

Design of Rear Axle of Automotive and Fabrication using 3-D Printing Technology

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Abstract: *The design and fabrication of rear axles using 3D printing technology have gained significant attention in recent years. This study aims to explore the feasibility and advantages of utilizing 3D printing for rear axle production. The research involved designing and optimizing the rear axle using computer-aided design (CAD) software, followed by its fabrication using additive manufacturing techniques. Various considerations, such as material selection, structural integrity, and weight reduction, were considered during the design process. The 3D printing technology employed was Fused Deposit Modelling (FDM), utilizing a high-strength metal alloy. The fabricated rear axles underwent rigorous testing to evaluate their mechanical properties and performance characteristics. The results demonstrated that 3D printed rear axles exhibited comparable or even superior mechanical properties to traditionally manufactured counterparts. Additionally, the utilization of 3D printing enabled the production of complex geometries and lightweight structures, which can lead to improved vehicle efficiency*

Keywords: 3D Printing, rear axle, additive manufacturing, FDM, lightweight structure

I. INTRODUCTION

The rear axle, which is also called the dead axle, is the final member of the power train. In the majority of automobiles, the real axle is the driving axle. It is situated in between the driving wheels and the differential gear, and transmits power from the differential to the driving wheels. It consists of two half shafts connected to the differential gear, one for each wheel. The sun gear of the differential is connected to the inner end of each half shaft and the outer ends are connected to the wheel. The rear axle and differential gear are completely encased in a housing which protects them from the environment. The rear axle supports the major load of the truck. Another function of the dead axle is that it rotates for transferring power from the engine to the wheels. Rear axles are classified either as a banjo axle or a split axle. A split axle is one in which split shafts are used with a central casing, called a housing, that contains the differential gear which is fitted with a tube at every side to carry the half axles and bearing.

The idea of 3D printing dates all the way back to 1945 when sci-fi writer Murray Leister first described the technology with surprising accuracy in his short story "Things Pass By". He envisioned a machine that could take his drawings and replicate them with a moving arm, using melted plastic to form 3D objects. Now somebody just needed to make his idea a reality. It took a while for these ideas to move beyond fiction, but in 1971 we had a breakthrough with Johannes F. Gottwaldov filing a patent for a Liquid Metal Extruder. He envisioned this extruder to be just like an office printer, only it would print 3D objects with metal rather than words with ink. Sounds an awful lot like FDM printing, huh? Unfortunately, Gottwald wasn't able to make the technology a reality before the patent expired, and he's often been forgotten as one of the fathers of 3D printing. With the first patent yielding no results, the world of 3D printing remained nothing more than ideas. It's at this point that David Jones came along with his popular column — Daedalus || in the magazine New Science.

Other methods of additive manufacturing being explored and developed in the 1980s included Selective Laser Sintering (SLS) invented by Carl Deckard, Direct Metal Laser Sintering (DMLS) from German Company EOS GmbH, and Fused Deposition Modeling (FDM) by S. Scott Crump. Stratasys, the company which Crump later co-founded with

his wife Lisa, has remained a leading producer of FDM printers. Early 3D printers were far beyond the price point of every day consumers and were primarily used by large manufacturing corporations as part of their prototyping process.

II. LITERATURE REVIEW

“DESIGN & STATIC ANALYSIS OF REAR AXLE.” By- Lalit Bhardwaj, Amit Yadav, Deepak Chhabra.

This experimental work considers the static analysis of rear dead axle with the help of computer aided engineering (CAE) tool. Finite element analysis of rear dead axle carried out with actual design consideration and loading conditions. Creo elements software is used to design the different parts and assembly of rear axle. Hyper mesh software is used to make finite element model of axle. Real life examples are continuous, so the basic concept of FEA to discretization reduces the infinite point to finite nodes & elements (meshing) & result is interpolating in the whole domain. Radioss Linear solver is used to perform static analysis of dead axle. Hyper view is used for post processing. Von Misses Stress distributions and displacement contours on rear axle are plotted at different load conditions with static analysis and safe load is determined. In this paper, they retrieved all the dimensions and geometric properties, with the help of reverse engineering and measurement of axle of car. Creo element is used to design the different parts and assembly of rear axle. Parts & assembly are made by solid & sheet metal module. To create parts in Creo software following commands are used; Extrude, Revolve, Blend, Sweep, Variable section sweep, Chamfer, Bend, Flange wall, Punch & Round. [1]

“STRUCTURAL ANALYSIS OF DIFFERENTIAL GEARBOX.” By - Daniel Das.A, Seenivasan.S, Karthick. S.

The main aim of this paper is to focus on the mechanical design and analysis on assembly of gears in gear box when they transmit power at different speeds. Analysis is also conducted by varying the materials for gears, Cast Iron, Cast Steels and Aluminium Alloy etc., presently used materials for gears and gear shafts is cast-iron, cast steel. In this paper to replace the materials with Aluminium material for reducing weight of the product. Stress, displacement is analysed by considering weight reduction in the gear box at higher speed. The analysis is done in ANSYS software. It's a product of Solid works. In the present work all the parts of differential are designed under static condition and modelled. The required data is taken from journal paper. Modelling and assembly is done in Pro Engineer. The detailed drawings of all parts are to be furnished.

Due the study of research paper it can help us to select the proper material for differential gearbox. As every material have different kind of density which is directly proportional to the its weight. This will help us to understand about properties of a material we are going to use for gearbox to reduce the overall weight. [2]

“DESIGN AND DEVELOPMENT OF ULTRA-LIGHT FRONT AND REAR AXLE OF EXPERIMENTAL VEHICLE.” By - Jan Kral, Miroslav Palko, Maroš Palko, & Ludmila Pavlikova.

They choose Aluminium 5754 for its high strength, which approximates conventional steel at significantly lower weight. Another advantage of this material is its good weldability, which they used in this case. Another material they had taken was Duralumin alloy 7075 in one piece. This material is mainly used in the aerospace industry for its high strength, where it overcomes conventional steels at a still relatively low weight. One of the disadvantages of this material is that it cannot be welded.

This research paper helps us to think about material we can use for rear axle to minimize its weight without compromising the rigidity and strength for rear axle. This research paper gives the idea about Aluminium 5754 Duralumin alloy 7075 to use it as a material in designing of rear axle. Due to this paper we got to know about how materials will behave when these 2 materials are used. [3]

III. METHODOLOGY

To Design the 3D model of Rear Axle

Initially, a 3D model of the dead axle is designed on the CAD software Solid works based on traditional banjo-type axles of heavy trucks. Parts are individually designed and then assembled. It is then visually optimized to reduce the weight of parts based on required thickness. Drafting of the parts is done on Solid works. An engineering drawing of the assembly where its exploded view along with a bill of materials is made.

Next, the step file of the assembly is imported to the static structural analysis system of the ANSYS Workbench which is a CAE software. Here, initially, the assembly is meshed. Then the supports are set and the loads are placed along with other constraints. The solution parameters are set and an analysis is carried out to obtain the stress distribution, the strain, the deformation, the life cycle and the factor of safety of the various parts. The results are then analyzed to check whether the axle was able to withstand the vertical load and the effect of the load and if it was increased on the other components of the axle.

Next, the assembly is scaled down and sliced using Ultimaker Cura 3D printing software. The printing parameters are in putted and the G-code of the tool path is generated by the software. This G-code is fed to a 3D printer via the computer itself through a USB cable or using an SD card. The 3D printer then prints the part. Post-processing on the part is done, i.e. removing the rafts and the supports to get the final 3D printed part.

The CAD model of the various parts of the dead axle is made using Solid Works CAD software. A full-scale model of all the parts of the axle, excluding the differential, is made on the software. The assembly of the parts is also done on Solid Works.

Major focus is given to the housing of axle, as it is the part that directly takes the vertical loads. It comprised thin-walled shells with a uniform thickness of 10 mm all over.

The assembly as a whole comprises the housing, the front plate, the back plate, the discs, the tires, the spindles, the shafts, the wheel rims, and nuts and bolts of various diameters and lengths. Each of the above parts is made individually and then assembled into a single product file. Table 1 shows the bill of materials of the assembly and shows the material of each of the parts.

Figure shows the CAD model of the rear axle without the tyres, along with center of gravity of the assembly highlighted by the intersection of the red, blue and green lines that signify the axes. The thick blue arrows signify the contact between the tyres and the road, and are the locations at which fixed supports are given to the axle. The thick red arrows signify the load acting on the housing, resulting from the weight and load of the truck. The white squares show where the leaf springs will be attached to the housing and the area at which the load will act. These areas of action are 75 mm × 100 mm.

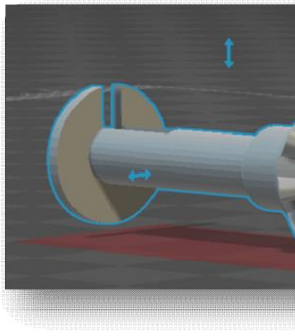


Fig.1 Axle gear LHS

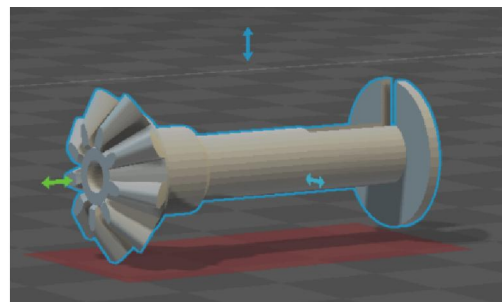


Fig.2 Axle gear RHS

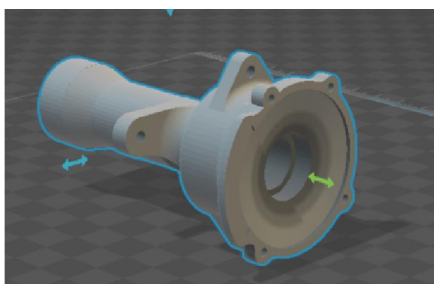


Fig.3 Axle cover 1

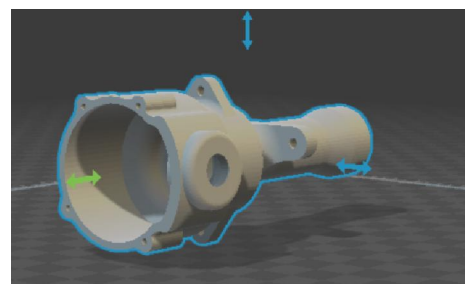


Fig.4 Axle cover 2



Fig.5 Differential Cap

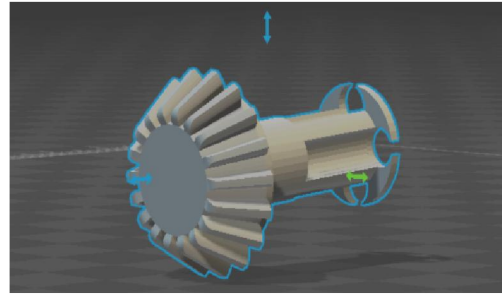


Fig.6 Rotor Gear

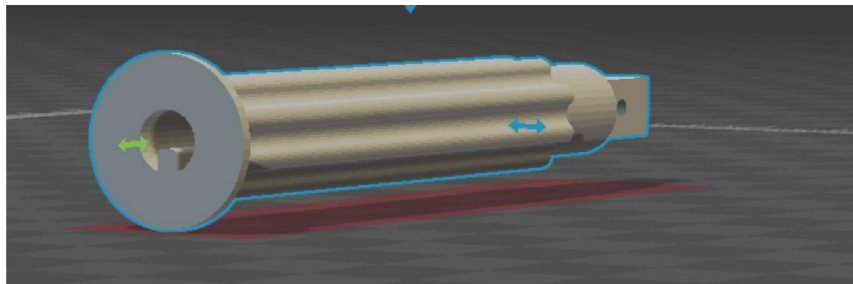


Fig.7 Differential Shaft LHS

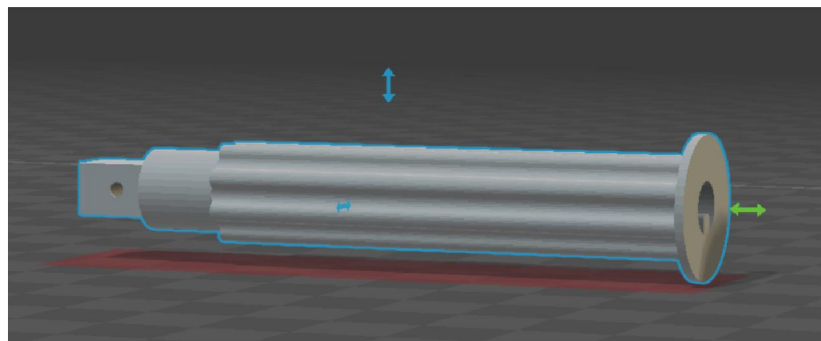


Fig.8 Differential Shaft RHS

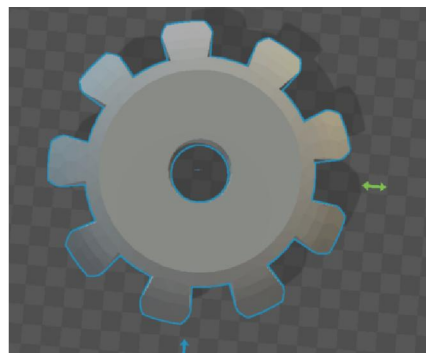


Fig.9 Spider Gear

To optimize the design which causes reduce weight

Reducing the weight of the rear axle in a design can be achieved through several methods. Here are some potential approaches:

- **Material Selection:** Choosing lightweight materials for the axle, such as aluminium or titanium, can significantly reduce its weight. However, the chosen material must be strong enough to withstand the stresses and loads the axle will experience during operation.
- **Optimization of Cross-Sectional Shape:** Analysing and optimizing the cross-sectional shape of the axle can also reduce its weight. By using computer-aided design (CAD) software and finite element analysis (FEA), engineers can determine the minimum cross-sectional area required to withstand the required loads.
- **Hollow Design:** Hollowing out the axle is another way to reduce its weight. By removing material from the center of the axle, it can maintain its strength while significantly reducing its weight.
- **Use of Composite Materials:** Composite materials, such as carbon fibre reinforced polymer (CFRP), can be used to manufacture the axle. CFRP is significantly lighter than traditional materials while maintaining high strength.
- **Elimination of Non-Essential Components:** Finally, any non-essential components can be eliminated from the design to further reduce the weight of the axle. This can include any excess brackets, mounts, or reinforcements that may not be necessary for the axle's functionality.

Material Used For 3-D printing.

There are several materials used for 3D printing, each with its unique properties and applications. Here are some commonly used materials for 3D printing:

- **PLA (Polylactic Acid):** This is a biodegradable and environmentally friendly plastic that is easy to use and widely used for 3D printing. It's perfect for creating simple models or prototypes.
- **ABS (Acrylonitrile Butadiene Styrene):** This is a durable, strong, and heat-resistant plastic that is commonly used in automotive parts and toys.
- **PETG (Polyethylene Terephthalate Glycol):** This is a strong and flexible plastic that is resistant to impact, making it suitable for parts that require durability.
- **Nylon:** This is a strong and flexible material that is resistant to abrasion, making it perfect for creating parts that are subject to wear and tear.
- **TPU (Thermoplastic Polyurethane):** This is a flexible and rubber-like material that is perfect for creating objects that require flexibility and elasticity.
- **Metal:** Metal 3D printing is becoming increasingly popular for creating parts that require strength and durability. Materials such as stainless steel, titanium, and aluminium can be used for 3D printing.
- **Wood:** Wood filament is a composite material made of wood particles mixed with a binding agent. It gives the printed object a wooden texture and appearance.
- **Carbon fiber:** This is a strong and lightweight material that is perfect for creating parts that require strength and rigidity.
- **PVA (Polyvinyl Alcohol):** This is a water-soluble material that is often used as support material for 3D printing. It dissolves in water, leaving the printed object intact.

Several compositions added with carbon-fibre to increase its properties.

There are several ways to increase the strength of carbon fibre reinforced composites. Here are some common techniques:

Increase the carbon fibre content: Increasing the amount of carbon fiber in the composite can improve its strength. However, increasing the carbon fibre content may also increase the brittleness of the material.

Use higher quality carbon fibre: Higher quality carbon fiber has a higher tensile strength and modulus, which can increase the strength of the composite.

Use a different weave pattern: The weave pattern of carbon fiber can affect its strength. A unidirectional (UD) weave pattern, where all the fibres are aligned in one direction, can provide the highest strength in that direction.

Add additional reinforcement layers: Adding additional layers of reinforcement, such as Kevlar or fiberglass, can improve the strength and toughness of the composite.

Use a different resin: The resin used to bind the carbon fibre can affect the strength of the composite. Using a resin with higher toughness or better adhesion to the carbon fibre can improve the strength of the composite.

Improve the manufacturing process: The manufacturing process can also affect the strength of the composite. Improving the manufacturing process, such as by controlling the curing temperature or pressure, can improve the strength and quality of the composite.

From all the above research we finalized the printing material i.e. *Carbon fibre with PC*

Properties of Carbon Fibre

Carbon fibre has several unique properties that make it desirable for a variety of applications. Some of these properties include:

- **High Strength-to-Weight Ratio:** Carbon fibre has a very high strength-to-weight ratio, which makes it much stronger and lighter than traditional materials like steel and aluminium. This property makes carbon fibre ideal for use in applications where weight is a critical factor, such as aerospace and automotive industries.
- **High Stiffness:** Carbon fibre is also very stiff, which means it does not bend or deform easily under load. This property makes it ideal for use in applications where rigidity is important, such as in sporting equipment and structural components.
- **Corrosion Resistance:** Carbon fibre is highly resistant to corrosion and can withstand exposure to a variety of chemicals and environmental conditions. This property makes it ideal for use in marine and industrial applications where exposure to harsh environments is common.
- **Electrical Conductivity:** Carbon fibre is an excellent electrical conductor, which makes it useful in a variety of electrical and electronic applications.
- **Thermal Conductivity:** Carbon fibre is also a good thermal conductor, which means it can dissipate heat quickly and efficiently. This property makes it ideal for use in high-temperature applications, such as in aerospace and Défense industries.

IV. EXPERIMENT VALIDATION

Validating the design of a rear axle typically involves a combination of simulation and physical testing. Here's an overview of the steps involved in experiment validation for the design of a rear axle:

- **Simulation and modeling:** Use computer-aided design (CAD) software to create a detailed 3D model of the rear axle and integrate it into the overall vehicle model. This allows for virtual testing and simulation of various scenarios, such as different loads, driving conditions, and maneuvers.
- **Finite Element Analysis (FEA):** Perform FEA simulations to analyze the structural integrity and stress distribution within the rear axle under different loading conditions. This helps identify potential areas of weakness or excessive stress that may require design modifications.
- **Dynamic analysis:** Utilize multimode dynamics simulation software to study the dynamic behavior of the vehicle with the designed rear axle. This analysis includes evaluating the axle's response to various inputs like acceleration, braking, and cornering forces. It helps assess factors like stability, handling, and ride comfort.
- **Bench testing:** Build physical prototypes of the rear axle and subject them to laboratory bench testing. This typically involves applying controlled loads, vibrations, and other mechanical stimuli to simulate real-world operating conditions. Various parameters, such as load-bearing capacity, stiffness, durability, and fatigue life, can be evaluated through these tests.
- **Vehicle-level testing:** Install the rear axle in a vehicle or a test rig and conduct comprehensive on-road or track-based tests. This allows for the evaluation of the axle's performance, handling, and overall vehicle dynamics under real-world conditions. The tests can include acceleration, braking, cornering, and various maneuvers to assess the axle's behavior and validate its design.

Results of FEA Analysis using Ansys.

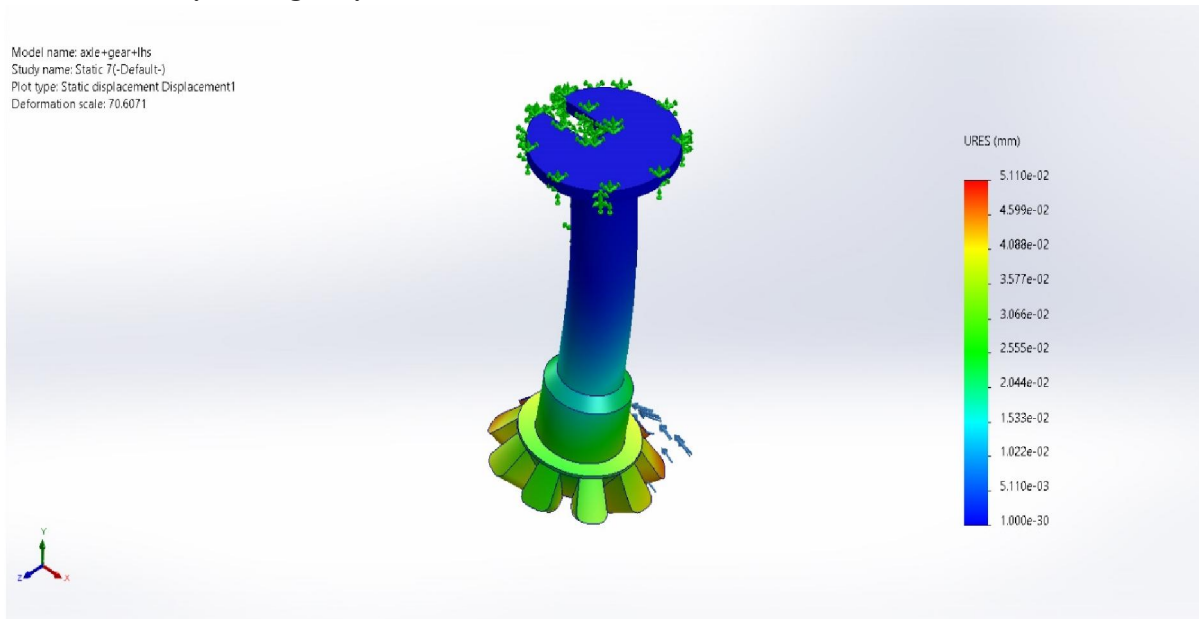


Fig. 10 Total Deformation of Axle Gear LHS

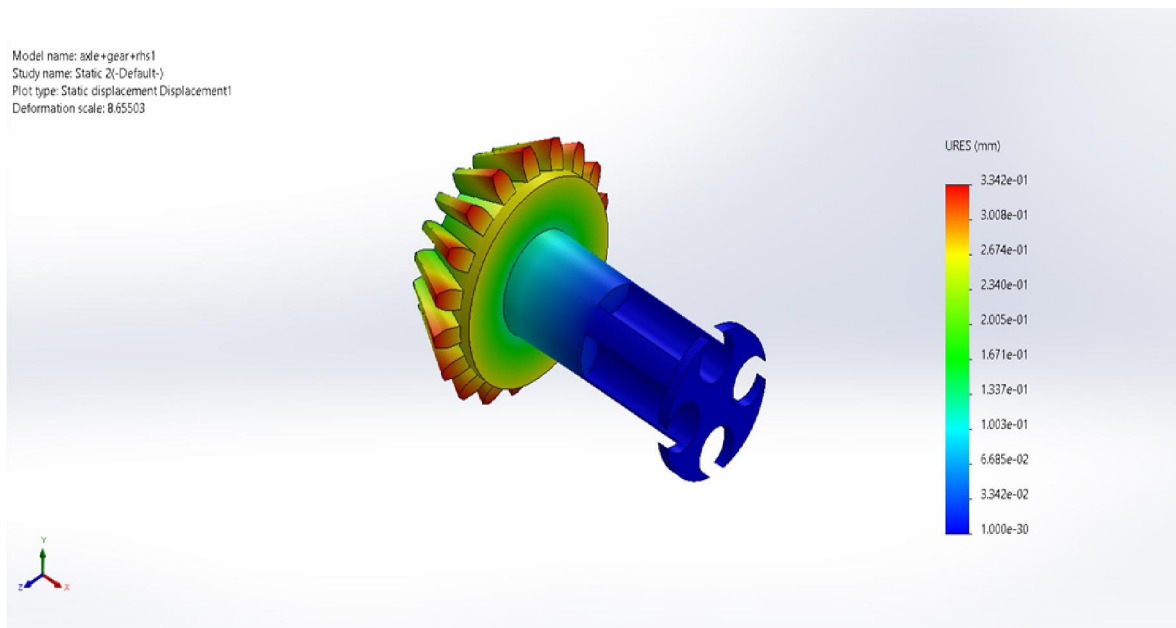


Fig. 11 Total Deformation of Axle Gear RHS

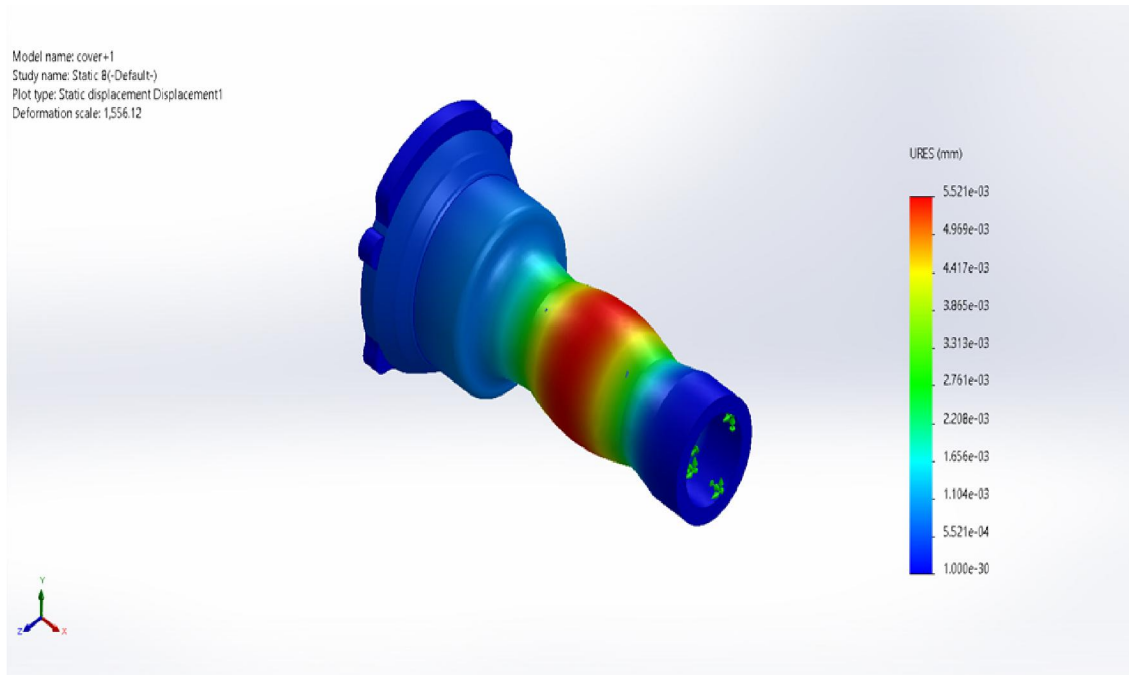


Fig. 12 Total Deformation of Axle Cover 1

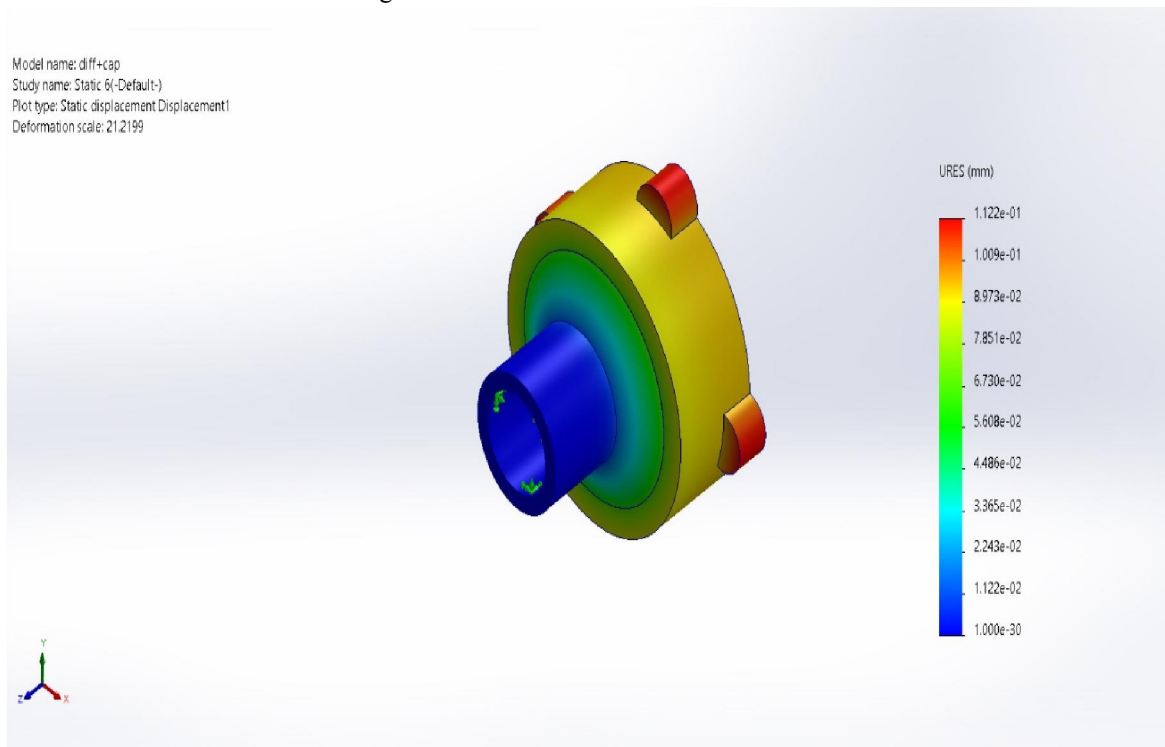


Fig. 13 Total Deformation of Differential Cap

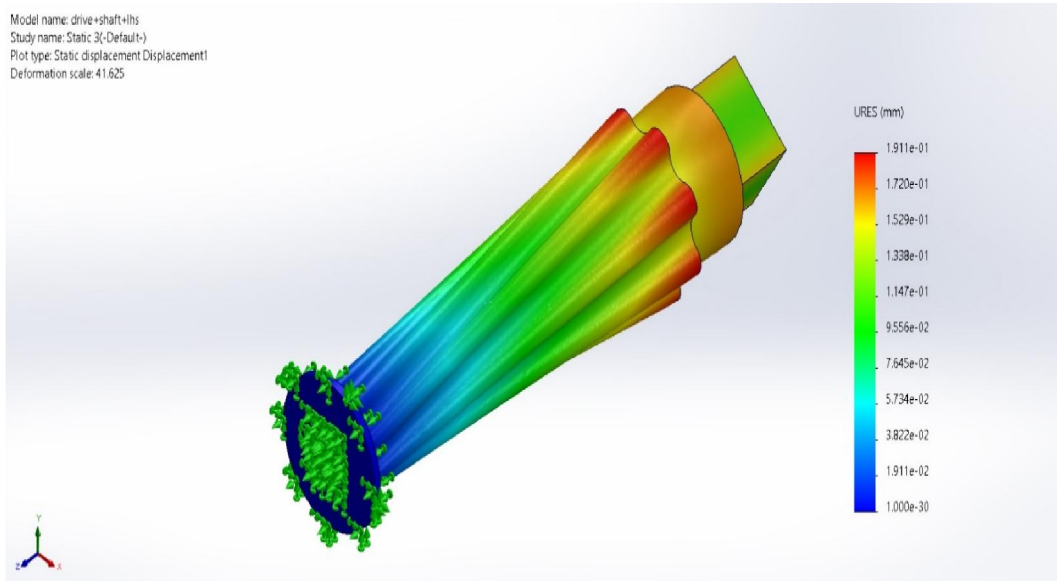


Fig. 14 Total Deformation of Differential Shaft

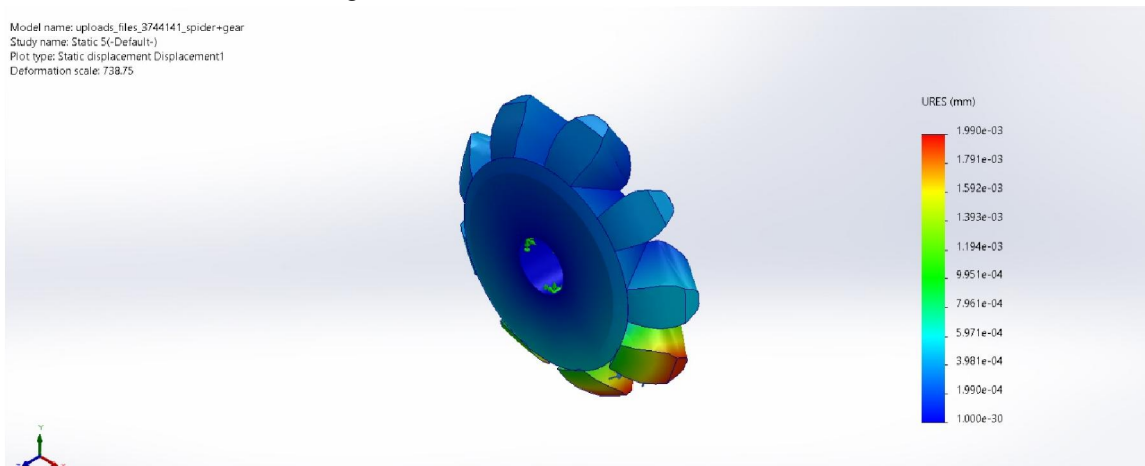


Fig. 15 Total Deformation of Spider Gear

Actual Experimental Setup





V. CONCLUSION

In conclusion, the design and fabrication of the rear axle is a critical aspect of vehicle engineering, contributing to the overall performance, stability, and safety of a vehicle. Throughout the design and fabrication process, several key considerations must be addressed to ensure optimal functionality and durability.

Firstly, the selection of suitable materials is vital to ensure strength, stiffness, and resistance to fatigue. Common materials used for rear axles include forged or cast steel, aluminum alloys, and high-strength composite materials. The choice of material depends on factors such as vehicle weight, load capacity, and cost considerations.

Secondly, the design of the rear axle must consider the vehicle's intended use and performance requirements. Factors such as load capacity, torque distribution, and suspension characteristics should be considered to determine the appropriate axle geometry, including length, diameter, and mounting points. Advanced design techniques, such as finite element analysis, can aid in optimizing the design for strength and weight efficiency.

Furthermore, the fabrication process should adhere to strict quality control standards to ensure dimensional accuracy and structural integrity. Precision machining and welding techniques are commonly employed, along with rigorous inspections and testing procedures, including non-destructive testing methods, to detect any defects or flaws.

Lastly, collaboration and communication between design engineers, fabrication experts, and vehicle manufacturers are crucial for a successful rear axle implementation. Continuous feedback and iteration during the design and fabrication stages help address any issues, refine the design, and ensure that the final product meets the desired performance and safety standards.

Overall, the design and fabrication of the rear axle require a comprehensive understanding of engineering principles, materials science, and manufacturing

techniques. By considering factors such as materials selection, design optimization, fabrication quality, and collaboration, a well-designed and fabricated rear axle can contribute significantly to the overall performance and reliability of a vehicle.

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