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Analysis and Enhancement of Rear Axle for Hybridization of Electric Drive on Swift Dzire

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Abstract - ***The project's goal is to improve vehicle drive shafts by investigating performance characteristics, material choices, and structural integrity. Torque, stress, and vibration are all examined to meet safety criteria through theoretical calculations and simulations. Surface treatments are used to improve the longevity of materials by reducing wear and corrosion. Iterative optimization and validation through testing ensures reliability. The findings provide useful information for improving drive shaft designs in a variety of technological applications. There is little research into optimal design characteristics like as motor placement and torque distribution, which can improve overall vehicle dynamics and energy economy. Investigating these gaps could provide valuable insights into the field, and most budget vehicles lack hybrid technology and rear wheel drive. In this project, the rear wheel is powered by an electric motor, for which a drive shaft has been designed and manufactured. Exploring trailing arm modifications while retaining the original equipment manufacturer (OEM) knuckle and shaft provides a nuanced option for improving vehicle performance. This adjustment allows for fine-tuning of suspension dynamics, such as camber and toe angles, which improves handling, traction, and responsiveness. The basic objective is to create a rear wheel drive shaft with an optimized diameter to improve power transmission efficiency while minimizing energy loss through the electric motor. The alteration of the vehicle will aid in maintaining and managing fuel usage effectively. Overall vehicle performance might be improved to cut emissions, representing a substantial leap in hybrid technology.***

Key Words**: *Drive shaft, FEA Analysis, Material Study, EV Kit, Testing Specimen.***

1. INTRODUCTION

This project entails a thorough evaluation of the current axle system to identify opportunities for improvement and the incorporation of hybrid components. It emphasis on improving the axle's structural integrity while also introducing a drive shaft and knuckle to power the rear wheels, weight distribution achieved by centering the motor, and compatibility with electric drive components. Design changes, material selection, and technical integrations may be made to assure the Swift Dzire's smooth hybrid functionality, increased efficiency, and overall performance. The project also includes the creation of a versatile shaft with variable discontinuities that can adjust to diverse loading conditions, assuring optimal performance. [2]. Solid shafts are preferred over hollow shafts because of:

- More Strength than hollow shaft under bending forces.
- Less diameter shaft could be used to make a compact assembly.
- Easy machining
- Cost efficient.

Engineers revise the shaft's diameter to reduce stress and distortion while retaining structural integrity to deal with these challenges. A unibody driveshaft is employed in this case, and it is attached to the gearbox on one side and the wheel hub on the other side via a flange and spindle. A drive shaft is an essential component of a vehicle's power transmission system, transmitting torque from the powertrain to the wheels. Drive shafts are often employed in rear-wheel-drive and four-wheel-drive systems, and they play an important part in ensuring effective power transmission and the vehicle's overall drivability. Geometry optimization is an important function that modifies characteristics such as length, diameter, and wall thickness to minimize problems like vibration-induced fatigue and work in harmony with vehicle dynamics.

In order to ensure robustness under a variety of loads, fatigue life, deformation, and stress distribution are examined using finite element analysis in structural analysis. Axial loads, bending moments, and torsional vibrations are all taken into account in dynamic simulations to maximize resistance against wear and fatigue in real-world situations.

Fig:- 1 Driveshaft

2. Literature Survey

1. P. Jayanaidu et.al, had reported that Ti-6Al-7Nb titanium alloys are used in place of traditional steel driveshafts in the case study in this research because of its strong toughness and small weight. The ANSYS software was used to perform the simulation and impose a fixed boundary condition on one end of the shaft and a torque of 3000 rpm on the other. The shaft model was made in Pro-E. The study produced the maximum stress and equivalent stress parameters after computing deformation. This indicates that the titanium alloy (Ti-6Al-7Nb) is a better choice for a drive shaft due to its low weight and complete deformation of steel and titanium alloy.

2. Dr. B. P. Patel1 et.al, had examined that the core of this study was a detailed analysis of shaft design under varying loading conditions and discontinuities. They have also previously published on fatigue fractures, shaft design, and failure analysis using a variety of analytical techniques, including mathematical techniques. On the other hand, they note less about discontinuities and combination loading and advise that research focus on it.

3. He Pan1 et.al, had investigated a thorough analysis of several lightweight, extremely durable materials. He begins by classifying steel into two categories: high-strength steel and advanced high-strength steel. Advanced high-strength steel is defined as having a resistance ratio of at least 700 MPa. The weight of cars is said to be responsible for 60% of fuel consumption. They also aim to produce material that is lightweight and strong. The Japanese developed BL385, SA440, and SA630, which have tensile strengths of up to 550 MPa, 590 MPa, and 780 MPa, respectively. China needs a lot of HSS since the building industry utilizes it so much. Only steel high-strength alloys are more in demand than aluminum alloys as low-weight, high-strength materials. High-strength aluminum alloy's performance: Lithium and Al-Li alloy are used to make the lightest metal product. The density may decrease by 3% and the module may rise by 5% for every 1% increase in lithium concentration in the aluminum alloy. The lightest structural metal is magnesium alloy, which has a density of 1.75g/cm3. It is made up of around two thirds aluminum alloy and one quarter steel. Tensile strengths of up to 1500 MPa are achieved by titanium alloys in contrast to ultra-high-strength steel.

4. Prof. Vijoy Kumar et.al, had outlined how this research includes a thorough analysis of roller shaft failures, which may be improved by employing mechanical repair approaches that are preventive. He mentioned several earlier research investigations that looked at defects and working conditions. An analysis demonstrates that the conveyor's pulley's shaft breaking is due to fatigue. Another experiment found that the reduced true radius of the chamber caused the draft fan shaft of a steam boiler to collapse. An extended examination of the locomotive's turbocharger malfunction. Investigations into Charpoy Fractography employing SEM, spectrometers, spectroscopes, and Finite Element Analysis using ANSYS have been made possible by the introduction of bearing sleeves.

5. Aniket Bhilare1 et.al, had stated that this study paper's objective is to lighten the car's weight by changing its numerous components. The study of the driveshaft revealed two examples of completed analyses: the maximum principal stress and the equivalent stress.

6. Li-Hui Zhaoa et.al, had used two drive shafts to examine the failure and underlying cause of a recurring drive shaft fracture. Drive shafts were discovered to have fatigue failure indicators during the test while they were in operation. The FEA performed while the machine was running at high torque revealed an apparent stress concentration that is compatible with the location of the fracture site. Moreover, a limited fillet radius causes undue stress, which is thought to be the main cause of the drive shaft failure.

7. Samuel O. Afolabi a et.al, had confirmed and said that a Palm Kernel cracking machine with a 20 mm & 30 mm shaft diameter was examined in this study using FEA analysis and 3D modeling. This demonstrates that the optimal configuration has the load and Von Mises stress of 102.4 MPa for mild steel composition, with a total yield stress of 156 MPa. The best shaft diameter for production, according to the data, is 20 mm.

8. Carlos M.S. Vicente et.al, their paper focuses on a connected shaft shredder failure that has been evaluated. The failure was examined using every experimental technique, in addition to statistical evaluations intended to identify the fundamental causes of connected shaft failure. The shaft collapsed due to fatigue at a plane perpendicular to the rotation axis, close to the connecting transverse aperture.

3. Objectives

- To optimize diameter of shaft for rear wheel to transmit power through electric motor.
- Develop a drive shaft design that maximizes power transmission efficiency.
- To minimize failure of shaft at high loading condition on uneven road surface.
- To optimize the design based on analysis results, ensuring it meets safety standards and regulatory requirements.

4. Problem Statement

Electric battery packs are a great way to reduce fuel costs and convert existing front-wheel drive cars into hybrid vehicles by adding a battery pack and motor to the rear and creating a completely hybrid vehicle by transmitting power to the rear wheels. This is especially useful given the rise in carbon credits and pollution these days. The majority of ordinary cars transfer power through their front wheels; the rear wheels are devoid of any kind of power-producing equipment. In order to enable rear wheel drive with the installation of an electric motor to transfer power, this project's design incorporates half shaft calculations and analysis for the rear wheels.

5. Methodology

Methodology for Designing, Analyzing, Material Selection, Validating, Testing, and Manufacturing of a Driveshaft:

Designing includes outlining the specifications and limits, such as torque, speed, and available space.
Analysis helps to model stress, strain, and vibration under varied operating conditions.
Material Selection includes selecting materials according to their mechanical attributes, including fatigue resistance, modulus of elasticity, and tensile strength.
Verifying and making sure the design is sound by using computer simulations and computations. Making sure it complies with industry standards like ASTM or ISO.
Production includes selection of suitable production techniques, such as heat treatment procedures and machining based on material and design specifications.
Testing to confirm the performance of the design, do hands-on testing using prototypes.
Analyzing performance in real-world scenarios to find any possible problems.

By following this comprehensive methodology, you can ensure the successful design, analysis, material selection, validation, testing, and manufacturing of a driveshaft, meeting performance requirements and industry standards.

6. Design & Calculations

- Material Properties:

Mechanical properties of selected AISI 4130 material:

Elastic Modulus – 210000 N/mm^2

Shear Modulus – 80000 N/mm^2

Poisson's Ratio – 0.29

Ultimate Tensile Strength – 560 N/mm^2

Yield Tensile Strength – 460 N/mm^2

- Specifications of car:

The specifications of the car on which the project is carried out:

Make & Model – 2020 Swift Dzire.

Kerb Weight – 915 kg.

Considering the car in fully loaded condition with 5 passengers each of 100 kg weight. There-fore total weight including passengers – 915+500*9.81 = 13881.15 N

- Technical Specifications of motor:

Torque – 100000 n-mm.

Weight – 28 kg.

Type – Reluctant Motor Drive.

- Calculations:

Load Path Calculations –

Calculation of Torsional Force:

We have,

$$Mt/J = G\theta * r/L$$

where,

Mt = torque.

J = polar moment of inertia.

G = modulus of rigidity.

θr = angle of twist.

L = length of the shaft.

To calculate Polar Moment of Inertia,

$$J = \pi (R)^4/2 \text{ .... (for solid shaft)}$$

$$J = 3.14\,(11.5)*4/2$$

$$J = 27473 \text{ mm*4}$$

To calculate Torsional Force,

$$Mt/J = G\theta r/L$$

$$100000/27473 = 80000*\theta r/1000$$

$$\theta r = 100000*1000/27473*80000$$

$$\theta r = 0.0250 \text{ radian}$$

$$\theta r = 2.6094 \text{ degree}$$

To calculate Torsional Stress,

$$\tau = Mt/J.R$$

$$\tau = 100000/27473*11.5$$

$$\tau = 41.85 \text{ N/mm}^2$$

To calculate Permissible Tensile Strength,

$$\sigma t = Syt/FOS = 460/3$$

$$\sigma t = 155 \text{ N/mm}^2$$

Torque and Diameter equation,

$$T = \pi/16.\ \tau.\ d^3$$

$$100000 = 3.14/16*41.85*d^3$$

$$d^3 = 1600000/3{,}14*41.85$$

$$d^3 = 12175.72$$

$$d = 23 \text{ mm}$$

Hence the above diameter should be considered for the design of solid shaft.

7. Cad Design

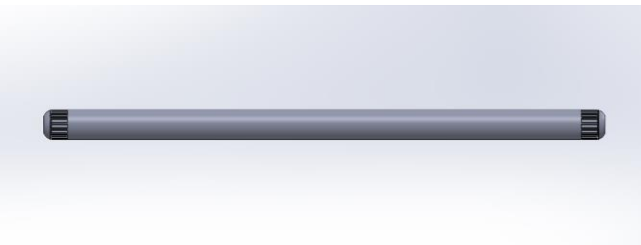

Fig:- 2 CAD Design of Driveshaft

8. Finite Element Analysis

A. Pre-processing: Pre-processing for driveshaft torsional analysis involves creating a geometric model, assigning material properties, considering material nonlinearity.

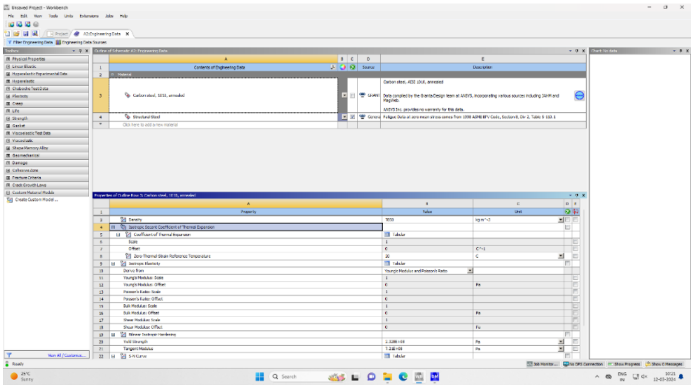

Fig:- 3 Material Selection

The material assigned is AISI 4130 because of its excellent strength and toughness.

TABLE 1 Material Properties of AISI 4130

AISI 4130	**Properties**
Elastic Modulus	210000 N/mm2
Shear Modulus	80000 N/mm2
Poisson's Ratio	0.29
Ultimate Tensile Strength	560 N/mm2
Yield Tensile Strength	460 mm2

B. Post Processing: Post processing refers to meshing of the component with proper element size. Then applying boundary conditions like application of load / moment, providing constraints.

TABLE 2 Torsion Analysis Boundary Conditions

Sr No.	**Boundary Conditions**	**Remark**
1	Number of Constraints	1
2	Type of force applied	Moment
3	Magnitude of moment	100 n-m
4	Meshing Size	1mm

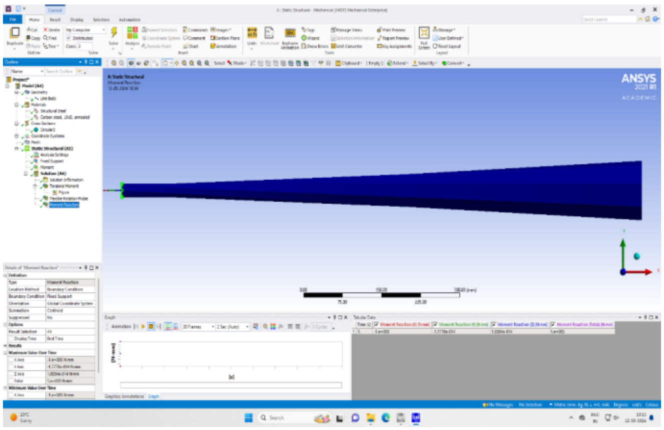

Fig:- 4 Moment applied to the Driveshaft

The drive shaft moment reaction, also known as the torque reaction, refers to the reactive force experienced by the vehicle.

C. Solution: Solution found for the analysis of the driveshaft include finding of angle of twist, total deformation, maximum equivalent stress and factor of safety.

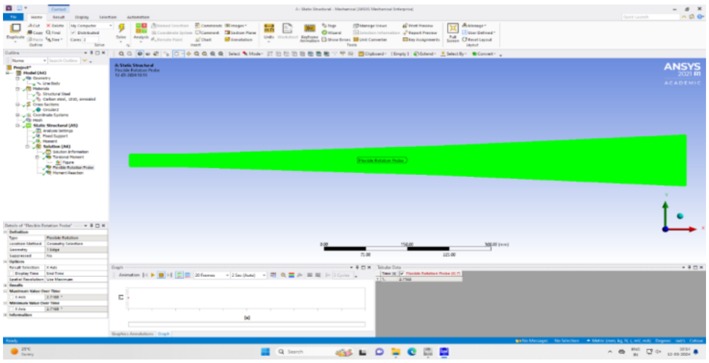

Fig:- 5 Angle of Twist from the analysis was found to be 2.7168

The drive shaft torsional moment refers to the twisting force applied to the drive shaft, resulting in torsional stress and deformation. Torsional moment of 100000 n/mm is applied in the above analysis.

9. Experimental Testing

The testing was being performed by us on a tortional testing machine. We performed the torsion test on the specimen of material AISI 4130 of total length of 540mm with the test piece length of 400mm. The testing was performed to check for the material strength when it undergoes a torsional moment with magnitude 100 N/m. The requirements from the testing were of the permissible torque and the angle of twist for that amount of torque. It was a non-destructive test in which we applied a torque of magnitude120 N/m so as to get the angle of twist of the specimen.

Fig:- 6 Torsion Testing Specimen of material AISI 4130

Fig:- 7 Specimen Clamped in torsional setup

Fig:- 8 Torsion Testing Machine

10. Validation

TABLE 3 Comparison of Angle of Twist

	THEORETICAL	ANALYTICAL	EXPERIMENTAL
ANGLE OF TWIST	2.6094	2.7168	2.7659
TORQUE	100 Nm	100 Nm	102.64 Nm

Angle of twist analytical percentage error = (2.7168 – 2.6094/2.6094)*100 = 4.1%
Angle of twist analytical percentage error = (2.7659 – 2.6094/2.6094)*100 = 6 %

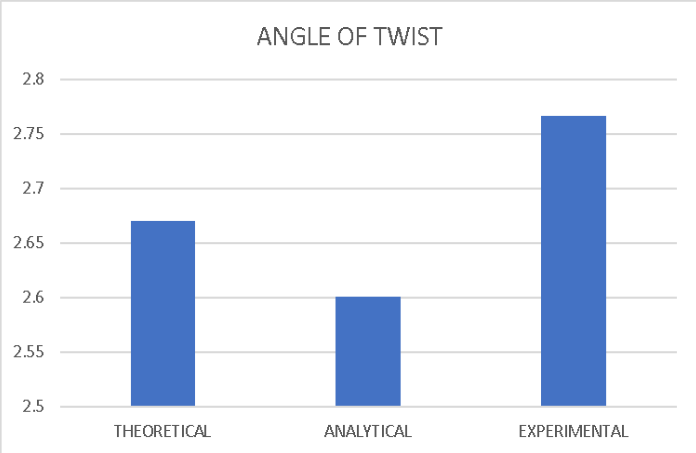

Fig:- 9 Comparison of angle of twist values.

11. Conclusion

From the experimental and analytical data, we can conclude that the driveshaft which is being designed and manufactured is completely safe and follows the international safety standards. The driveshaft can be used to transmit a torque of magnitude 100 Nm without any failure and with high efficiency. It is concluded that the driveshaft so manufactured in this project has greater strength, durability, and can be used in different automobiles to transmit power from the powertrain to the driven wheels. The results we got from the torsion test were validated and the percentage error between the analytical and experimental result was quite negligible, as per the international safety standards.

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