Weight Optimization of Drive Shaft Using Various Composite Materials in FEA

Sandeep V. Raut[1], Aditya R. Wankhade[1], Nilesh A. Jadhav[1], Chetan E. Kolambe[1]
[1]Department of Mechanical Engineering, Anantrao Pawar College of Engineering & Research, Parvati, Pune (MH)

Article Info
Page Number:1999-2012
Publication Issue:
Vol 70 No. 2 (2021)

Abstract
In sesctor of Automobile Engineering the power transmission through the shaft is very much important and in any power transmission, the drive shaft plays very important role. The torque generated through the engine of vehicle is converted in usable motive force and transmitted a drive shaft, is a mechanical part that transmits the torque generated by a vehicle's engine into usable motive force to propel the vehicle. By replacing the composite structure with conventional metallic structure one can achieve more advantages with respect to the strength and specific stiffness which is very high in composite material. In current study the fiber composite, fiber glass epoxy and hybrid material is used instead of conventional metallic drive shaft. The optimized design parameters is induced with the composite drive shaft which give the objective of reduction in weight of the drive shaft as well as it enhance the overall performance of the drive shaft. Present work deals with FEA analysis of composite shaft with different composite material. It includes the modeling of shaft in CATIA. The meshing and boundary condition application will be carried using Hypermesh; Structural analysis of composite shaft will be carried out using ANSYS. Composite shaft will be fabricated and tested to validate with numerical values.

Article History
***Article Received**: 05 September 2021*
***Revised**: 09 October 2021*
***Accepted**: 22 November 2021*
***Publication**: 26 December 2021*

Keywords—SHAFT, FEM, drive shaft, bending stress

1. Introduction

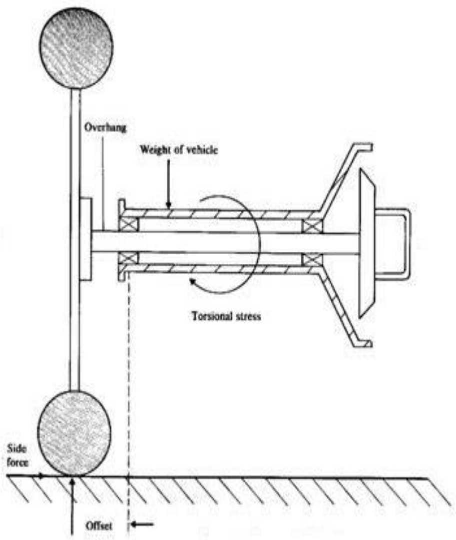
Functions of rear axle drive shaft First, it must transmit torque from the transmission to the differential gear box.

- The drive shaft must also be capable of rotation at the very fast speeds required by the vehicle.
- During the operation, it is necessary to transmit maximum low-gear torque developed by the engine
- The Transmission of the torque should be in the capabilities of the shaft in desired length of shaft. Due to axel moment braking load, torque reaction and most importantly road deflection. The length of the shaft is going to get change. For the same motion the slip joint is introduced within the system for composite material which usually come up with internal and external spline. It is connected to transmission system and located at front end of the drive.
- Constantly changing angles with in transmission system, axels and differential will come under the consideration in the system and shaft should sustained within operating condition

with these fluctuating conditions. The axel and the differential will move up and down as the rear wheels roll through potholes and over bumps in the road.

➢

The axle shaft (half shaft) transmits the drive from the differential sun wheel to the rear hub. The arrangement of a simple rear axle can be seen in the figure, the road wheel attached to the end of the half shaft, which in turn is supported by bearing located in the axle casing. The diagram illustrates the forces acting on the rear axle assembly under a under different operating conditions.



Axle shafts are divided into three main groups:

- Semi-floating
- Three-quarter floating
- Fully floating

Semi-floating: Fig. 1 shows a typical mounting of an axle shaft suitable for light cars. A single bearing at the hub end is fitted between the shaft and the casing, so the shaft will have to resist the stresses. To reduce the risk of failure at the hub end (this would allow the wheel to fall off), the shaft diameter is increased. Any increase must be gradual, since a sudden change in cross-sectional area would produce a stress-raiser and increase the risk of failure.

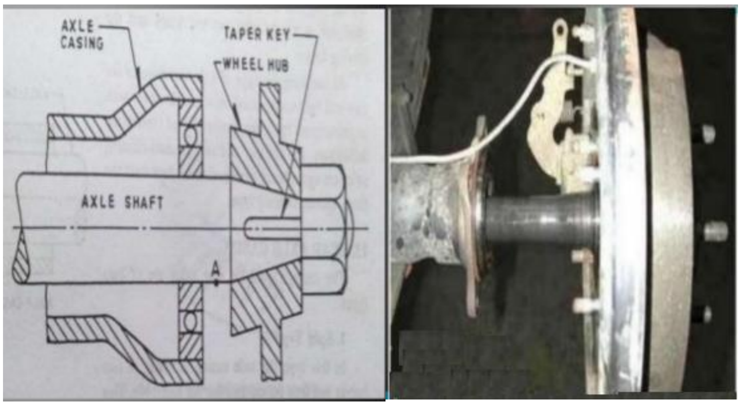


Fig1: Semi floating axle shaft

Although the final-drive oil level is considerably lower than the axle shaft, the large amount of ‘splash’ would cause the lubricant to work along the shaft and enter the brake drum. Sealing arrangements normally consists of an oil retainer fitted at the hub end (the lip of the seal is positioned towards the final drive). The half shaft in this assembly required to be able to withstand the torsion load involved in driving the road wheel, and bending loads in both the horizontal and vertical planes plus the percentage of car weight on the wheel.

Semi floats are limited in capacity, but lighter and cheaper to manufacture. Semi floats are seen on cars and light duty trucks.

Advantage:

- Semi floating axle is the simplest and cheapest and they are widely used in cars

Disadvantage:

- The axles has to be designed for carrying higher loads i.e they are of higher diameter for the same torque transmitted by other types of axle supporting.

Three-quarter floating

Having defined the semi-and the fully floating shaft, any alternative between the two may be regarded as a three-quarter floating shaft. Fig. 2 shows a construction which has a single bearing mounted between the hub and the casing. The main shear stress on the shaft is relieved but all other stresses still have to be resisted. The half shaft must withstand bending loads due to side thrust when cornering and, of course, at the same time transmit driving torque.

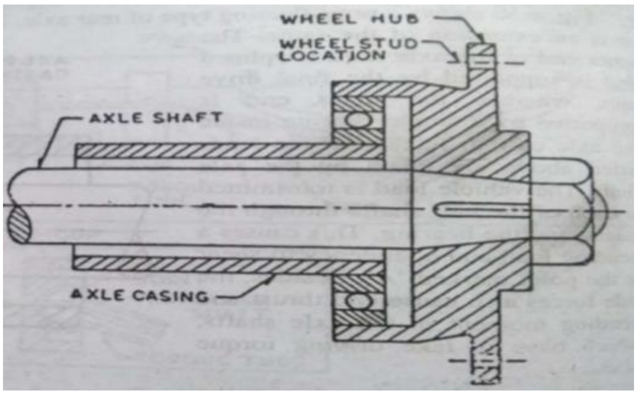


Fig 2: three quarter axle shaft

Advantage:

- At one time, this axle was commonly used for cars and light commercial vehicles.

Disadvantage:

- These axles are no longer preferred. Instead semi floating axles are used.

Fully floating:

This is generally fitted on commercial vehicles where torque and axle loads are greater. The construction shown in Fig. 3 consists of an independently mounted hub which rotates on two bearings widely spaced on the axle casing. This arrangement relieves the shaft of all stresses except torsional, so the construction is very strong. Studs connecting the shaft to the hub transmit the drive and when the nuts on theses studs are removed, the shaft may be withdrawn without jacking up the vehicle. The shaft is to transmit only the driving torque to the rear wheel.

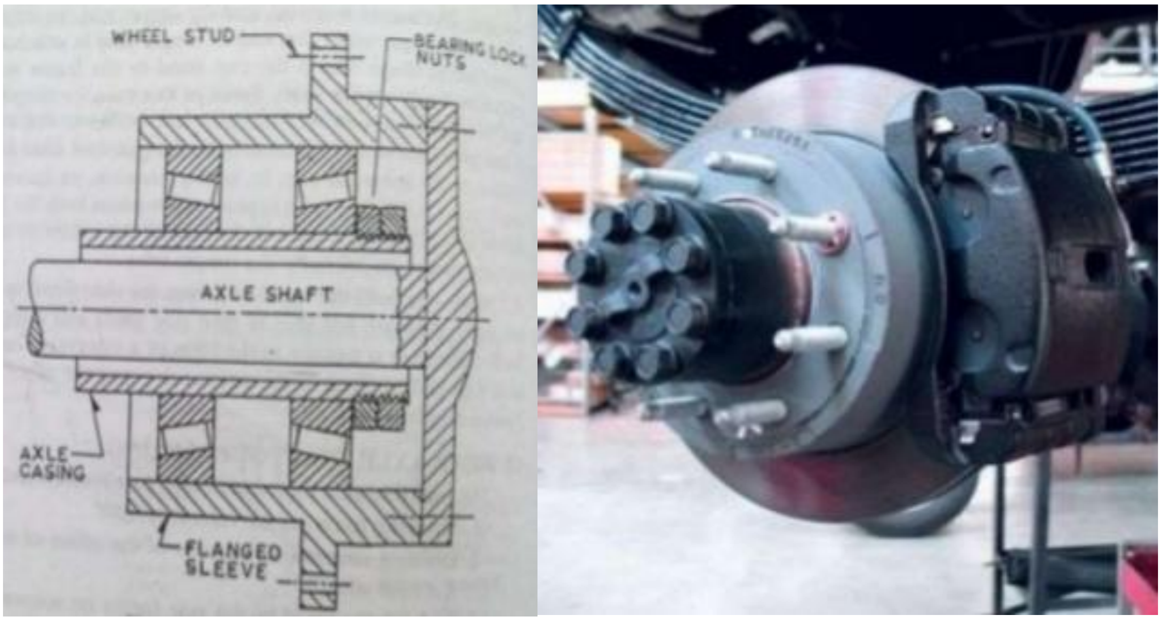


Fig 3: Fully floating drive axle

Advantage:

- These are very robust type and used for heavy vehicles.
- Axle shaft carryout the drive torque so their failure does not affect the vehicle wheels.
- Vehicle can be towed with the broken axle shaft
- Axle shaft can be replaced by without jacking.

Disadvantage:

- Costliest type of axle supporting

Type of axle used:

Semi floating type of drive axle of Bolero car is used for the project purpose. Drive axle and related components are shown here.

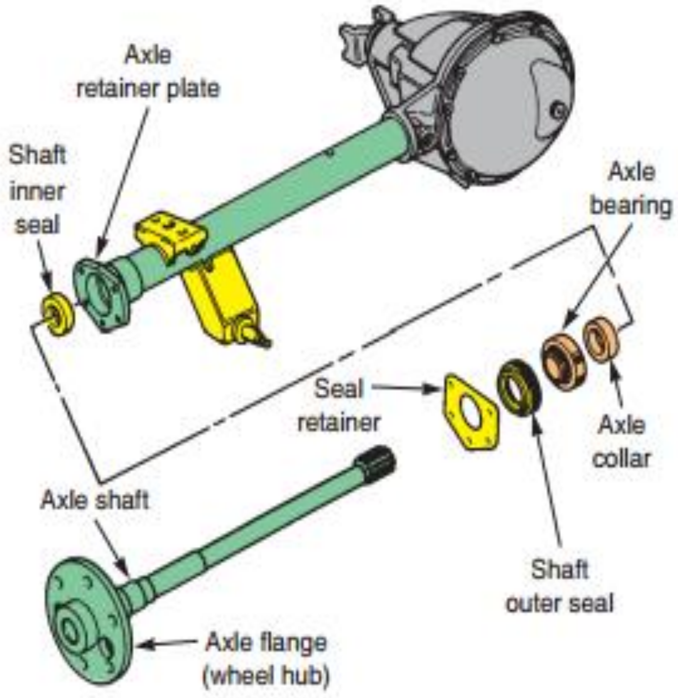


Fig: Drive axle and related component

What are composite materials:

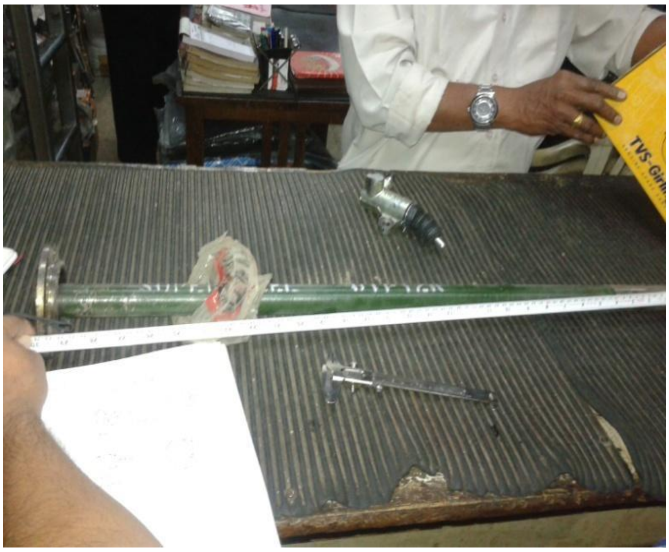
When two or materials comes together in the specific proportion, it will definitely achieve some specific material and structural properties. The solubility of the individual material is not achievable or not merge completely, but both the material can give the results as one new component or material. The extra ordinary and superior properties can be observed in composite material with respect to different factors like mechanical properties end electrical resistivity than the two or more individual materials which is used to develop the same composite material. Fibrous material embedded in a resin matrix is consider as an advanced composite material, generally laminated with fibers oriented in alternating directions to give the material strength and stiffness.

In all directions an isotropic material is having uniform properties. The measured properties of an isotropic material are independent of the axis of testing. The examples of metals for isotropic materials are aluminium and titanium. In composite material, fiber is act as a primary load carrier. one can found out the strong and stiff direction of the fiber. Components made from fiber reinforced composites can be designed so that the fiber orientation produces optimum mechanical properties, but they can only approach the true isotropic nature of metals, such as aluminum and titanium.

In the composite materials, the bonding of the fibers can be achieved through the matrix. Any applied load can be transferred to the fiber s with the help of the matrix by keeping the fibers in their own position and chosen orientation, which gives environmental resistance through composite material and determine the maximum temperature condition in which it can work.

For calculating the boundary conditions the dimenssions are required. Hence it is manditory to have CAD model. Bolero vehicles are embedded with conventional model. With help of hand calculation through reverse engineering the dimensions are calculated. With the use of commands pad, pocket, fillet and geametrical selection in part design module from CATIA, CAD model is designed. To get the dimensions which are useful in forces calculation of axel shaft in terms of static and dynamics loading condition paramatric generation of drawings is use.

Some Hand measurement images:



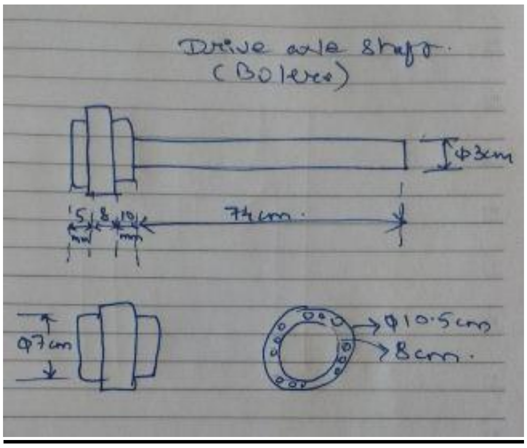
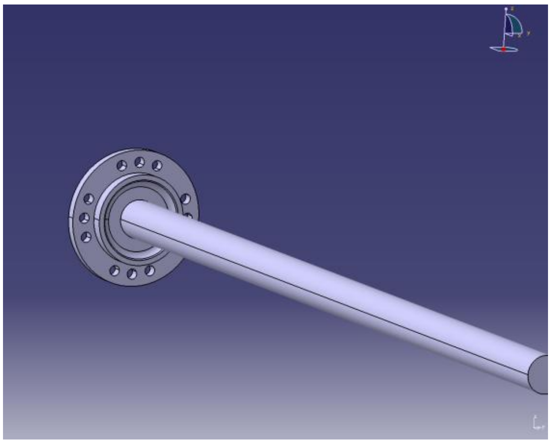


Fig: hand sketch of drive axle



Meshing-:

Infinite number of particles or points are used to form structure or component, hence they must be divided in to some finite number of parts. So in meshing, components are going to get divided in many finite numbers. Dividing helps us to carry out calculations on the meshed part. with the help of nodes and elements one can divide the component. Using 3D element one can mesh the component easily. After all these we used Tetra-Hedral element after getting all the drive shaft dimensions in proportion for meshing.

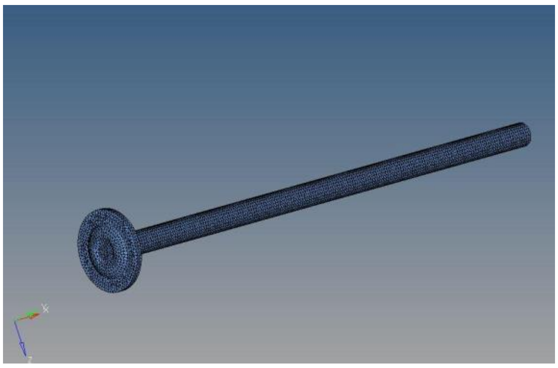


Fig: tetra-hedral meshing on rear axle shaft

Because all software's having limits in number of element, size of the element have to take under the consideration while meshing the mesh size. Less the mesh size more will be the number of elements and coarse the mesh size less will be the number of elements. Run time will increase, as the number of elements increases. Quality is to be checked as one is finished with the meshing of the element. i.e. elements have some definite quality criteria which should be met by all elements. Minimum and maximum angles criterion of the element is fullfill with respect to the quality A quality criterion consists of minimum and maximum angles of the elements, jacobian, warpage etc.

Number of nodes: 10039
Number of elements: 52656
Element size = 4mm

Element
Depending upon the conditions to be satisfied various types of elements are used for meshing.
Point/Mass: This is the basic element: This is represented by a point in space. This element can be used to represent the mass as well as inertia of a component(s) or a portion of a system. Hence this element is also called as a mass element. Mass elements are used to define concentrated mass in a model.

Force calculation:
Condition I: In static condition:

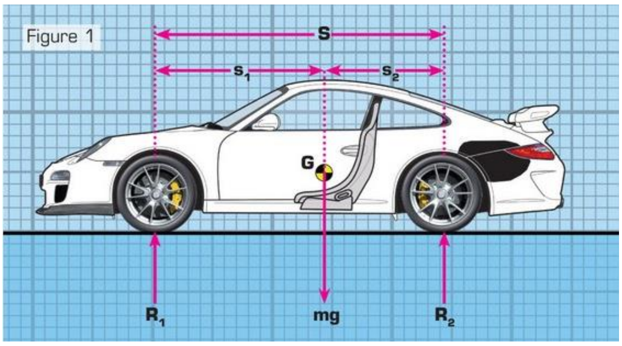


Fig shows the forces on a stationary car. The earth's gravitational pull (mg) acts through the centre of gravity and the reaction (remember: to every action there is an equal and opposite reaction) acts through the contact patches between the tyres and the road. The vectors shown represent the combined reactions at both front wheels (R_1) and both rear wheels (R_2).
Total weight of the car = 1615 kg = 15843.15 N
This weight must be divided into front axle weight and rear axle weight. 52% of total weight is taken by front axle and 48% of total weight is taken by rear axle.
∴ Front axle weight = 839.8 kg = 8238.4 N
∴ Rear axle weight = 775.2 kg = 7604.7 N

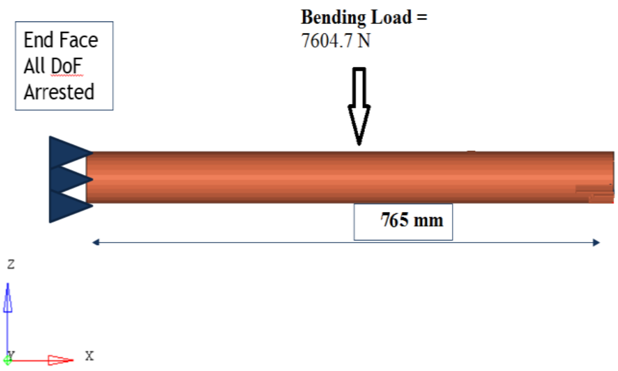


Fig: showing boundary condition for static condition

Condition II: Static + Dynamic loads:
Following is the forces in three directions on wheels:

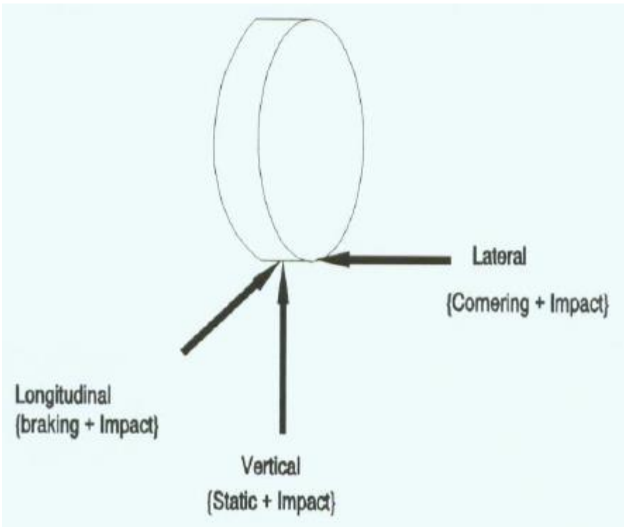


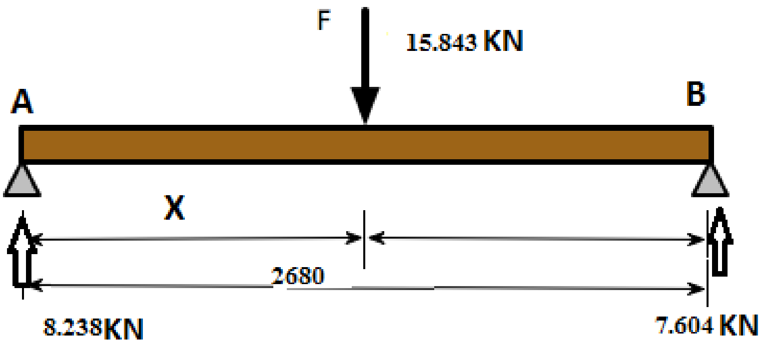
Fig: Wheel loads and directions

Inputs for load calculation:

Sr No.	Description	Symbol	Value
1	Total weight of vehicle	W	15843.15 N
2	Front axle weight	F1	8238.4 N
3	Rear axle weight	F2	7604.712 N
4	Tire rod coefficient	μ	1.5
5	Wheel base	l	2680 mm
6	Avg acceleration	ā	2.5 m/s^2
7	Vehicle mass	m	1200 kg
8	Centre of gravity height	hcg	940 mm

1. **Front Axle Breaking Force (*FB*) per Wheel:**
   FB= μ/2[Static+ dynamic load]
   = μ/2[W* bcg/l + m* ā *hcg/l]
   = μ/2 W [bcg/l +ā/g hcg/l]

We have to find the term bcg, Consider a simply supported beam, where force F= 15.843KN which acts at a distance X from point A



Taking moment at point A-
ΣmA= 15.843 * X – 7.604 * 2680 = 0,
X= 1286.3 mm.
bcg = 2680 – X = 1393.7 mm
Breaking force FB can be calculated as FB = 13.92 KN

2. **Vertical Force (*FV*)-**

FV = 3/2 [Static+ dynamic load]
FV = 3/2 [W *bcg/l + m* ā *hcg/l]
=3/2 W [bcg *g + ā *hcg / gl]
= 26.887 KN

3. **Lateral Force (*FL*)-**

FL = W [Static+ dynamic load]
FL = W [bcg* g + ā* hcg / gl]
= 9.018 KN

Material Properties for steel:

Property	Value
Young's Modulus, E	205 GPa
Poisson's Ratio ,ν	0.29

Density, ρ	7850 kg/m^3

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Dr. Pradeep J. Awasare (Adjunct Professor), Er. Ashok Saraf (Innovation Club Member) for their invaluable guidance and support throughout the research process. We also wish to thank Dr. Sunil B. Thakare (Principal, APCOER, Pune) for their support. Finally, we are grateful to all of the research participants who generously gave their time and effort to this project.

REFERENCES

2. Bhirud Pankaj Prakash, Bimlesh Kumar Sinha, "Analysis Of Drive Shaft**",** International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Volume- 2, Issue- 2, Feb.-2014
3. Pandurang V Chopde, Prof. R.B.Barjibhe, "Analysis of Carbon/Epoxy Composite Drive Shaft for Automotive Application", International Journal of Latest Trends in Engineering and Technology, Vol. 5 Issue 1 January 2015, ISSN: 2278-621
4. Dhablia, D., & Timande, S. (n.d.). Ensuring Data Integrity and Security in Cloud Storage.
5. Dhabalia, D. (2019). A Brief Study of Windopower Renewable Energy Sources its Importance, Reviews, Benefits and Drwabacks. Journal of Innovative Research and Practice, 1(1), 01–05.
6. Mr. Dharmesh Dhabliya, M. A. P. (2019). Threats, Solution and Benefits of Secure Shell. International Journal of Control and Automation, 12(6s), 30–35.
7. Verma, M. K., & Dhabliya, M. D. (2015). Design of Hand Motion Assist Robot for Rehabilitation Physiotherapy. International Journal of New Practices in Management and Engineering, 4(04), 07–11.
8. Bhimagoud Patil, Fayaz Kandagal, Vinoth M.A, "Weight Optimization and FEA Analysis of Al-Si Metal Matrix Composite Drive Shaft", International Journal Of Engineering And Computer Science ISSN:2319-7242 Volume - 3 Issue - 8 August, 2014 Page No. 7713-7717
9. D. Patil, Prof. D.S.Chavan, Prof. M.V.Kavade, "Investigation of Composite Torsion Shaft for Torsional Buckling Analysis using Finite Element Analysis", Journal of Mechanical and Civil Engineering, ISSN: 2278-1684 Volume 4, Issue 3 (Nov-Dec
10. M.Arun, K.Somasundara Vinoth, "Design and Development of Laminated Aluminum Glass Fiber Drive Shaft for Light Duty Vehicles", International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-2, Issue-6, May 2013
11. Chaitanya G Rothea, A.S.Bombatkarb, **"**Design and Analysis of Composite Material Drive Shaft", International Journal of Innovative and Emerging Research in Engineering Volume 2, Special Issue 1 MEPCON 2015
12. Chaitanya G Rothea, A.S.Bombatkar, "Design and Analysis of Composite Material Drive Shaft", International Journal of Innovative and Emerging Research in Engineering Volume 2, ISSN- 2394-3343".
13. Ashish R. Pawar, "Roof Crash Simulation of Passenger Car for Improving Occupant Safety in Cabin" in Elsevier Journal

14. Ashish R. Pawar, “Design and Development: A Simulation Approach of Multi-Link Front Suspension for an All-Terrain Vehicle”, SAE Technical Paper, SIAT 2021
15. Aditya Pawar, Aniket Wanjale, Harshal Wanjale, Yash Sathe, Ashish R. Pawar, “Static Structural 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
16. 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 of Analysis & Computation (IJAC, UGC), Volume XV Issue VI, June 2021 ISSN: 0973-2861, pp. 91-100
17. 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
18. 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
19. 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
20. 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
21. 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
22. 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
23. 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
24. 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
25. 13. 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
26. 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.

27. 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
28. 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
29. 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
30. 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
31. 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
32. 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
33. Ashish Pawar, Balasaheb Takale, “ ” in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
34. 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
35. 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
36. 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
37. Ashish Pawar, Makarand Patil, Ganesh Kondhalkar, “Predication of Effect of Welding Process Parameter of MIG Process on Weld Bead Geometry” in Journal of Analysis & Computation (IJAC, UGC), Volume XIV Issue VII, July 2020 ISSN: 0973-2861
38. 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
39. 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
40. 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

41. 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
42. 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