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Finite Element Analysis of Leaf Spring Fabricated Via Fused Deposition Modeling (FDM)

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Abstract:- An introduction to fused deposition modeling, or 3D printing technology, will be given in this chapter. The basic idea of additive manufacturing and its underlying scientific theory will be presented at the outset of this chapter as a novel and emerging industrial technology. The parameters used to predict the melt deposition of polymers and their basic interactions with the structural component qualities will also be covered in this chapter. The chapter will provide a brief description of the quality features of FDM products concerning the process parameters. The additive manufacturing process will involve layering material to produce three-dimensional (3D) parts using a class of manufacturing technologies known as additive manufacturing (AM). This substance will include composite, metal, polymer, or concrete materials. A manufacturing process will need to have the following three main elements to be designated as an AM technique: making visual 3D models with computers and computer-aided design (CAD), utilizing a variety of CAD tools such as AutoCAD, SolidWorks, CATIA, and others. Some of these programs will be either closed-source or open-source. For additive manufacturing to be successful, an engineer or artist working with several computers will need to be proficient in using multiple operating systems. With these CAD tools and user experiences, it will be possible to produce a variety of complex 3D product models. The amount of material a 3D printer will take and the time it will require will be important factors influencing the additive manufacturing process.

Keywords:- *Leaf Spring, Composite Material, Automobile Suspension System, Finite Element Analysis.*

I. INTRODUCTION

Automotive leaf spring suspension system has great potential for weight reduction, it is 10 % to 20% build up %. From zero weight, the introduction of composite materials can reduce weight without compromising load capacity or stiffness. Weight reduction is important for energy savings in vehicle design and directly affects fuel consumption. Composite materials, such as fiber-reinforced plastics (FRP), provide better strength-to-weight ratios and more elastic strain energy storage than steel, enhancing fatigue resistance and durability.

The leaf spring's role in automobile applications is multifaceted, providing suspension, shock absorption, and support for lateral loads, brake, and driving torque. Unlike helical springs, leaf springs can be guided along a defined path during deflection, serving both as structural components and energy absorbers. Weight reduction in leaf springs, achieved through composite materials like FRP, improves vehicle ride quality without compromising load capacity or stiffness. In practical testing, determining load rate and fatigue life is time-intensive, requiring approximately 2-3 days for 100,000 cycles of fatigue life assessment using a full-scale testing machine. Factors affecting fatigue life, such as material treatment, loading conditions, surface characteristics, size, and environment, must be carefully considered.

Engineers face the challenge of developing reliable and timely methods for fatigue life assessment. Although analytical and simulation methods provide approximate results, they still need to be validated.

A. Conventional Methods:

- Hand layup,
- Extrusion,
- Vacuum bagging,
- Resin transfer molding,
- Hot Isostatic resin pressure molding.

B. Additive Manufacturing Methods:

- Selective laser sintering,
- Multijet modeling.
- 3D printing,
- Fused deposition modeling.

➤ *FDM Modeling Process: -*

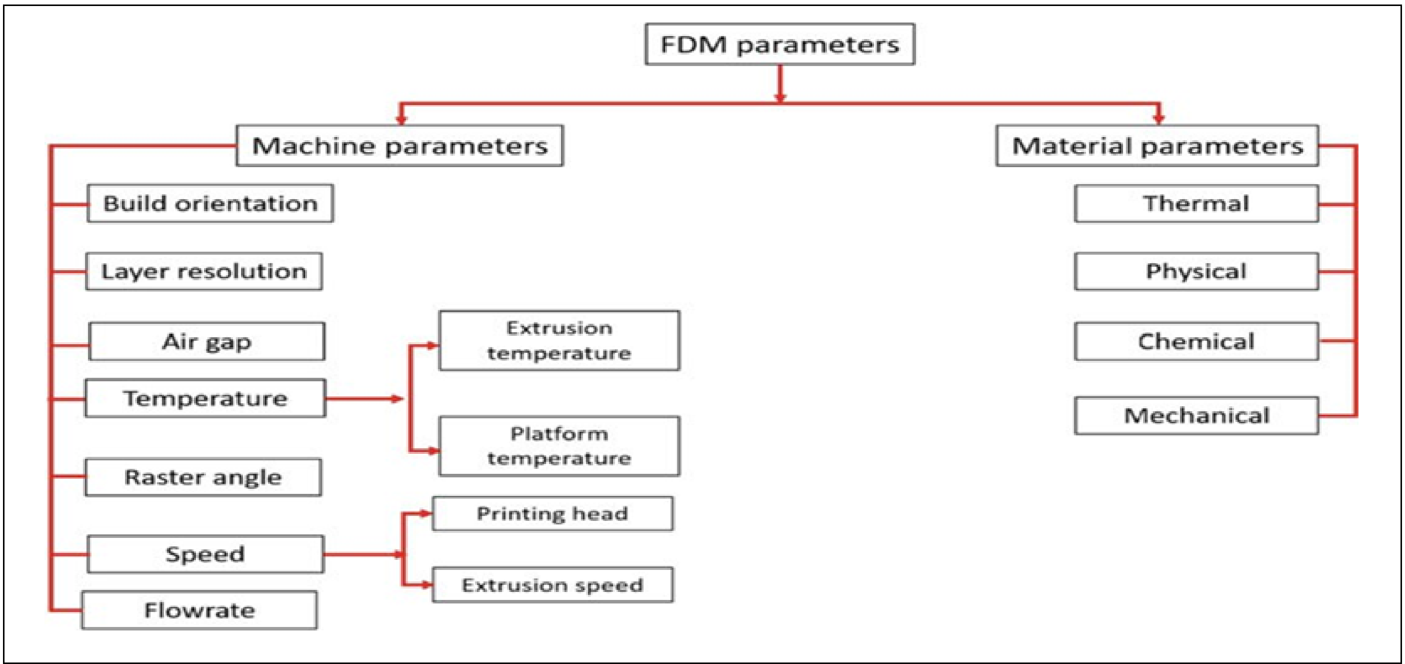

Fig 1: Factors Affecting the Modeling of Fused Deposition

II. PROBLEM STATEMENT

We list a few of the issues that typically arise while using leaf springs. Several issues with the typical composite leaf spring have been noted, and they are as follows:

- Maximum deformation: - Maximum deformation change in shape that a material or structure experiences under applied loads or conditions.
- Low strength: - Low strength indicates that a material or structure lacks the necessary capacity to withstand applied forces or loads without deformation or failure.
- High weight: - Steel leaf springs are heavy, as compared to the composite leaf springs adding significant weight to the vehicle. This affects fuel efficiency and handling.
- Continuous operation of the mini loader vehicle reduces the spring's comfort level.
- Leaf springs often break and weaken near the shackle end and the center.
- The conventional steel leaf spring is heavy, reducing fuel efficiency.

➤ *Objectives:*

The objective of this review paper is to perform a finite element analysis of the FDM sheet spring and its experimental validation.

The following steps will be taken to achieve the objective of this work.

➤ *Experimental Validation:*

An example of an FDM leaf will be made for UTM testing based on the leaf spring dimensions of the Maruti 800 car. FEM results will be validated using UTM. The following steps are followed for test validation.

- The setup sequence is complete with UTM.
- Selection of measurement point.
- Deflection measurement under defined loading conditions.
- Comparison of load/deflection values obtained from FEM analysis with values obtained from testing and UTM for carbon fiber plate specimens
- Comparison of load/deflection values obtained from FEM analysis for fdm plate and steel plate.

III. METHODOLOGY

- The available literature has been reviewed to study the current state of the art in the design and construction of composite leaf springs.
- Design of composite leaf springs and selection of materials for additional construction based on different conditions.
- Analysis of leaf springs will be done using finite element analysis software such as ANSYS.
- The design of composite leaf springs with materials such as E-glass/epoxy and plastic is suitable for fabrication using additive manufacturing techniques.
- Results will be validated by manufacturing and testing composite sheet springs for defined designs and composites.

➤ *Selection of Composite Material: -*

To ensure a good suspension system, the ability to absorb and store energy is important. However, the issue of heavy springs remains. This problem can be solved by using composite materials instead of steel springs.

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Studies have shown that there are many better options in terms of power and cost.

E-glass fiber, a high-quality reinforced fiber, meets the requirements for mechanical properties and is widely used in today's systems.

Therefore, the selected material is E-glass/epoxy.

IV. MATERIAL AND THEIR PROPERTIES

Table 1: General Design Parameters of Composite Leaf Spring

Properties	Value	Unit
Density (Kg/m^3)	7850	(Kg/m
Tensile Strength	650-880	Mpa
Young's Modulus (MPa)	200000-200000	Mpa
Elongation	8-25	%
Fatigue	275-275	Mpa
Yield strength	350-550	Mpa

Table 2: The Mechanical Properties of the E-Glass/Epoxy.

Properties	Value
Tensile modulus along X-direction (Ex),Mpa	34000
Tensile modulus along Y-direction (Ey),Mpa	6530
Tensile modulus along Z-direction (Ez),Mpa	6530
Tensile strength of the material,Mpa	900
Compressive strength of the material,Mpa	450
Shear modulus along XY-direction (Gxy),Mpa	2433
Shear modulus along YZ-direction (Gyz),Mpa	1698
Shear modulus along ZX-direction (Gzx),Mpa	2433
Poisson's ratio along XY-direction (NUxy)	0.217
Poisson's ratio along YZ-direction (NUyz)	0.366
Poisson's ratio along ZX-direction (NUzx)	0.217
Mass density of the material	2.6.106
Flexural modulus of the material, Mpa	40000
Flexural strength of the material, Mpa	1200

➢ *Procedure to be Followed:*

- Choose the Vehicle (Maruti800).
- Measuring the Parameters of the current leaf spring.
- Analyze various leaf designs using ANSYS 14.
- Fabricate the composite leaf spring.
- Test different leaf configurations using a fatigue testing machine.

➢ *Components to Be Design:* -

- Master leaf
- Graduated leaf

➢ *FEA (Finite Element Analysis):*

FEA is a computer technique that models real systems. It divides the structure into smaller elements, assigns equations to each, and solves them simultaneously to predict the overall behavior of the system. This method is particularly useful for complex geometries, loads, and materials where accurate analytical solutions are difficult to obtain.

FEA is used for structural, thermal, and fluid analysis, but it can also be used for other types of simulations.

V. CONCLUSIONS

- Through computer analysis, the maximum deflection in the horizontal and vertical direction and the von Mises stress will be determined using a vertical load of up to 150 kg in increments of 50 kg, in the middle of the hundred fdm spring called by Maruti 800 cars. producer. These deflections and von Mises stresses are favorable compared to steel plate analysis observed with a 9% acceptable variation.
- When compared to the current standard metal spring, the weight of the composite leaf spring ought to be lower. A composite variant constructed of E-glass/epoxy composites will take its place.
- The stresses and strains resulting from a composite leaf spring should be less than the stresses of a conventional steel spring.

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