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DESIGN, ANALYSIS AND COMPARISON OF VARIOUS PROFILE GEOMETRY OF DISC BRAKE

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ABSTRACT:

In the human race, everything is related to speed and accuracy. In terms of speed, it is a great thing which is having both positive and negative results. Every Automobile needed to control the speed, for which required different types of brake systems.

Brake is a device which simulate frictional force through mechanical moving parts to connect the moving mechanical parts to control the motion of the vehicle. In the process of brake application, the generated kinetic energy or the potential energy is absorbed or transmitted to the surrounded mechanical parts. The kinetic energy and potential energy absorbed by the brake partsare scattered as heat.

Now a day's disc brakes are widely in use than any other brake system. The disc brake contains several mechanical parts. The disc is compressed in between two brake pads. These brake pads are controlled by cylinders in the calipers.The caliper is mounted to the study shaft in position with the disc simultaneously. When brake is applied, the brake force is converted in to hydraulic pressure in the cylinders. The pressurized hydraulic fluid in the contradicting cylinders, push forward the brake pads. The brake pads with the pressure of brake force, sandwiches the rotating or moving disc. In the process of brake application, in between the brake pads and the disc, an opposite friction force will be generated. When the friction force is generated, the thermal heat will be generated among the brake parts. The continuous and long-term utilization of the brakes may be damaged the brakeassembly, for examplebrake wear and thermal splits.

The current work is designing a disc and optimization of Automotive Brake disc with different materials and velocities. The deformation and von misses stress are determined in the disc structural analysis. A CATIA V5R21 software is used in modeling the brake disc and ANSYS 15.0 is used to analyze the structural conditions on disc brake.

1. INTRODUCTION:

Brake can be defined as a device, which is used for retard velocity of a vehicle and also for holding the vehicle in static condition. when a vehicle is moving, equal and opposite energy concept is applied. If a vehicle is in motion, in order to stop the vehicle, we will apply brakes. When we apply the brakes, the moving energy is going to convert in to heat energy by the friction generated in between the brake disc and brake pads. That friction causes both brake disc and brake pads to undergo wear, and the heat energy may damage the entire braking system to fail. There are different kinds of brakes available. Classification of braces according to construction is divided in to two types.

- Drum brake
- Disc brake

1.1. DRUM BRAKE:

Drum brake is mounted over the axle hub, on which return spring, shoe holding spring, wheel cylinder, leading shoe, back plate, parking lever, trailing shoe,anchor, lining, and adjuster lever are attached in their places to accomplish brake operation. When brake is applied, the force is transferred to the respective parts through various energy mediums. Finally, the motion of the vehicle will be nullified when brake drum and brake shoe are come together in contact.

1.2. DISC BRAKE:

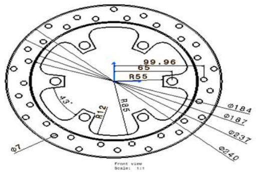
In disc brake, disc is mounted to rotating wheel. Disc will rotate along with wheel. The brake pads are attached to caliper along with pistons. The entire caliper system is mounted to a standard position. When brake is applies, brake pads present in the caliper will come to contact in both sides of disc to stop the rotations. In this process, heat can be easily dissipated to atmosphere.

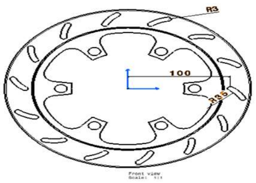
Types of brake discs:

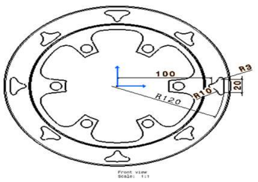
1. Flat brake disc
2. Vented brake disc
3. Drilled brake disc
4. Slot or grooved brake disc
5. combination-slotted and drilled brake disc

2. DESIGN AND MODELING:

2.1. 2D DESIGN:







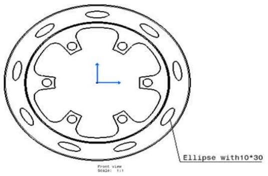
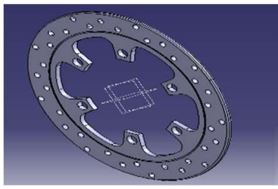
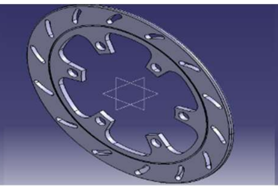
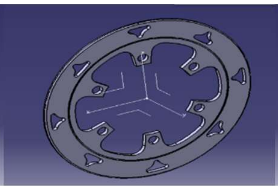


Figure.1. 2Ddrilleddisc Figure.2. 2Dslotted disc Figure.3. 2Dclouded disc Figure.4. 2Delliptical disc

2.2. 3D MODELING:







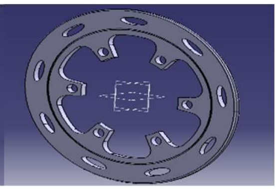


Figure. 5. 3d drilled disc Figure. 6. 3d slotted disc Figure. 7. 3d clouded disc Figure. 8. 3d elliptical disc

3. MATERIAL PROPERTIES:

Table 1: Material Properties of the selected materials

Properties	Carbon-Carbon	Aluminum	Stainless Steel	Titanium alloy
Young's Modulus (MPa or N/mm²)	50,200	70,000	190,000	96,000
Density (Kg/m³)	1800	2700	7750	4620
Poisson's Ratio	0.3	0.3	0.3	0.36
Thermal conductivity (W/m-K)	50	210	26	7.3

4. CALCULATIONS:

Given Data for Automobile:

When velocity of the vehicle (v) =100Kmph.

$$V = \frac{100 * 1000}{60 * 60}.$$

V=27.778 m/s.

Stoppingtime of a Vehicle=4 seconds.

Vehicle Mass, M =205 Kg (Including the weight of passenger).

Step 1:

$$Kinetic\ Energy = \frac{1}{2} * M * V^2.$$

$$K.E = \frac{1}{2} * 205 * 27.778^2.$$

K.E =79090.772 Joules.

Total kinetic energy induced in the vehicle is under motion.

Step 2:

The total K. E. = Total Heat generated.

Q_g =79090.772 Joules.

Generated Heat for single wheel= $\frac{Qg}{2wheels}$.

Heat generated for single wheel=39545.386 Joules.

Step 3:

Area of Rubbing Face = 15000 mm². (Calculated from Catia software)

Step 4:

Heat Flux Generated = Heat generated/Deceleration Seconds/(2* Projected Area)

Heat Flux Generated =39545.386/4/ (2*15000).

Heat Flux Generated = 0.3295 W/mm².

Analyzethe efficiency ofbraking forceis 30%.

Heat dispersedwith front to rear wheel is 70:30.

Thermal flow = 0.3295*0.7.

Thermal flow =0.23065 W/mm².

Brake system Absorbed heat = Work done by the traction Force.

E=Ft*π*d*n*t

$$Ft = \frac{E}{\pi * d * n * t}$$

$$Ft = \frac{E}{2\pi * (Do - Di) * \left(\frac{V}{2}\right) * 4}$$

$$Ft = \frac{39545.386}{2\pi * (0.237 - 0.187) * \left(\frac{27.778}{2}\right) * 4}$$

Ft =2265.766 N

Pressure (P) $= \frac{Breaking\ Force}{Rubbing\ Area}$

Pressure (P) $= \frac{2265.766}{15000}$ N/mm²

Pressure (P) =0.15105 MPa

When velocity of the vehicle (v) =60Kmph.

$$V = \frac{60 * 1000}{60 * 60}.$$

V=16.667 m/s.

Stopping time of a Vehicle = 4 seconds.

Vehicle Mass, M =205 Kg (Including the weight of passenger).

Step 1:

$$Kinetic\ Energy = \frac{1}{2} * M * V^2.$$

$$K.E = \frac{1}{2} * 205 * 16.667^2.$$

K.E =28473.36 Joules.

Total kinetic energy induced in the vehicle is under motion.

Step 2:

The total K. E. = Total Heat generated.

Qg =28473.36 Joules.

Heat generated for single wheel= $\frac{Qg}{2wheels}$.

Heat generated for single wheel=14236.68 Joules.

Step 3:

Area of Rubbing Face = 15000 mm². (Calculated from Catia software)

Step 4:

Heat Flux Generated = Heat generated/Deceleration Seconds/(2*Projected Area)

Heat Flux Generated =14236.68 /4/ (2*15000).

Heat Flux Generated = 0.1186 W/mm².

Analyze the efficiency of braking force is 30%.

Heat dispersed with front to rear wheel is 70:30.

Thermal Flux = 0.1186*0.7.

Thermal Flux=0.08302 W/mm².

Brake system Absorbed heat = Work done by the traction Force.

E=Ft*π*d*n*t

$$Ft = \frac{E}{\pi * d * n * t}$$

$$Ft = \frac{E}{2\pi * (Do - Di) * \left(\frac{V}{2}\right) * 4}$$

$$Ft = \frac{14236.68}{2\pi * (0.237 - 0.187) * \left(\frac{16.667}{2}\right) * 4}$$

Ft =1359.476 N

$$\text{Pressure (P)} = \frac{Breaking\ Force}{Rubbing\ Area}$$

$$\text{Pressure (P)} = \frac{1359.476}{15000}\ \text{N/mm}^2$$

Pressure (P) =0.0906 MPa

6.ANALYSIS:

Testing the Catia models by using ANSYS.

Table 2: Nodes and elements of disc models.

Models	No. of nodes	No. of elements
Hole	16799	8726
Slot	14321	7418
Cloud	13065	6993
Ellipse	12441	6610

At 60Kmph speed drilled design disc stress distribution

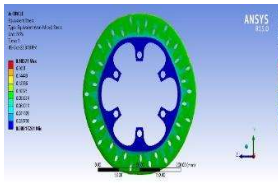
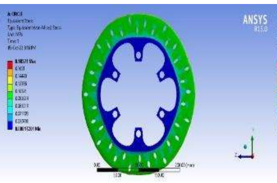
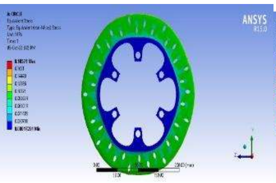
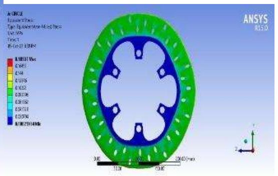





Figure. 9. carbon-carbondisc Figure. 10. aluminum disc Figure. 11. stainless steel dis
Figure. 12. titanium alloy disc

At 60Kmph speed slotted design disc stress distribution

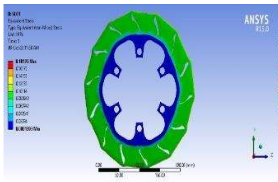
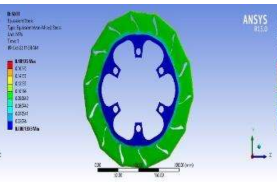
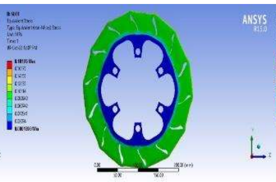
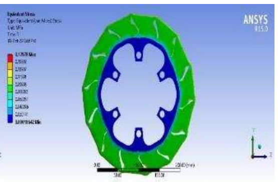





Figure. 13. carbon-carbon disc Figure. 14. aluminum disc Figure. 15. stainless steel dis
Figure. 16. titanium alloy disc

At 60Kmph speed cloud design disc stress distribution

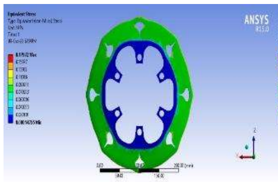
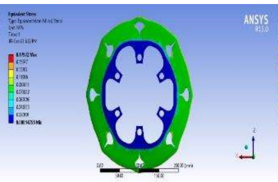
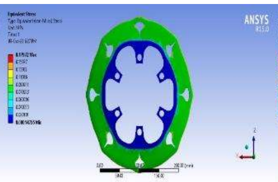
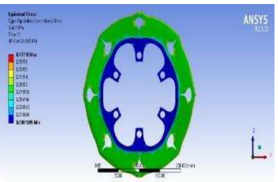





Figure. 17. carbon-carbon disc Figure. 18. aluminum disc Figure. 19. stainless steel dis
Figure. 20. titanium alloy disc

At 60Kmph speed ellipse design disc stress distribution

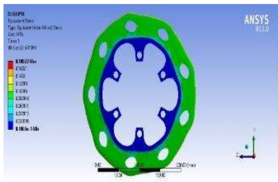
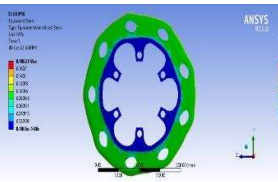
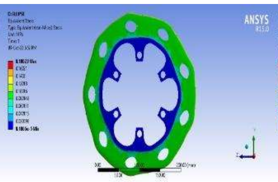
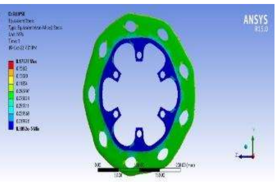





Figure. 21. carbon-carbon disc Figure. 22. aluminum disc Figure. 23. stainless steel dis
Figure. 24. titanium alloy disc

At 100Kmph speed drilled design disc stress distribution

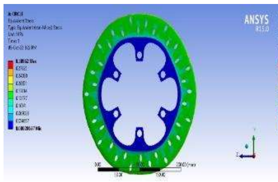
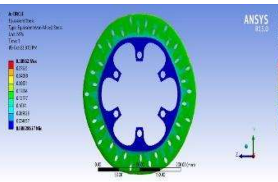
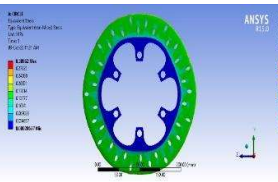
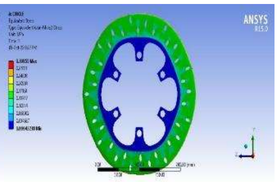





Figure. 25. carbon-carbon disc Figure. 26. aluminum disc Figure. 27. stainless steel dis
Figure. 28. titanium alloy disc

At 100Kmph speed slotted design disc stress distribution

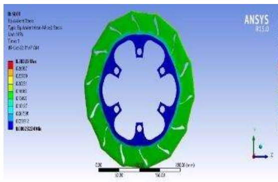
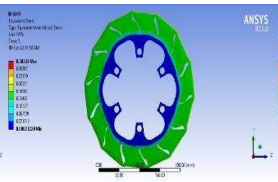
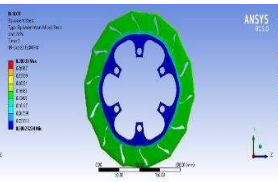
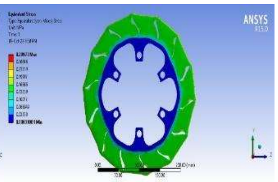





Figure. 29. carbon-carbon disc Figure. 30. aluminum disc Figure. 31. stainless steel dis
Figure. 32. titanium alloy disc

At 100Kmph speed cloud design disc stress distribution

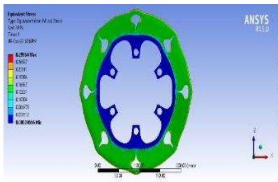
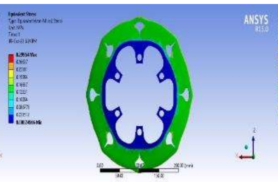
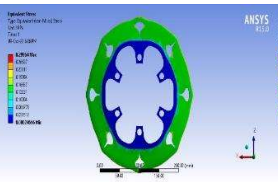
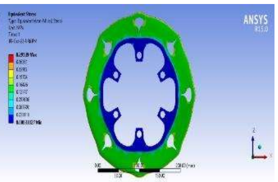





Figure. 33. carbon-carbon disc Figure. 34. aluminum disc Figure. 35. stainless steel dis
Figure. 36. titanium alloy disc

At 100Kmph speed ellipse design disc stress distribution

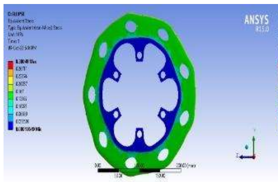


Figure. 37. carbon-carbon disc

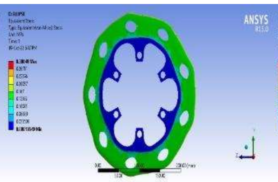


Figure. 38. aluminum disc

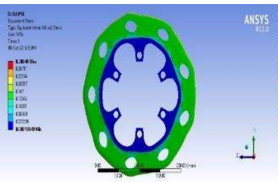


Figure. 39. stainless steel dis

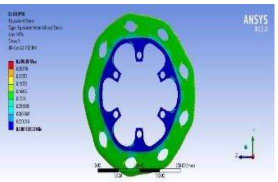


Figure. 40. titanium alloy disc

6.CONCLUSION:

The brake disc was designed in CATIA and analyze the same by ANSYS 15.0. The stresses are same in all the materials namely Carbon-Carbon, Aluminum and Stainless Steel, except in Titanium alloy. The comparison is made between different materials and designs of Circles, Slots, Cloud and Ellipse with various speeds such as 60 Kmph and 100 Kmph.

The current study shown evident that maximum stress and minimum stress between the designs, materials and speeds.

7.RESULTS AND DISCUSSION:

Table 3: Analysis of the drilled disc with selected materials at 60&100 Kmph.

circles	**60 Kmph**			**100 Kmph**		
	Von-misses stress	**Total deformation**	**Von-misses strain**	**Von-misses stress**	**Total deformation**	**Von-misses stress**
Carbon-Carbon	0.18571	3.1436 E^{-5}	3.7108 E^{-6}	0.30962	5.241 E^{-5}	0.30962
Aluminum	0.18571	2.2544 E^{-5}	2.6612 E^{-6}	0.30962	3.7586 E^{-5}	0.30962
Stainless steel	0.18571	8.3057 E^{-6}	9.8044E^{-7}	0.30962	1.3847 E^{-5}	0.30962
Titanium alloy	0.18507	1.9602 E^{-5}	1.9332 E^{-6}	0.30855	3.2681 E^{-5}	0.30855

Table 4: Analysis of the slotted disc with selected materials at 60&100 Kmph.

Slot	**60 Kmph**			**100 Kmph**		
	Von-misses stress	**Total deformation**	**Von-misses strain**	**Von-misses stress**	**Total deformation**	**Von-misses strain**
Carbon-Carbon	0.18195	3.2464 E^{-5}	3.6249 E^{-6}	0.30335	5.4125 E^{-5}	6.0435 E^{-6}
Aluminum	0.18195	2.3281 E^{-5}	2.5996 E^{-6}	0.30335	3.8815 E^{-5}	4.334 E^{-6}
Stainless steel	0.18195	8.5773 E^{-6}	9.5773 E^{-7}	0.30335	1.43 E^{-5}	1.5967 E^{-6}
Titanium alloy	0.17978	2.0202 E^{-5}	1.8729 E^{-6}	0.29973	3.3681 E^{-5}	3.1226 E^{-6}

Table 5: Analysis of the clouded disc with selected materials at 60&100 Kmph.

	60 Kmph	**100 Kmph**

Cloud	Von-misses stress	Total deformation	Von-misses strain	Von-misses stress	Total deformation	Von-misses strain
Carbon-Carbon	0.17972	4.522 E^{-5}	3.5982 E^{-6}	0.29964	7.5391 E^{-5}	5.999 E^{-6}
Aluminum	0.17972	3.2429 E^{-5}	2.5804 E^{-6}	0.29964	5.4066 E^{-5}	4.3022 E^{-6}
Stainless steel	0.17972	1.1947 E^{-5}	9.5069 E^{-7}	0.29964	1.9919 E^{-5}	1.585 E^{-6}
Titanium alloy	0.17718	2.6219 E^{-5}	1.8489 E^{-6}	0.29539	4.3713 E^{-5}	3.0826 E^{-6}

Table 6: Analysis of the ellipse disc with selected materials at 60&100 Kmph.

Ellipse	60 Kmph			100 Kmph		
	Von-misses stress	Total deformation	Von-misses strain	Von-misses stress	Total deformation	Von-misses strain
Carbon-Carbon	0.18023	3.7162 E^{-5}	3.5905 E^{-6}	0.30048	6.1957 E^{-5}	5.9861 E^{-6}
Aluminum	0.18023	2.6651 E^{-5}	2.5749 E^{-6}	0.30048	4.4432 E^{-5}	4.2929 E^{-6}
Stainless steel	0.18023	9.8186 E^{-6}	9.4864 E^{-7}	0.30048	1.637 E^{-5}	1.5816 E^{-6}
Titanium alloy	0.17777	2.3207 E^{-5}	1.8519 E^{-6}	0.29638	3.8692 E^{-5}	3.0874 E^{-6}

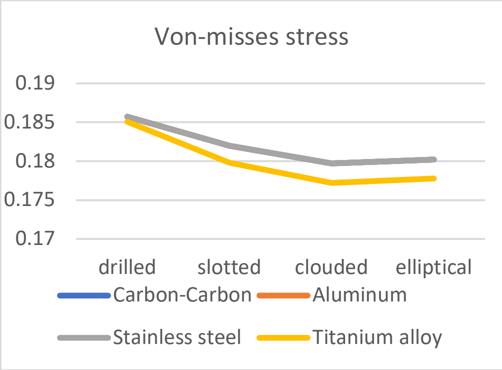


Fig. 41. Comparison of von-misses stress at 60 Kmph

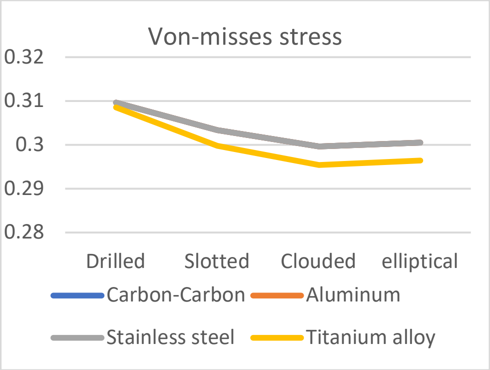


Fig. 42. Comparison of von-misses stress at 100 Kmph

Table 7: Stress comparison between design models and speeds.

Materials	Models	60 Kmph	100Kmph

Carbon-Carbon	Hole	0.18571	0.30962
	Slot	0.18571	0.30962
	Cloud	0.18571	0.30962
	Ellipse	0.18507	0.30855
Aluminum	Hole	0.18195	0.30335
	Slot	0.18195	0.30335
	Cloud	0.18195	0.30335
	Ellipse	0.17978	0.29973
Stainless Steel	Hole	0.17972	0.29964
	Slot	0.17972	0.29964
	Cloud	0.17972	0.29964
	Ellipse	0.17718	0.29539
Titanium alloy	Hole	0.18023	0.30048
	Slot	0.18023	0.30048
	Cloud	0.18023	0.30048
	Ellipse	0.17777	0.29638

8. FUTURE SCOPE:

The present work can be continued by thermal and model analysis, it can also test for different alloys with high varying speeds.

19. REFERENCES:

1. Vishvajeet, F. Ahmad, M. Sethi et al., “Thermo-mechanical analysis of disk brake using finite element analysis”, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.04.614
2. M.H. Pranta, M.S. Rabbi, S.C. Banik, M.G. Hafez and Yu-Ming Chu in 2021 conducted “A computational study on structural and thermal behavior of modified disk brake rotors” Alexandria Engineering Journal (2022) 61, 1882–1890
3. Joyson Sam Devapaul P, Paul Gnanam J “Thermal and Structural Analysis of Two Wheeler Disc Brake Using Softwares” International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 11, November 2018
4. Abbas Mohammed Ismael “STUDY OF THERMAL ANALYSIS OF DISC BRAKE ROTOR FOR DIFFERENT DISC BRAKES”, International Journal of Mechanical Engineering and Technology (IJMET) Volume 9, Issue 3, March 2018, pp. 731–738, Article ID: IJMET_09_03_074

5. S. J. Kishore, B. S. Rao, and P. K. Babu, FEM Analysis on Submarine Propeller Blade for Improved Efficiency by using Solid Works and ANSYS-Workbench, Int. J. Emerg. Eng. Res. Technol., vol. 3, no. 11, pp. 144– 151, 2015
6. Deekshith Ch, Udaya kiran C, Vijaya kumar Y “Design, Analysis and Manufacturing of Disc Brake Rotor”, International Journal Of Engineering Research And Development, Volume 13, Issue 11 (November 2017), PP.15-23
7. MAHMOOD HASAN DAKHIL, A. K. RAI, P. RAVINDER REDDY& AHMED ABDULHUSSEIN JABBAR “DESIGN AND STRUCTURAL ANALYSIS OF DISC BRAKE IN AUTOMOBILES” International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 4, Issue 1, Feb 2014, 95-112
8. Yogesh H. Mishra, Vikas R. Deulgaonkar, P.A. Makasare “Design AndOptimisation Of Disc Brake Rotor (For Two Wheeler)” International Engineering Research Journal Page No 288-300
9. S. Abdul Mutalib, S. Suresh, S.Jaya Kishore, Design and Analysis of Composite Marine Propeller using ANSYS WORK BENCH, International Journal of Science, Engineering and Technology Research (IJSETR), 4, 2015,pp. 3224-3228.
10. Mahmood Hasan Dakhil, Dr. A. K. Rai, Dr. P. Ravinder Reedy & Ahmed Abdulhussein Jabbar “Structural Design and Analysis of Disc brake in Automobiles”
11. K Srinivasa Rao, U V Narayana Rao, G Sridhar Babu and M Rajesh “MODELLING AND ANALYSIS OF ROTOR BRAKING SYSTEM” International Journal of Mechanical Engineering and Technology (IJMET) Volume 10, Issue 03, March 2019, pp. 1217-1226. Article ID: IJMET_10_03_124
12. UTKARSH GAHLAUT, PRIYESH GUPTA, RAGHAV AGNIHOTRI, PURU MATHUR & SANATAN RATNA “A COMPARATIVE THERMAL AND STRUCTURAL ANALYSIS OF DIFFERENT DISC BRAKE MATERIALS” International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 8, Issue 6, Dec 2018, 419-424
13. S. Jaya Kishore, M. Lava Kumar” Structural Analysis of Multi-Plate Clutch” International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2013
14. M.Govindan, B.Viji “Design and Analysis of Automobile Brake Disc by Using Al/SiC MMC” International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 3, March 2017
15. Aniket Bharambe “Modelling and Analysis of Disc Brake with Composite Material” International Journal of Science and Research (IJSR)” Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391