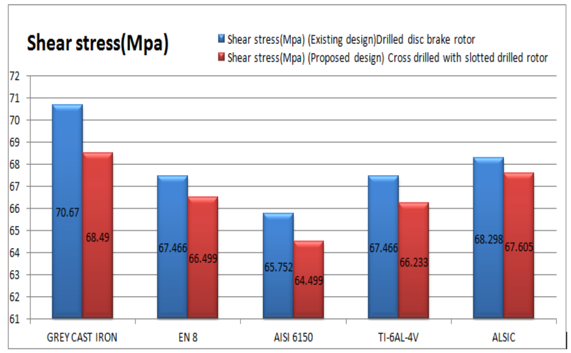
we can observe that in case of Total deformation disc rotor made of Two designs and with analysis various materials Grey cast iron, Alsic, Ti6AL4V, AISI 6150, EN8 finally AISI 6150 is found to have total deformation of cross drilled with slotted driller rotor have 0.202 mm as shown below graph



Graph 2 total deformation

SHEAR STRESS GRAPH:

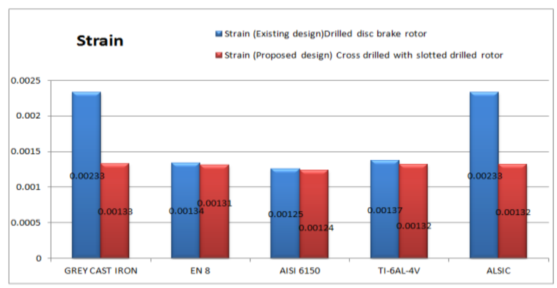
we can observe that in case of shear stress disc rotor made of Two designs and with analysis various materials Grey cast iron, Al-Si-C, Ti6AL4V, AISI 6150, EN8 finally AISI 6150 is found to least shear stress of cross drilled with slotted driller rotor have 64.99Mpa as shown below graph



Graph 3 shear stress

STRAIN GRAPH:

we can observe that in case of strain disc rotor made of Two designs and with analysis various materials Grey cast iron, Alsic, Ti6AL4V, AISI 6150, EN8 finally AISI 6150 is found to least strain of cross drilled with slotted driller rotor have 0.00124 as shown below graph



Graph 4 strain

TOTAL HEAT FLUX:

we can observe that in case of Total heat flux disc rotor made of Two designs and with analysis various materials Grey cast iron, Alsic, Ti6AL4V, AISI 6150, EN8 finally AISI 6150 is found to Highest heat transfer least shear stress of cross drilled with slotted driller rotor have 2.7461 W/mm2as shown below graph

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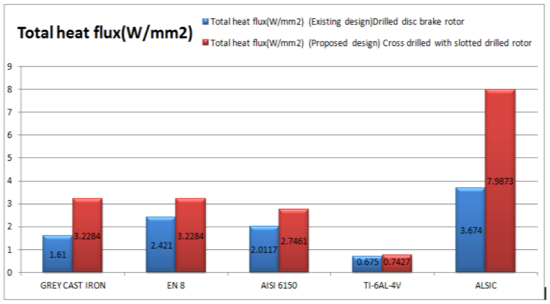

Graph 5 total heat flux

V. CONCLUSION

Design and analysis are done perform the static and thermal analysis this project work has provided an excellent opportunity and experience, to use limited knowledge. It helps to gain a lot of practical knowledge regarding planning, purchasing, assembling and machining while doing this project work. The work is a good solution to bridge the gates between institution and industries. The work is completed with the limited time successfully. The figures and graphs which are shown above reveals the stress, strain, shear stress, Total deformation, thermal stress, of the disc brake rotor with Grey cast iron, ALSIC, Ti6AL4V, AISI 6150, EN8 Materials. From all materials which are taken into consideration, AISI 6150 show the best material desirable results for disc brake rotor (vented with cross-drilled holes) because of Less stress, deformation, shear stress, strain and better heat transfer rate .so it is suitable for manufacturing purpose .This is important to understand action force and friction force on the disc brake new material, which use disc brake works more efficiently, which can help to reduce the accident that may happen in each day.

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