Thermal Fatigue FE Analysis of Brake Disc under Different Parameters

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Abstract
A brake is the most important part of a vehicle necessary for good control of vehicle to avoid accidents. Brakes are required to stop the vehicle within minimum possible distance and it is done by converting kinetic energy of the vehicle into heat energy by friction which is dissipated into atmosphere. Most important requirement of brakes is that they should have good anti fade, anti-wear properties & ability to withstand large temperature generated during braking. Due to generation of heat by rise in temperature during braking, thermal fatigue failure of brake can occur which hampers normal braking of vehicle. So it is necessary to analyze thermal behavior of disk under elevated temperature to get optimum design of disc. Objective of this paper is to Compare thermal behavior of solid disk i.e. disk without hole and then disk with hole using FEA approach which can assist in disc rotor design and analysis to avoid thermal damage of disk brake.

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1. INTRODUCTION

A brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. In the process of performing this function, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators etc. this energy absorbed by brakes is dissipated in the form of heat. This heat is dissipated in the surrounding atmosphere. Recently, there is tremendous use of disk brakes due to its good performance in vehicles.. One of the problems associated with that is long repetitive braking leads to rise in temperature of brake components.

Hence there is need for transient, Thermal and Structural Analysis of the Rotor Disc to evaluate performance of disc brake rotor under severe braking conditions.

1.1 Requirements for good braking

1. In order to stop the vehicle within a minimum distance during emergency the brakes must be strong enough so that driver can have proper control over the vehicle during braking and there less probability of skidding.
2. After repetitive application for long time, braking Effectiveness should not decrease with time then it is said to have good anti fade characteristics.
3. The brakes should have resistance to wear & abrasion for increase in life.

A brake disc usually made of cast iron or ceramic composites includes carbon, Kevlar and silica.

The brake disc, may in some cases be made of composites such as reinforced carbon or ceramic matrix composites.
Ceramic is recently developed material, as it have all the above requirements specified for the brakes, hence it is widely used for brake pads.

1.2Principle of Disk Brake:
Disc is attached to rotor hub of the wheel. Principle is to provide frictional force with the help of a brake pads which are pushed against both sides of the disk surface.
Pads are pushed mechanically, hydraulically, pneumatically or electromagnetically. This eventually leads to friction causing the disc and attached wheel to slow or stop. Generally, methodologies like regenerative braking and friction braking are used in a vehicle for braking.

2. LITERATURE REVIEW

Some of the important work done by different researchers is given below.

Mr. P. N. Gunjal, Prof. Hredeya Mishra, in their work on disk brake, showed that as Equivalent stress values of grey cast iron are less than the permissible values, design of disc is safe.

Er. N. B. Shinde, Prof. B.R. Borkar[3] carried out C.A.D. & F.E.M. Analysis of Disc Brake System & investigated the effects of the rotating speed of the disk and the material properties on wear behaviours. It helped to reduce solution time for the problem in FEA by utilizing ANSYS's contemporary advantages in contact and thermo-mechanical problems.

Swapnil R. Abhang, D.P.Bhaskar[5] done Design and Analysis of Disc Brake which Helped to understand action force and friction force on the disc brake new material.

N.Balasubramanyam, Prof. Smt. G. Prasanthi in their paper entitled 'Design and Analysis of Disc Brake Rotor for a Two Wheeler' studied & analysed Thermo elastic instability (TIE) phenomenon (the unstable growth of contact pressure and temperature) of disk brake.

Structural Analysis of Disc Brake Rotor was carried out by K.Sowjanya & S.Suresh[6] guiding about selection of optimum material for disk.

Manjunath T V & Dr., Suresh P M[2] carried out Structural and Thermal Analysis of Rotor Disc of Disc Brake to get the best suitable design, material and rotor disc is suggested based on the performance, strength and rigidity criteria.

Initially, when disk brake was invented disk was solid that is no holes were drilled on it. In later days, hole improvement was done to get better thermal fatigue life.

3. GENERAL DESIGN PROCEDURE

Design of disk brake is done considering following design considerations.

1. Brake Power
More will be brake power when larger is the diameter of rotors with the same amount of clamp force.

2. Coefficient of friction

Higher the coefficient of friction for the pad, the more brake power will be generated

3. Type of material used for the brake rotor.

4. Speed Sensitivity:

Coefficient of friction typically drops as the speed of the vehicle increases

5. Pressure Sensitivity:

Coefficient of friction typically drops as more clamp force is generated.

6. Temperature Sensitivity:

Coefficient of friction typically drops as the temperature of the brake system increases.

7. Surface Area:

The more surface area available for brake system, there will be better heat dissipation via convection.

8. Material Selection:

Material selection is important in to control where the heat dissipation

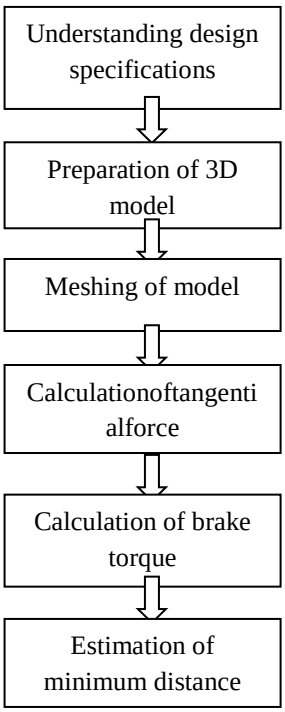
9. Wear:

Wear is proportional to pressure intensity (p) and relative velocity (v) which is proportional to radius.

10. Thermal Mass:

Enough material mass is required to properly handle the temperatures during braking.

General design procedure adopted is given as below.



3. FINITE ELEMENT ANALYSIS

Finite Element Method is widely used to predict behavior of components under different parameters. Hence it is used for analysis of disc using Ansys 14.5 as a software tool.

Steps followed for this are as given below.

3.1 Preparation of 3D model

In this work, 3D specimen model of disk is prepared in solid works. It is shown in below figure. Dimensions are taken are of Bajaj pulsar 100 disk. 2D drawing and its 3D model is generated as shown below.

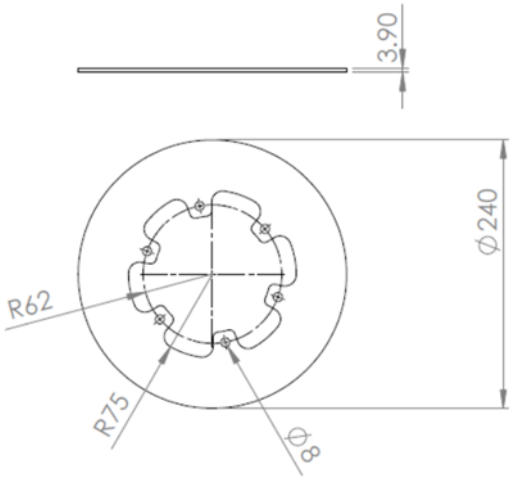


Fig-1: 2D drawing of disk.

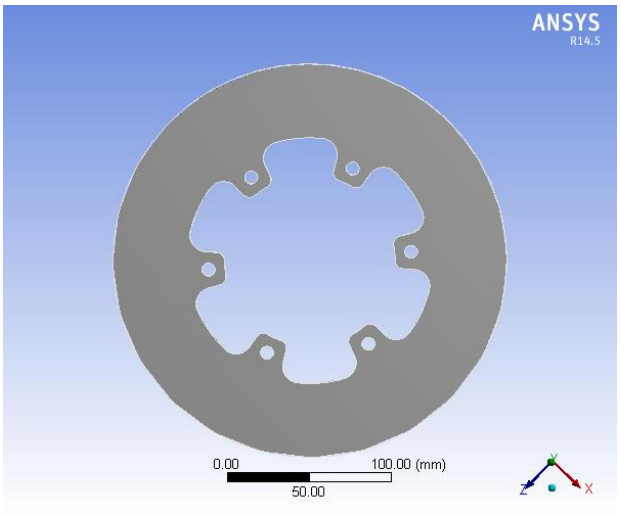


Fig-2: 3D model of disk.

3.1.1 Disk brake model without hole:

Solid disk is modeled without considering holes.

3.1.2 Disk brake model with hole:

Holes of diameter 8mm are drilled in 3D model prepared in solid works with the help of cut extrude command.

3.2 Importing the prepared model in Ansys 14.5

Prepared 3D model is imported in Ansys14.5in design modeler of Ansys.

3.3 Meshing the model

3.3.1 3D model is initially modeled in default manner but to gate better results element size is reduced.

3.3.2 Element size is kept as 2mm. In statistics of meshing element quality is taken and mesh is generated to get finer mesh.

3.4 Application of boundary conditions for steady state thermal module

As it is thermal fatigue analysis,

3.4.1Constant heat flux of 23000W/m^2 is applied on surface of disk. It is kept same for both disk with hole and without hole.

3.4.2For convective heat transfer, film coefficient is taken as 230W/m^2 and for radiative heat transfer default conditions are set selecting surface of the disk.

3.5 Application of boundary conditions for static structural module

3.5.1Solution obtained from steady state thermal mode are inputted to static structural mode to get fatigue life and damage.

3.5.2Holes which are connected to rotor hub are applied with fixed support.

3.5.3Axial force of 3500 on both side surface of disk is applied which acting as force is provided by brake pads causing frictional force.

3.5.4Moment of 300Nm is applied at periphery of the disk. It is caused due to rotation of disk.

3.6 Solution & Result

3.6.1 In solution, parameters required for analysis i.e. equivalent stress, Total deformation caused, fatigue life and damage caused to the disk are inserted and it is solved.

4. ANSYS RESULTS

After importing solid model of disk rotor it is analyzed first in steady state thermal module of Ansys 14.5. Then results inputted to static structural module to get thermal fatigue life, damage and equivalent stress.

Results are as shown below for disk without holes.

4.1Disk without holes:

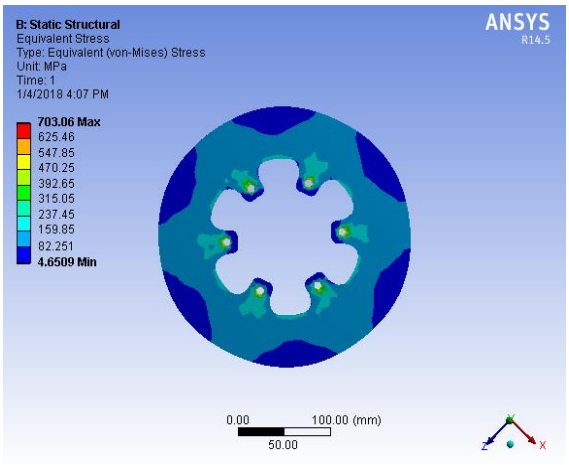


Fig-3: Equivalent stress

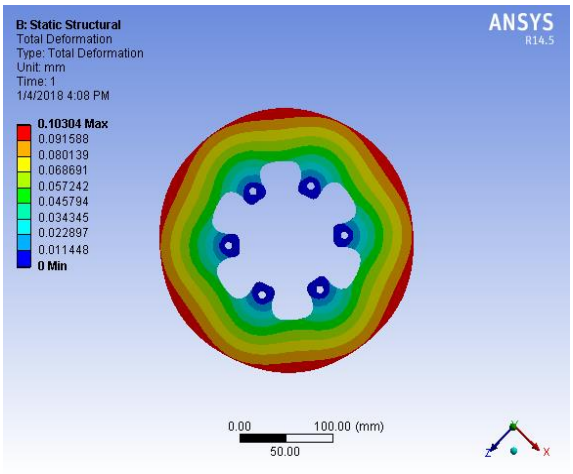


Fig-4: Total deformation

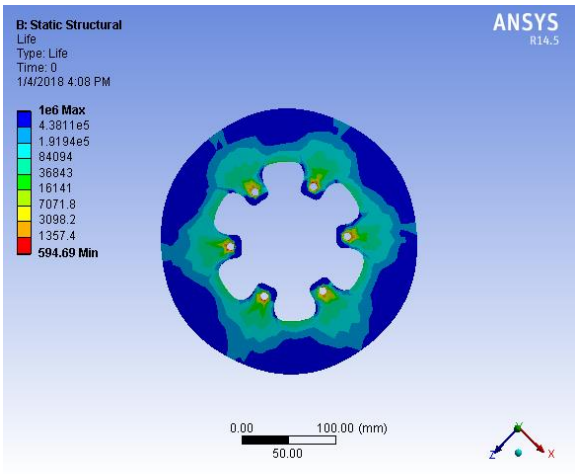


Fig-5: Fatigue life

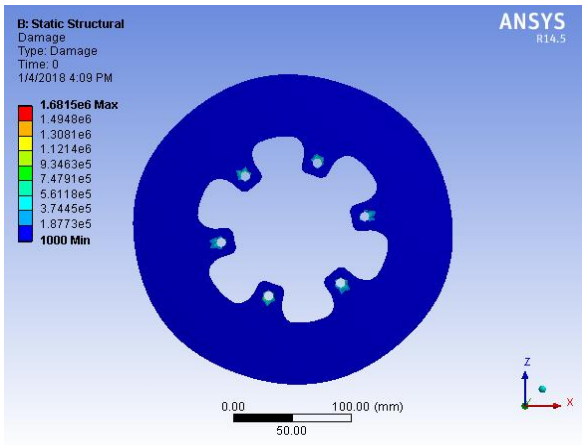


Fig 6: Damage

It can be observed from this that,
Maximum equivalent stress developed is at the holes which are fixed hence it is critical area.

Maximum deformation is developed at the peripheral zone of the disk.
Again due to maximum development of stress at holes, there is more probability of damage in hole region as compared to other region of the disk.

4.2Disk with holes:

Holes of diameter 8mm are drilled in 3D model prepared in solid works with the help of cut extrude command.
Now this model is imported in Ansys 14.5 to get results under same parameters.

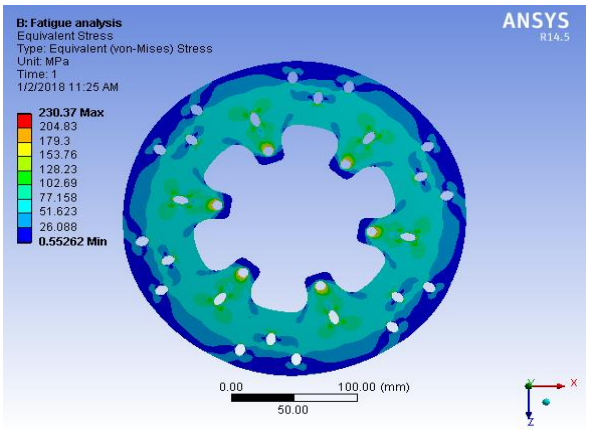


Fig-7: Equivalent stress

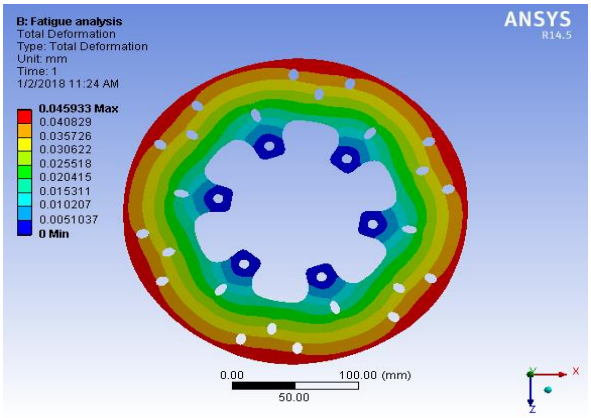


Fig-8: Total deformation

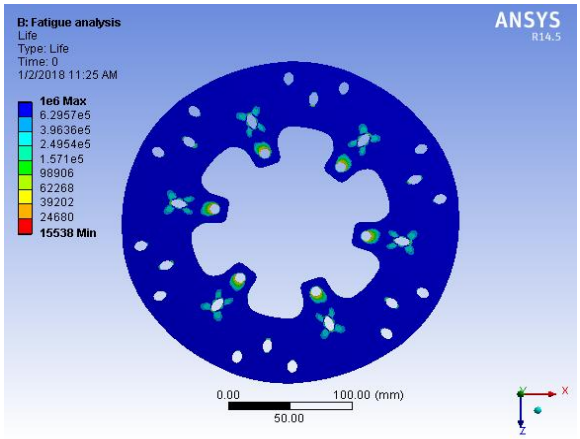


Fig-9: Fatigue life

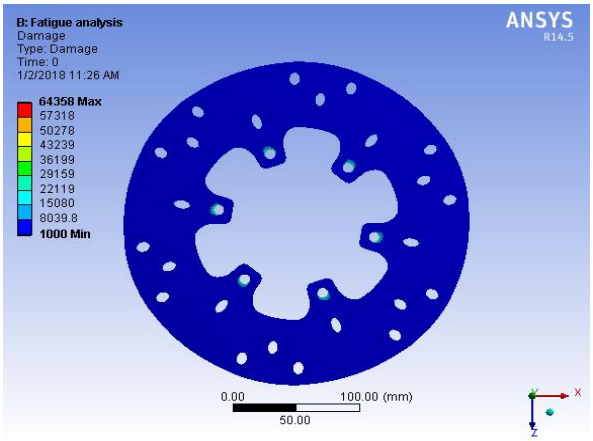


Fig 10: Damage

It can be observed from this that,Maximum equivalent stress developed is at the inner side holes which are fixed hence it is critical area. This is almost same as that of disk without holes.
Also Probability of stress development is maximum at inner peripheral zone of the disk that at outer peripheral zone.

5. RESULTS

From above Ansys results obtained, Comparison of disk without holes and with holes is carried out and results are tabulated as given below.
Table-1: Comparison of results

Disk Brake	Fatigue life	Damage	Equivalent stress
With Hole	15538	64358	230.37
Without hole	594	1.6815e6	703.06

6. CONCLUSION

From above tabulated results obtained from FEA, it can be concluded that,
Rotor disk provided with holes are efficient than without hole as it give better fatigue life under than that of solid disk i.e. disk without hole.
Again maximum damage occurrence in disk with holes is less than that of solid disk i.e. disk without hole.
Maximum equivalent stress developed in disk with holes is much less as compared to solid disk i.e. disk without hole.
Main reason behind this is that cooling of disk with holes takes place rapidly than solid disk due to ventilation in the form of holes resulting in better heat dissipation.
Hence it is verified that Disk brake with holes is more efficient than solid disk i.e. disk without holes.

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REFERENCES

1. Venkatramanan R, Kumaragurubaran S Vishnu Kumar C, Sivakumar S, Design & and analysis of disk brake rotor, Research gate, V.10,Number19 (2015)
2. Manjunath T V, Dr Suresh P M, Structural and Thermal Analysis of RotorDisc of Disc Brake, Vol. 2, Issue 12, December 2013
3. Dhabliya, D. (2019). Security analysis of password schemes using virtual environment. International Journal of Advanced Science and Technology, 28(20), 1334-1339. Retrieved from www.scopus.com
4. Dhabliya, D., & Dhabliya, R. (2019). Key characteristics and components of cloud computing. International Journal of Control and Automation, 12(6 Special Issue), 12-18. Retrieved from www.scopus.com
5. Dhabliya, D., & Parvez, A. (2019). Protocol and its benefits for secure shell. International Journal of Control and Automation, 12(6 Special Issue), 19-23. Retrieved from www.scopus.com
6. Er. N. B. Shinde, Prof. B.R. Borkar, 'C.A.D. & F.E.M. Analysis of Disc Brake System', Volume 4, Issue 3 March 2015, Page No. 10697-10706
7. Mahmood Hasan Dakhil, Dr. A. K. Rai, Dr. P. Ravinder Reddy & Ahmed Abdul Hussein Jabbar, 'Structural Design and Analysis of Disc brake in Automobiles', Research gate /publication/274373222, January 2014
8. Swapnil R. Abhang, D.P.Bhaskar, 'Design and Analysis of Disc Brake',International Journal of Engineering Trends and Technology (IJETT) – Volume 8 Number 4- Feb 2014
9. K.Sowjanya, S.Suresh,'Structural Analysis of Disc Brake Rotor',International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2013
10. N. Balasubramanyam, Prof. Smt. G. Prasanthi,'Design and Analysis of Disc Brake Rotor for a Two Wheeler', International Journal of Mechanical and Industrial Technology (IJMIT) ,Vol. 1, Issue 1, pp: (7-12), Month: October 2013-March 2014
11. Mr. P. N. Gunjal, Prof. Hredeya Mishra,'Design, Analysis & Optimization of Disk Brake'Vol-1 Issue-5 2015 IJARIIE- ISSN (O)-2395-4396
12. Ashish R. Pawar, "Roof Crash Simulation of Passenger Car for Improving Occupant Safety inCabin" in Elsevier Journal
13. Ashish R. Pawar, "Design and Development: A Simulation Approach of Multi-Link Front Suspension for an All-Terrain Vehicle", SAE Technical Paper, SIAT 2021
14. Aditya Pawar, Aniket Wanjale, Harshal Wanjale, Yash Sathe, Ashish R. Pawar, "StaticStructural Analysis & Optimization Of Driver Cabin Mounting Bracket Of Heavy

Commercial Vehicle", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973-2861, pp. 111-124

15. Siddharth P. Patil, Saurabh R. Birwatkar, Pranil D. Phadke, Karan R. Pawar, Ashish R. Pawar, "Static Structural Analysis & Topology Optimization Of Automotive Track Control Arm For Light Passenger Vehicle", Journal ofAnalysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973-2861, pp. 91-100
16. Sandhya R. More, Ganesh E. Kondalkar, Ashish R. Pawar, "Crash Analysis Of A Conformable CNG Tank Using FEA Tool", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973-2861, pp. 71-78
17. Sumit Ekbote, Sidhhesh Gade, Sanket Mhetre, Raj Dhawade, Ashish R. Pawar, "Experimental Analysis Of Automatically Manufactured Chain Link Fencing Wire", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973- 2861, pp. 57-67
18. Tushar S. Kalaskar, Kashinath H. Munde, Ashish R. Pawar, "Design And Analysis Of Hybrid Aluminium-Composite Driveshaft With Crack Using Experimental Modal Analysis And FEA", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973-2861, pp. 27-40
19. Sandhya R. More, Ganesh E. Kondalkar, Ashish R. Pawar, "Review Of Conformable Cng Tank Storage In Light Goods Vehicle", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973-2861, pp. 21-26
20. Deepak N. Patil, Ganesh E. Kondhalkar, Ashish R. Pawar, "Improvement In Productivity And Quality Of Bumper Punching Machine", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue V, May 2021 ISSN: 0973-2861, pp. 1-6
21. Shubham A. Andore, Ashish R. Pawar, P. N. Abhyankar, "Study Of Effects Of Different Profiles Of Dental Implant Using FEA", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue V, May 2021 ISSN: 0973-2861, pp. 1-13
22. Abhilash D. Bhosale, Ashish R. Pawar, "Experimental & Numerical Investigation Of Pretention Effect On Fatigue Life Of Double Lap Bolted Joint Under Dynamic Shear Loading", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue V, May 2021 ISSN: 0973-2861, pp. 1-19
23. Deepak N. Patil, Ganesh E. Kondhalkar, Ashish R. Pawar, "Structural Optimization Of Bumperfog Lamp Punching Machine", Journal of Analysis & Computation (IJAC, UGC), Volume XV Issue V, May 2021 ISSN: 0973-2861, pp. 71-84
24. Ashish Pawar, Suraj Jadhav, "Investigate Optimum Shape of Crash Box Analysis Experimentally & Numerically on Geometry Aspect" in Journal of Analysis & Computation(IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
25. Ashish Pawar, Yogesh Vyavahare, Ganesh Kondhalkar, "Roof Crash Simulation of Passenger Car for Improving Occupant Safety in Cabin" in IUP Journal of Mechanical Engineering, Volume 13 Issue 2/3.
26. Ashish Pawar, Suraj Jadhav, "Experimental & Non-Linear Analysis to Investigate Optimum Shape Crash Box" in Journal of Interdisciplinary Cycle Research (JICR, UGC), Volume XII Issue VII, July 2020 ISSN: 0022-1945, pp. 966-973
27. Ashish Pawar, Swastik Kumar Pati, Ganesh Kondhalkar, "Comparative Analysis of Kenaf & Jute E Glass Epoxy Specimen Along with B Pillar Natural & Synthetic Combination

Replica Test Under UTM" in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861

28. Ashish Pawar, Harshal Dharmale, Ganesh Kondhalkar, "Experimental FEA Investigation of Bolt Loosening in a Bolted Joint Structure " in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861, pp. 1-12
29. Ashish Pawar, Harshal Dharmale, Ganesh Kondhalkar, "Numerical Investigation Of Bolt Loosening In A Bolted Joint Structure" in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861, pp. 1-12
30. Ashish Pawar, Abhijeet Salunkhe, Kashinath Munde, "Optimization of Power Lift Gate Spindle & Socket Assembly" in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
31. Ashish Pawar, Abhijeet Salunkhe, Kashinath Munde, "Investigate Numerical Analysis of Power Lift Gate Spindle & Socket Assembly with Modifications" in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
32. Ashish Pawar, Balasaheb Takale, " " in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
33. Ashish Pawar, Sampada Ahirrao, Ganesh Kondhalkar, "Fatigue Analysis of Leaf Spring Bracket for Light Duty Vehicles on Topology Optimization Approach" in Journalof Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861, pp. 1-11
34. Ashish Pawar, Rahul Nimbalkar, "Investigation of Carbon Fiber & E Glass Epoxy Composite with Multi-Bolt Joints using Tensile Loading " in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
35. Ashish Pawar, Rahul Nimbalkar, "Numerical Analysis of Carbon Fiber & E Glass Epoxy Composite Plates in Tensile Loading with Multi-Bolt Joints" in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
36. Ashish Pawar, Makarand Patil, Ganesh Kondhalkar, "Predication of Effect of WeldingProcess Parameter of MIG Process on Weld Bead Geometry" in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
37. Ashish Pawar, "Topology Optimization Of Leaf Spring Bracket For Light Duty Vehicle" in Journal of Emerging Technologies and Innovative Research (JETIR, UGC), Volume 6 Issue 5, May 2019 ISSN: 2349-5162
38. Ashish R. Pawar, Dr. K. H. Munde, Vidya Wagh, "Stress Analysis of Crane Hook with Different Cross Section Using Finite Element Method" in Journal of Emerging Technologies and Innovative Research (JETIR, UGC), Volume 6 Issue 1, Jan 2019 ISSN: 2349-5162, pp. 79-83
39. Ashish R. Pawar, Dr. K. H. Munde, Mahesh Mestry, "Pre-Stressed Modal Analysis of Composite Bolted Structure" in Journal of Emerging Technologies and Innovative Research (JETIR, UGC), Volume 5 Issue 7, July 2018 ISSN: 2349-5162
40. Ashish R. Pawar, Kashinath Munde, Vijay Kalantre, "Topology Optimization of Driver Cabin Mounting Bracket of Heavy Commercial Vehicle" in International Journal of Science & Engineering Development Research (IJSDR), Volume 3, Issue 7, July 2018 ISSN: 2455-2631

41. Ashish R. Pawar, Kashinath Munde, Vijay Kalantre, “Topology Optimization of Front Leaf Spring Mounting Bracket” in International Journal of Science & Engineering Development Research (IJSDR), Volume 3, Issue 7, July 2018 ISSN: 2455-2631