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DESIGN AND ANALYSIS OF 2 WHEELER HAND BRAKE LEVER

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ABSTRACT
The design and analysis of a 2-wheeler hand brake lever is a critical process in ensuring both safety and efficiency in automotive systems. Hand brake levers serve as a crucial interface between the vehicle's occupant and its braking mechanism. However, existing designs often appear over engineered, suggesting potential for optimization. In this study, we aim to refine the hand brake lever design through a combination of advanced modeling, analysis, and material optimization techniques. The process begins with solid modeling of the existing hand brake lever using CATIA V5 software, laying the foundation for a detailed analysis. Finite element analysis (FEA) is then employed to simulate the structural behavior of the lever under cantilever loading conditions. To further enhance the design, a topology optimization solver is utilized, which identifies non-critical regions where material can be removed without compromising structural integrity. This optimization process is expected to reduce the weight of the lever from its original mass. A significant weight reduction is achieved through the application of carbon fiber composite material, which is substituted for traditional materials in the optimized model. The use of carbon fiber not only decreases the overall mass but also enhances the strength and durability of the lever. Static analysis of the carbon fiber-reinforced lever is conducted using ANSYS19 software to evaluate its performance under various load conditions. Experimental validation is carried out using a Universal Testing Machine (UTM) to ensure that the optimized design meets real-world performance standards. A comparative analysis between the FEA results and experimental data confirms the reliability and accuracy of the simulation. The findings reveal that the optimized design successfully reduces the lever's mass by 12.16%, with a minimal increase in equivalent stress. The maximum deformation is significantly reduced, ensuring that the lever maintains its structural performance while benefiting from the reduced weight. The integration of carbon fiber epoxy further strengthens the lever, offering superior mechanical properties and long-term reliability. This study not only demonstrates the effectiveness of topology optimization and advanced materials in improving automotive components but also sets the stage for future developments in lightweight, high-performance brake systems for 2-wheelers.

Keywords—
Hand Brake, UTM, CATIA, Optimization.

I. INTRODUCTION

In the arrangement of street vehicles, the leaving brake, otherwise called the hand brake, crisis brake or e-brake, is utilized to keep the vehicle fixed and as a rule a crisis stop is additionally performed. Leaving brakes activity framework on more seasoned vehicles regularly comprise of a link associated with two wheel brakes toward one side and the opposite end to a pulling component which is worked with the driver's hand or foot. The instrument might be a hand-worked switch, at floor level close to the driver, or a straight draw handle situated close to the controlling section, or a (foot-worked) pedal situated next to the driver’s leg. In many vehicles the leaving stopping mechanism process works just on the back wheels, which have diminished footing while at the same time slowing down. A few vehicles have the leaving brake on the front wheels, for example, most Citroens made since the finish of the Second World War and early models Saab 900.

Fig.1 Hand break Leaver

The most widely recognized use process framework for a leaving brake is to keep a vehicle unmoving when it is left fig no.1.1. The stopping framework brake has a fastener or other locking instrument that will keep it connected with until physically discharged. On vehicles with programmed transmissions process framework, this is normally utilized working together with a leaving pawl in the transmission. An ongoing variety is the electric stopping brake. First introduced in the 2001 BMW 7 Series (E65), electric leaving brakes have since showed up in various vehicles. Two varieties process framework are accessible: In the more-conventional "link pulling" type, an electric engine essentially pulls the stopping brake link on the press or pull of a catch rather in the lodge, as a mechanical pedal or handle. A progressively intricate unit (first observed on the 2003 Audi A8) utilizes a PC controlled engine connected to every one of the two back brake calipers alluded to as the Motor on Caliper(MoC) framework. Hand brake levers are cantilever structure utilized for moving movement from inhabitant to slow down instrument. Existing plan should be examined for mass improvement, subsequently decreasing in general expense of brake levers. The destinations of this undertaking is to accomplish geography improved model for hand brake switch utilizing FEA and exploratory pressure investigation method. To draw 3 D model utilizing CATIA and to investigate hand brake utilizing ANSYS. To approve the outcomes. [1]

1.1 BRAKE HANDLE SYSTEMS

There are two main types of brake handle systems: conventional and radial. In a conventional system (Fig. 2a), the vibrations and reaction forces of the hydraulic circuit are acting on the brake lever in a perpendicular direction with respect to the force made by the pilot's hand. Furthermore, the forces are typically transmitted between components of the mechanism by contact, without pivots that prevents slipping. In a radial system (see Fig. 2b), the piston moves in radial direction with respect to the motorcycle handlebar. Therefore, the hydraulic force acts on the brake lever in the same direction to the force made by the pilot's hand. In addition, forces are transmitted through pivot linkages and since longer lever arms are habitually used, higher mechanical multiplications are achieved. When a radial brake handle is used more sensibility and control is obtained, which involves greater driving safety. Nevertheless, it is a less robust system against possible impacts. Looking at the configuration of a conventional system, this presents a compact structure in which the mechanism is protected inside the body of the brake pump. If damages are produced, these likely only will affect to the lever. Due to their better qualities, it is expected a more elevated use of the radial system on large displacement motorcycles that do not incorporate ABS and even on other types of motorcycles.

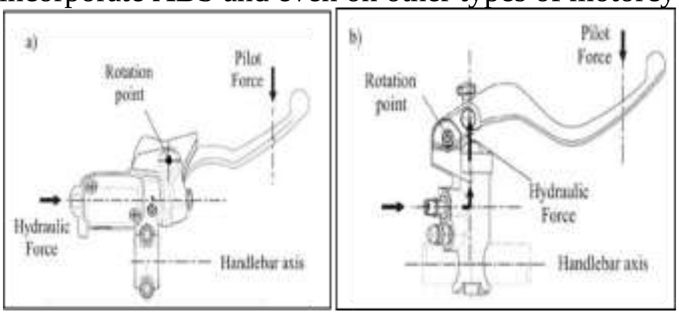

Fig. 2 Brake handle systems

II. LITERATURE REVIEW

M.R. Mansor et al. In this article writer portray about glass strands strengthened polymer composites material and car brake switch structure. Because of late pattern and expanding mindfulness towards supportable item plan, characteristic based fiber materials are increasing a recovery fame to supplant manufactured based fiber in the detailing of composites particularly for car basic and semi auxiliary applications. Improvement of car parts only from time to time requires the thought of three central point which are the segment geometrical structure determination, material choice and assembling process choice, most fundamentally in the early item configuration stage. [2]

J.L. Santolaya et al.In this paper creator chiefly engaged to configuration front brake handle for huge removal bikes. In a stopping mechanism that follows up on the front wheel of a bike is conceivable recognize three distinct parts (De Castro, 2001): the brake handle, which works the pilot with his correct hand, the pressure driven transmission and the unit shaped by the cylinders and the brake braces, which at last makes the power on the brake circles fixed to the wheel. This work centers around the plan of a brake handle, which is framed by two principle pieces: the switch and the ace chamber.[3]

M.R. Mansor et al. This paper presents the calculated structure of kenaf fiber polymer composites car leaving brake switch utilizing the mix of Theory of Inventive Problem Solving (TRIZ), morphological outline and Analytic Hierarchy Process (AHP) techniques. The point is to create and choose the best idea plan of the part dependent on the item structure details with uncommon regard for consolidate the utilization of common fiber polymer composites into the segment plan. In this paper, the TRIZ inconsistency grid and 40 innovative standards arrangement apparatuses were applied in the early arrangement age stage.[2]

Yvan Champouxa et al. This paper speaks to Dynamic adjustment of an instrumented bicycle brake hood in estimating power consumed by the hands. One of the most huge variables in ride quality in cycling sports are the vibrations produced by street surface imperfections going through the bike and sent to the cyclist's hands and backside. To examine comfort, one metric that has been advanced is the estimation of the force assimilated at the cyclist's hands. Estimating consumed power requires the utilization of the power and the speed at the hands and gives a general vitality based amount. The point of this examination is to progressively adjust an instrumented brake hood transducer to gauge the force assimilated at the cyclist's hands.[4]

Zhaobo Qina et al. In this paper creator portray about half and half followed vehicles. Cross breed followed vehicles have gotten progressively well known for rough terrain applications because of their better mileage and higher yield power. Right now, the most mainstream in the creation of followed vehicles are the arrangement half and half, due to the straightforward powertrain plans. In any case, they experience the ill effects of high vitality transformation misfortunes and huge drive engines. To defeat these issues, multi-mode half and half followed vehicles are utilized since they have high productivity and astounding in general execution.[5]

Mohd-Razmi Ishak et al The effect of the reduction of drum brake temperature on the clamping force of the parking brake system has not been well addressed despite the fact that it may result in vehicle roll away. In view of this, parking brake model that takes into account the temperature reduction of the drum brake has to be developed and more importantly, it must comply with the applicable standards or regulations such as FMVSS 135. This paper develops a one- dimensional (1D) model of leading trailing drum-type parking brake model. This brake model is then verified with experiments carried out on a test bench that has been calibrated with the hand brake system in the vehicle.[6]

M.M. Davoodi Et Al. In this paper, a study of conceptual design of fiber reinforced epoxy composite bumper absorber is presented. This study describes the use of the composite in energy absorption in car bumper as a pedestrian energy absorber. The systematic exploitation of proven ideas or of experience was used to generate the ideas and the most suitable idea was followed as a guide for

Industrial Engineering Journal
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conceptual design. The absorber was analyzed experimentally and the data from these experiments were used to decide on the number of energy absorber to be used in the design. Final design of the composite energy absorber in elliptical shape with two slots at both ends was considered.[7]
G.X. Chen Et Al In this article suppress or eliminate brake squeal of light rail trains, a field test measurement and a finite element analysis of disc brake squeal were carried out. In the field test measurement, the braking air pressure, speed of the axle, vibration accelerations of a back plate were measured. The brake squeal test was carried out in five brake conditions frequently used. Test results show that disc brake squeal generally occurred in the maximum common compound brake condition. The occurrence propensity of brake squeal depends on the variation of braking air pressure against time.[8]

III. PROBLEM STATEMENT

The hand brake lever in two-wheelers is a crucial cantilever structure designed to transfer motion from the rider to the braking mechanism. Current designs often result in suboptimal mass distribution and excessive material usage, leading to increased production costs and potential performance inefficiencies. There is a need to investigate and optimize the design of hand brake levers to enhance their structural efficiency while reducing overall mass. This optimization aims to lower production costs, improve performance, and ensure the lever meets safety and durability standards effectively.

IV. MATERIALS AND METHODS

Safety and performance depend on two-wheeler hand brake lever design and analysis. The ideal design parameters and material characteristics of two-wheeler hand brake levers are investigated in this study figure 3.1. After reviewing brake lever design literature, a prototype is developed using theoretical ideas. The brake lever's mechanical behaviour under different load circumstances will be assessed using Finite Element Analysis (FEA) to ensure its durability and efficiency. Experimental testing will verify FEA findings and improve the design. This method will help improve two-wheeler brake lever performance and safety.

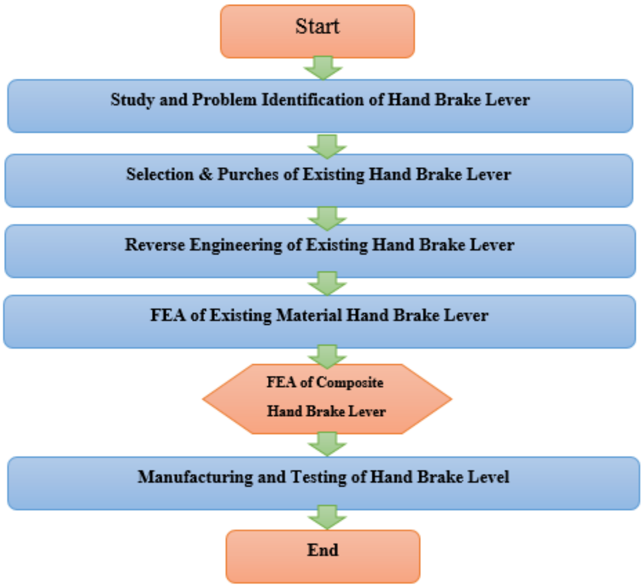

Fig. 3 Research Methodology Flowchart

V. DESIGN

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and

Industrial Engineering Journal
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Volume : 54, Issue 5, No.3, May : 2025

to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

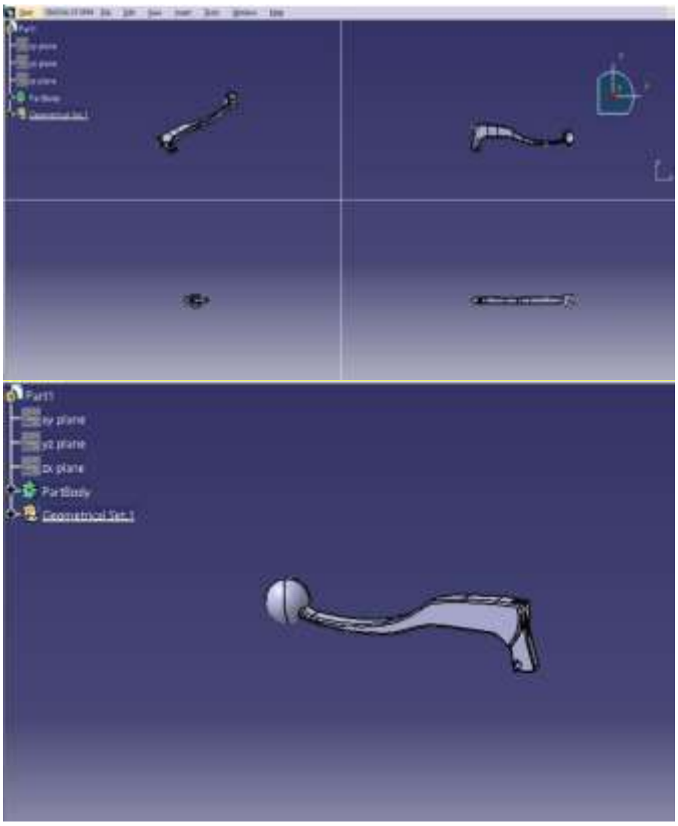
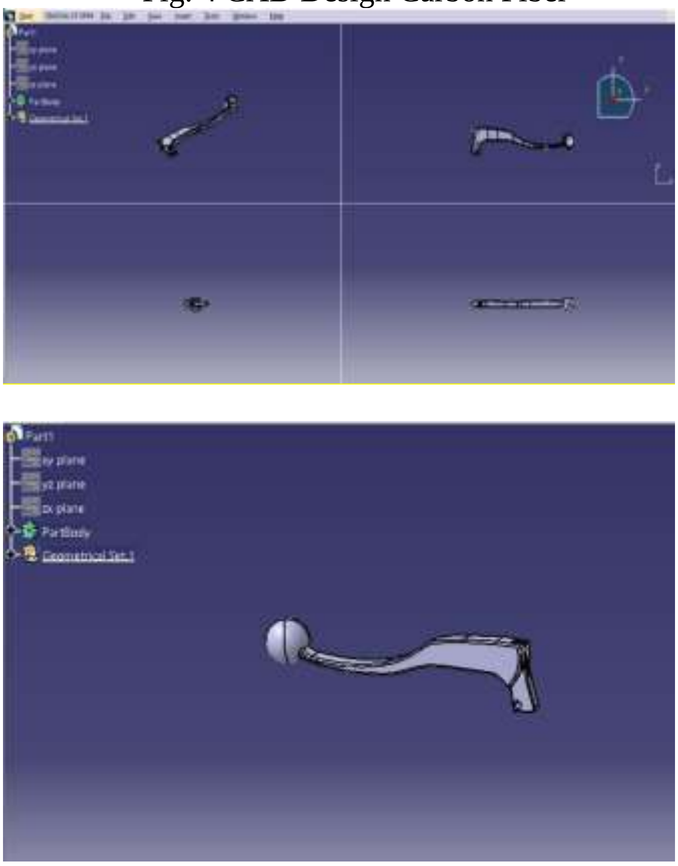


Fig. 4 CAD Design Carbon Fiber



Industrial Engineering Journal
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Volume : 54, Issue 5, No.3, May : 2025

Fig. 5 CAD Design Aluminum

Figure 5 illustrates the CAD design of a two-wheeler hand brake lever made from aluminum. The design incorporates ergonomic features for user comfort and operational efficiency, ensuring durability and light weight. The lever's geometry is optimized for smooth functioning and strength under load.

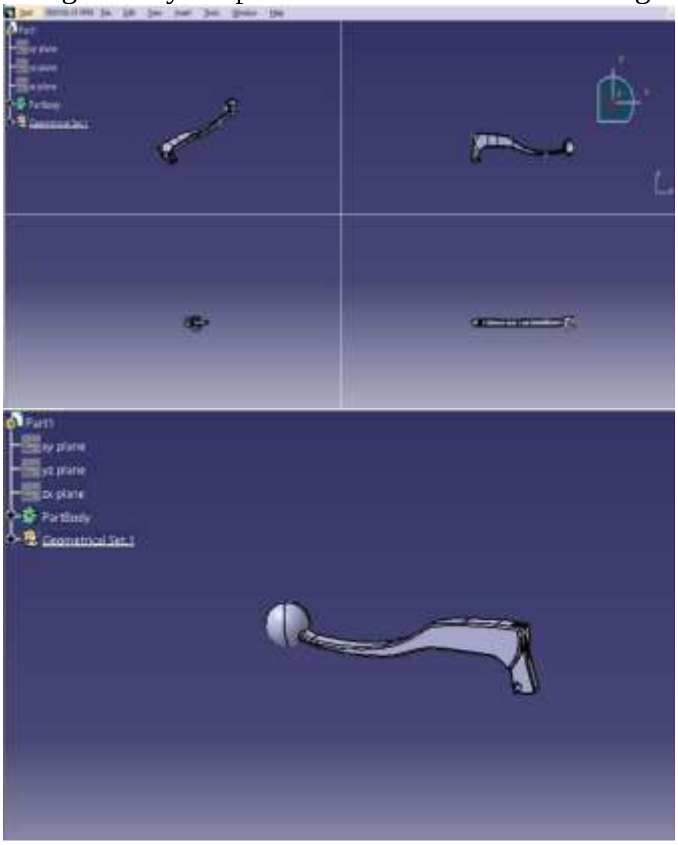


Fig. 6 CAD Design Magnesium Alloy

Figure 6 illustrates the CAD design of a two-wheeler hand brake lever made from magnesium alloy. The design focuses on optimizing strength and reducing weight, essential for enhancing performance. Magnesium alloy is chosen for its high strength-to-weight ratio, corrosion resistance, and durability.

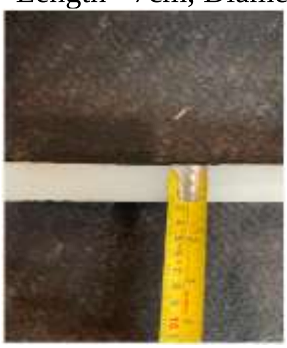
VI. MANUFACTURING OF COMPOSTE MATERIAL

6.1 OPEN MOLDING

Composite materials (resin and fibers) are placed in an open mold, where they cure or harden while exposed to the air. Tooling cost for open molds is often inexpensive, making it possible to use this technique for prototype and short production runs.

6.2 HAND BRAKE LEVER DESIGN

Length= 7cm, Diameter= 1cm, Width= 7cm



Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 5, No.3, May : 2025

Fig. 7 Hand Brake Lever Dimension

As shown above this design features a compact and efficient lever tailored for effective braking performance in two-wheeler applications.

VII. SPECIFICATION OF UTM

1	**Max Capacity**	**400KN**
2	Measuring range	0-400KN
3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase, 440Volts, 50 cycle, A.C
9	Overall dimension of machine (L*W*H)	2100*800*2060
10	Weight	2300Kg

Fig. 8 Specification of UTM

As shown in above table illustrates a testing machine with a maximum capacity of 400 kN and a measuring range extending from 0 to 400 kN, ensuring precision with a least count of 0.04 kN. It accommodates tensile tests with a clearance range of 50-700 mm and compression tests with a 0-700 mm clearance. The machine features a 500 mm column spacing and a 200 mm ram stroke. It operates on a 3-phase, 440V, 50 Hz AC power supply and has overall dimensions of 2100 mm (L) x 800 mm (W) x 2060 mm (H). The machine weighs 2300 kg, making it robust and capable of handling substantial testing loads.

Fig. 9 UTM Machine

UTM TESTING RESULTS

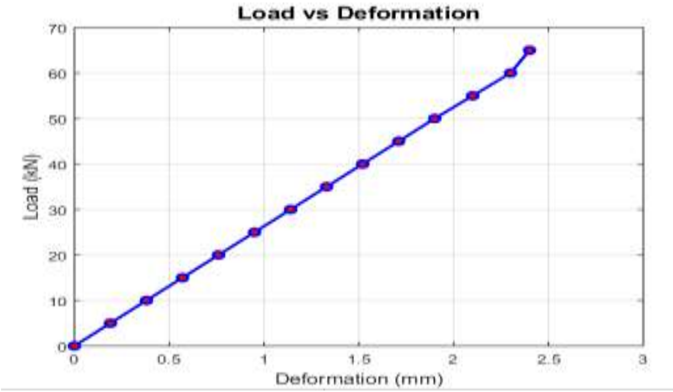


Figure 10 Aluminum Material UTM Test Results

As show above figure 9 he aluminum alloy used in the design of the two-wheeler hand brake lever can withstand a maximum load of 65 kN. It exhibits a yield strength of 210 MPa and an ultimate strength of 350 MPa, with an elongation percentage of 10%, indicating its ductility and suitability for structural applications.

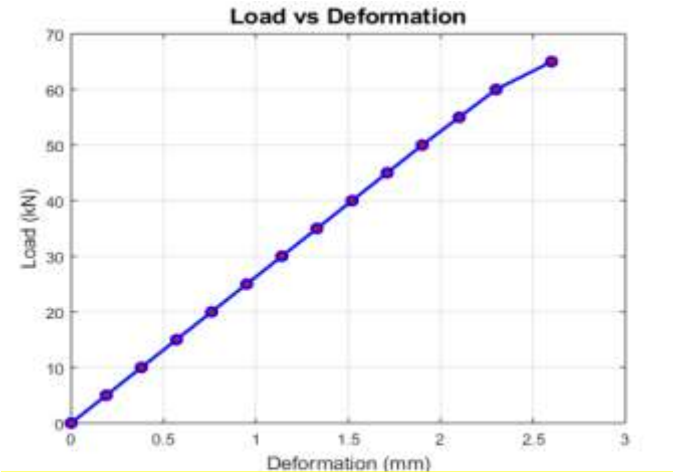


Fig 11 Carbon Fiber UTM Test Results

The design and analysis of a two-wheeler hand brake lever require consideration of various materials as shown figure 11 Carbon fiber, known for its high strength-to-weight ratio, can sustain a maximum load of 70 kN. With a yield strength of 400 MPa and an ultimate strength of 600 MPa, it demonstrates durability with an elongation of 5%.

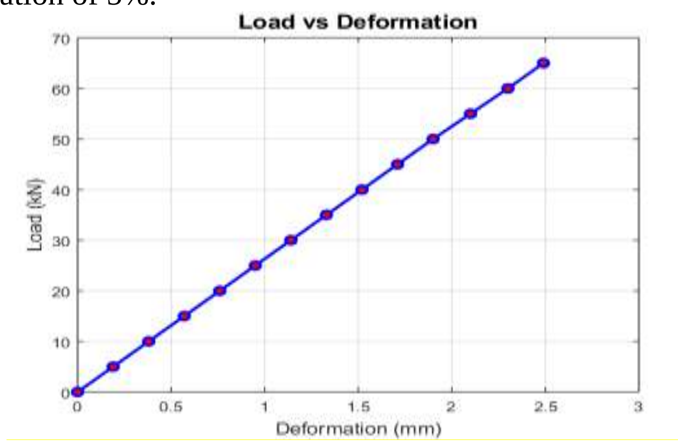


Fig. 12 Magnesium Alloy UTM Test Results

Industrial Engineering Journal
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Volume : 54, Issue 5, No.3, May : 2025

The hand brake lever for two-wheelers is designed using magnesium alloy due to its favorable properties as shown above figure 12 This material can withstand a maximum load of 60 kN, has a yield strength of 200 MPa, an ultimate strength of 330 MPa, and an elongation of 12%, ensuring durability and performance under stress.

VIII. MATERIAL COMPARISON RESULTS

Material	Maximum Load (kN)	Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation (%)
Aluminum Alloy	65	210	350	10
Carbon Fiber	70	400	600	5
Magnesium Alloy	60	200	330	12

Fig 13 Material Comparison Results

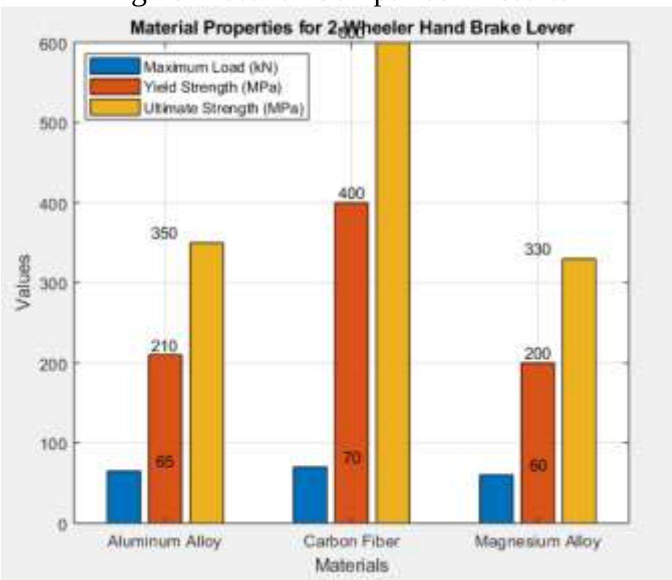

Fig. 14 Load Apply Different Material 2 Wheeler Hand Brake Lever

- Maximum Load: The maximum load capacity indicates the strength of each material under tensile loading. Carbon fiber exhibits the highest load capacity at 70 kN, making it the most suitable choice for high-load applications, while the magnesium alloy supports up to 60 kN.
- Yield Strength: This value represents the stress at which a material begins to deform plastically. Carbon fiber again shows the highest yield strength (400 MPa), indicating its superior ability to withstand initial deformation. Aluminum alloy has a yield strength of 210 MPa, while magnesium alloy has the lowest at 200 MPa.
- Ultimate Strength: This refers to the maximum stress that a material can withstand while being stretched or pulled before failing. Carbon fiber leads in ultimate strength (600 MPa), significantly higher than aluminum alloy (350 MPa) and magnesium alloy (330 MPa), making it ideal for high-stress applications.
- Elongation: Elongation percentage gives insight into ductility, showing how much a material can deform before it fractures. Magnesium alloy exhibits the highest elongation at 12%, indicating better ductility, followed by aluminum alloy at 10%. Carbon fiber has the lowest elongation (5%), suggesting it is more brittle compared to the others.

IX. RESULTS

Total Deformation

Industrial Engineering Journal
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Volume : 54, Issue 5, No.3, May : 2025

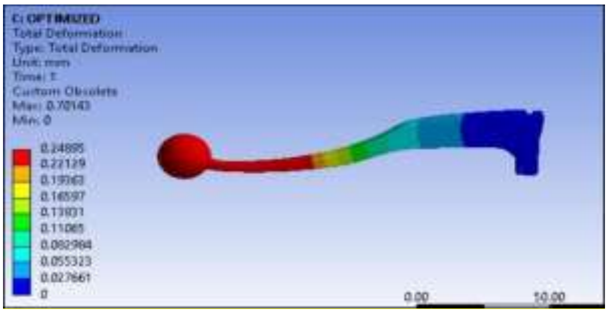


Fig. 15 Total Deformation of optimized hand brake lever

The figure 15 illustrates the total deformation of the optimized hand brake lever. The maximum deformation is 0.70143 mm, while the minimum deformation is 0 mm. The data points reflect incremental deformation values, ranging from 0.027661 mm to 0.70143 mm. The deformation is represented in millimeters, showcasing the lever's structural integrity under optimized conditions. The distribution of deformation values highlights the areas of maximum and minimum strain, essential for assessing the lever's performance and durability.

Equivalent Stress

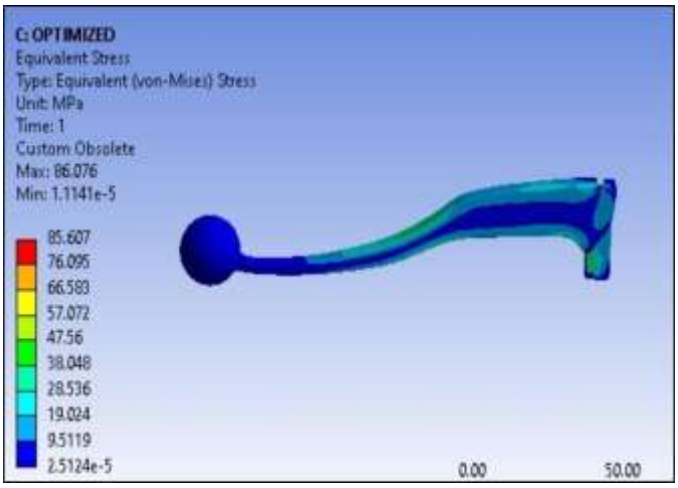
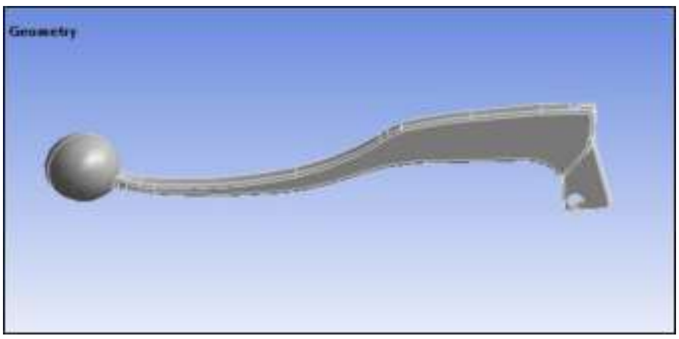


Fig. 16 Equivalent Stress of optimized hand brake lever

The figure 16 presents the equivalent stress distribution of the optimized hand brake lever. The von-Mises stress ranges from a minimum of nearly zero (1.1141e-5 MPa) to a maximum of 86.076 MPa. The stress values indicate a concentration of stress around critical areas of the lever, with the highest stress observed at specific points. The stress distribution suggests effective optimization, with most of the lever experiencing significantly lower stress levels, ensuring durability and performance.

X. STATIC ANALYSIS OF OPTIMIZE MAGNESIUM ALLOY HAND BRAKE LEVER

Geometry



Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 5, No.3, May : 2025

Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
1	Epoxy Carbon Woven (230 GPa) Prepreg	1	0
(-Z)			

	A	B	C
1	Property	Value	Unit
2	Density	1420	kg m^-3
3	Orthotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion X direction	2.2E-06	C^-1
6	Coefficient of Thermal Expansion Y direction	2.2E-06	C^-1
7	Coefficient of Thermal Expansion Z direction	1E-05	C^-1
8	Orthotropic Elasticity		
9	Young's Modulus X direction	6.134E+10	Pa
10	Young's Modulus Y direction	6.134E+10	Pa
11	Young's Modulus Z direction	6.9E+09	Pa
12	Poisson's Ratio XY	0.04	
13	Poisson's Ratio YZ	0.3	
14	Poisson's Ratio XZ	0.3	
15	Shear Modulus XY	3.3E+09	Pa
16	Shear Modulus YZ	2.7E+09	Pa
17	Shear Modulus XZ	2.7E+09	Pa

Fig. 17 Material Properties of Magnesium Alloy

As shown above figure 17 Magnesium Alloy exhibits exceptional strength-to-weight ratio, high tensile strength, low thermal expansion, and excellent fatigue resistance. It is lightweight, durable, and commonly used in automotive applications for improved performance.

Meshing

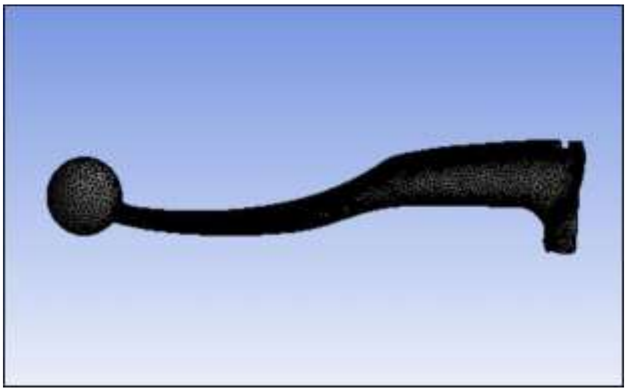


Fig. 18 Meshing

This figure 18 illustrates the meshing process in the design analysis of a two-wheeler hand brake lever, showing the grid pattern used for finite element analysis.

Boundary Condition

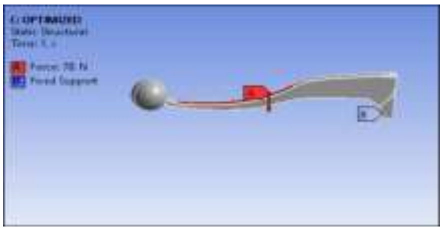


Fig. 20 Boundary Condition

This figure 20 illustrates the applied boundary conditions for the 2-wheeler hand brake lever analysis, showing fixed supports and load application points essential for structural integrity evaluation.

XI. RESULTS

Total Deformation

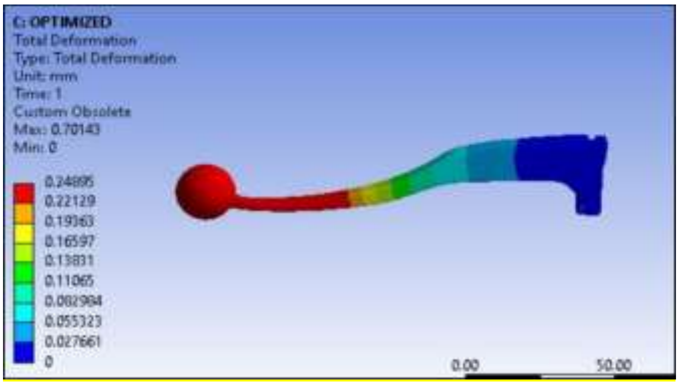


Fig. 21 Total Deformation of optimized hand brake lever with Magnesium Alloy

The figure 21 illustrates the total deformation of an optimized hand brake lever reinforced with carbon fiber. The deformation is measured in millimeters (mm), with the maximum deformation being 0.26564 mm and the minimum being 0 mm. The deformation values decrease progressively, showing a gradient from the maximum deformation at 0.26564 mm to lower values, indicating improved strength and reduced deformation due to the carbon fiber reinforcement. The data suggests effective enhancement in the lever's structural integrity.

Equivalent Stress

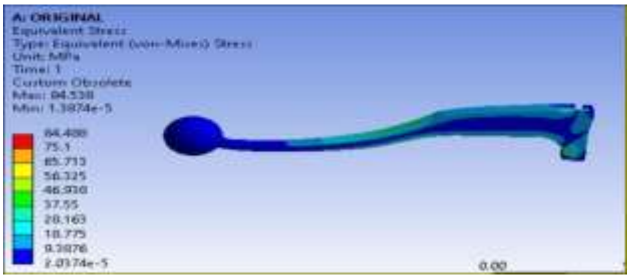
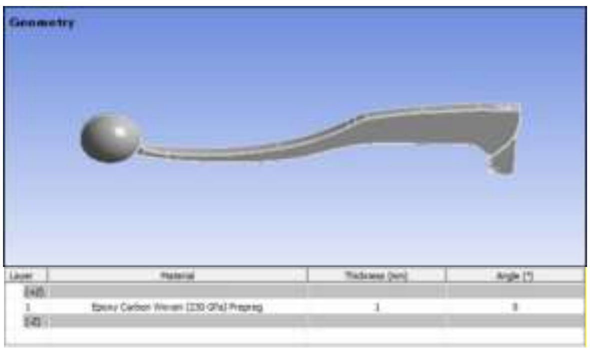


Fig. 22 Equivalent Stress of optimized hand brake lever with Magnesium Alloy

In the design and analysis of a two-wheeler hand brake lever with carbon fiber reinforcement, the figure shows the distribution of equivalent von-Mises stress across the component. The maximum stress observed is 84.488 MPa, while the minimum stress is 0.0000203 MPa. The stress distribution indicates that the lever's reinforcement effectively reduces the stress in certain areas, with the highest stress occurring at critical points where the lever experiences the most load. This analysis ensures that the hand brake lever is optimized for strength and durability.

ALUMINIUM ALLOY WITH CARBON FIBRE REINFORCEMENT HAND BRAKE LEVER ANALYSIS

Geometry



Industrial Engineering Journal
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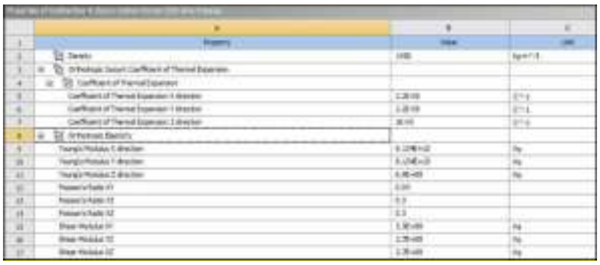

Fig 23 Material Properties of carbon fibre

As shown above fig. 23 Carbon fibre exhibits exceptional strength-to-weight ratio, high tensile strength, low thermal expansion, and excellent fatigue resistance. It is lightweight, durable, and commonly used in automotive applications for improved performance.

Meshing

This figure 24 illustrates the meshing process in the design analysis of a two-wheeler hand brake lever, showing the grid pattern used for finite element analysis

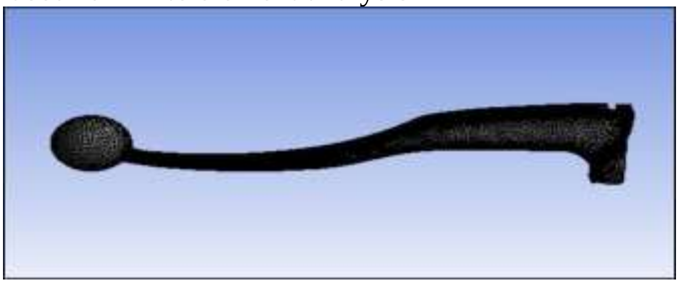

Fig. 24 Meshing

Boundary Condition

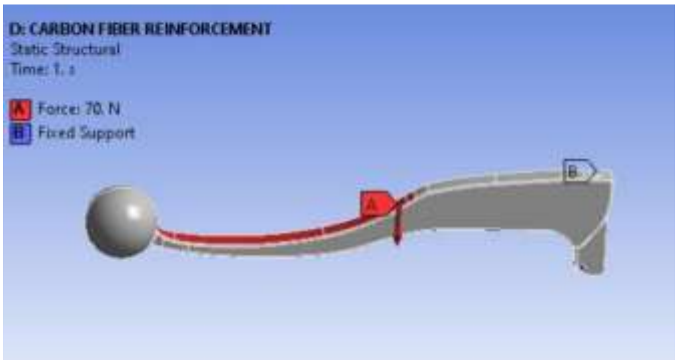

Fig. 25 Boundary Condition

This figure 25 illustrates the applied boundary conditions for the 2-wheeler hand brake lever analysis, showing fixed supports and load application points essential for structural integrity evaluation.

RESULTS

Total Deformation

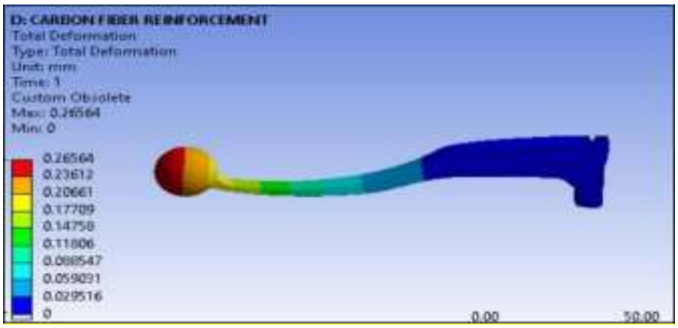

Fig. 26 Total Deformation of optimized hand brake lever with carbon fibre reinforcement

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 5, No.3, May : 2025

The figure 25 illustrates the total deformation of an optimized hand brake lever reinforced with carbon fiber. The deformation is measured in millimeters (mm), with the maximum deformation being 0.26564 mm and the minimum being 0 mm. The deformation values decrease progressively, showing a gradient from the maximum deformation at 0.26564 mm to lower values, indicating improved strength and reduced deformation due to the carbon fiber reinforcement. The data suggests effective enhancement in the lever's structural integrity.

Equivalent Stress

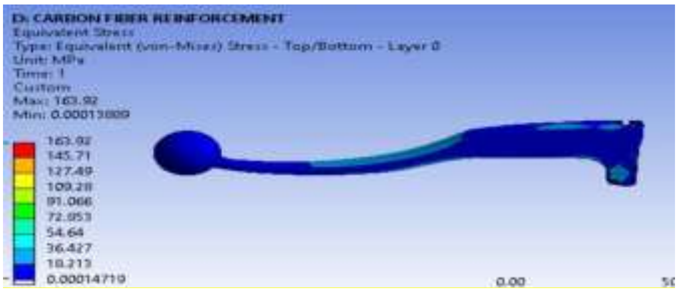

Fig. 27 Equivalent Stress of optimized hand brake lever with carbon fibre reinforcement

In the design and analysis of a two-wheeler hand brake lever with carbon fiber reinforcement, the figure shows the distribution of equivalent von-Mises stress across the component. The maximum stress observed is 163.92 MPa, while the minimum stress is 0.00013889 MPa. The stress distribution indicates that the lever's reinforcement effectively reduces the stress in certain areas, with the highest stress occurring at critical points where the lever experiences the most load. This analysis ensures that the hand brake lever is optimized for strength and durability.

XI. COMPARATIVE RESULTS

Total Deformation

Material	Deformation Values
Aluminum Alloy	0.24993
Carbon Fiber	0.26564
Magnesium Alloy	0.24895

Fig. 27 Total Deformation

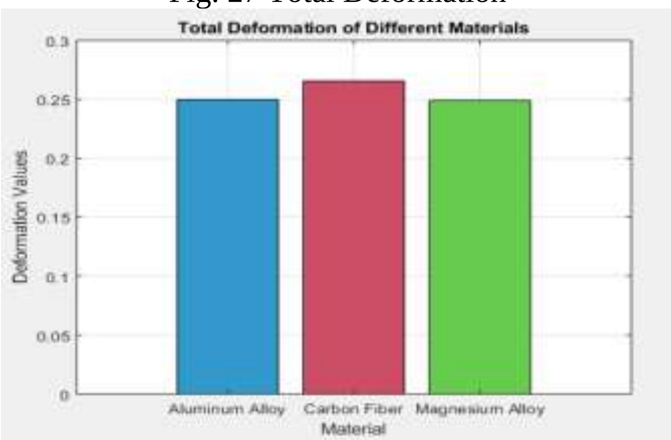

Fig 28 Total Deformation of Different Material

Above figure 28 shows comparative results of total deformation for different materials used in the design of a two-wheeler hand brake lever. Among the materials tested, Aluminum Alloy exhibits the least deformation at 0.24993 mm, indicating its superior stiffness and potential for enhanced performance under load. The Magnesium Alloy follows closely with a deformation value of 0.24895 mm, suggesting similar properties. In contrast, Carbon Fiber shows the highest deformation at 0.26564

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mm, which may impact its suitability for applications requiring minimal deflection. These results highlight the importance of material selection in optimizing brake lever design for durability and functionality.

Total Equivalent Stress

Material	Equivalent Stress
Aluminum Alloy	85.607
Carbon Fiber	163.92
Magnesium Alloy	84.488

Fig 29 Total Equivalent Stress

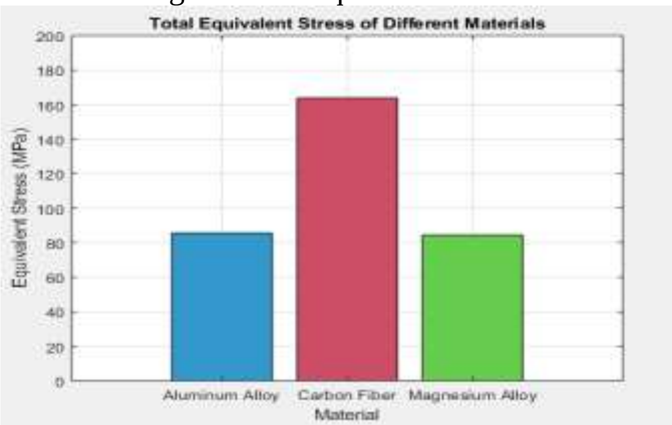

Figure No.6.17 Total Equivalent Stress of Different Material

In the comparative analysis of total equivalent stress for the hand brake lever materials, three materials were evaluated: Aluminum Alloy, Carbon Fiber, and Magnesium Alloy. The results show that Aluminum Alloy exhibits an equivalent stress of 85.607 MPa, closely followed by Magnesium Alloy at 84.488 MPa, indicating their similar performance under load. Conversely, Carbon Fiber displays a significantly higher equivalent stress of 163.92 MPa, suggesting that it experiences greater stress under similar conditions. This disparity highlights Carbon Fiber’s enhanced strength but may also imply a risk of failure if not properly managed in design applications.

CONCLUSION

• Static structural analysis of 2-wheeler hand brake is performed to determine deformation and equivalent stress. It is observed that around maximum deformation is 0.67 mm and equivalent stress is 84.48 MPa. An optimized model is obtained from topology optimization technique.

• It is concluded that the region indicated in red region in topology optimization provides information regarding removal of material from that area. In our case original mass is 74 g but removal of material is to 65 gram as per software. But it depends on us to removal of material by proper design and reanalysis as per existing conditions to sustain boundary condition.

• Static structural analysis of 2-wheeler hand brake optimized model is performed to determine deformation and equivalent stress. It is observed that around maximum deformation is 0.24 mm and equivalent stress is 85.6MPa.

• Weight reduction of around 12.16 % is observed.

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