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Modelling and Testing of Spur Gear made of Different 3D Printed Materials

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ABSTRACT

In this project work, Objective is to use advance manufacturing processes to produces complex Designs using 3d printing methods. Spur gear of Gear box of TATA SUPER ACE is considered in this project work. Theoretical designing of Spur gear is done as per Lewis equation and 3D modelling is done using Solidworks 2015 software. Finite Element analysis software ANSYS 15.0 is used to study the load carrying capacity of Spur Gear. Spur gear is manufactured using 3D printing FDM technique with four different filaments i.e. ABS, Nylon 12, PC and PLA. These types of Gears can be used in any power transmission system and can be manufactured with required load carrying capacity with short time of production and complex designs. Gear can be manufactured using additive manufacturing methods which will reduce the manufacturing time, easy to make customized gears instantly, reduce noise generated during meshing of gear at high speed, low rate of wear and increase in life of gear.

Keywords: 3D printing, Spur gear, Solidworks, Fused Deposition Modelling, ANSYS workbench.

I. INTRODUCTION

3D printing creates solid parts by building up objects one layer at a time. Producing parts via this method offers many advantages over traditional manufacturing techniques. 3D printing is unlikely to replace many traditional manufacturing methods yet there are many applications where a 3D printer is able to deliver a design quickly, with high accuracy from a functional material. Understanding the advantages of 3D printing allows designers to make better decisions when selecting a manufacturing technique that results delivery of the optimal product. One of the main advantages of additive manufacture is the speed at which parts can be produced compared to traditional manufacturing methods. Complex designs can be uploaded from a CAD model and printed in a few hours. Where in the past it may have taken days or even weeks to receive a prototype, additive manufacturing places a model in the hands of the designer within a few hours. While the more industrial additive manufacturing machines take longer to print and post process a part, the ability to produce functional end parts at low to mid volumes offers a huge time saving advantage when compared to traditional manufacturing techniques.

Consider a custom steel bracket that is made via traditional manufacturing methods. Similarly to additive manufacturing, the process begins with a CAD model. Once the design is finalized, fabrication begins with first cutting the steel profiles to size. The profiles are then clamped into position and welded one at a time to form the bracket. Sometimes a custom jig will need to be made up to ensure all components are correctly aligned. The welds are then polished to give a good surface finish. Next holes are drilled so the bracket can be mounted to the wall. Finally the bracket is sand blasted, primed and painted to improve its appearance.

In this project work, 3D printing technique in imparted to produce a Spur gear for Customized requirements. This manufacturing Process helps the designer to produce the component for small orders, Complex designs and in short time. Spur gear is designed using 4 Different filaments i.e. ABS, PLA, PC and Nylon. These types of gears are designed for customers who needed the gear to Transfer the torque as per there requirement.

Objectives

- ✓ To Design the 3D printed spur gear using different polymer filament materials and to study the behavior.
- ✓ To select affordable 3D printing method for spur gear.
- ✓ To select suitable polymer materials for spur gear.
- ✓ To find the strongest 3D printed filament for spur gear application for noise reduction.

Problem Definition

Traditionally gears are manufactured using cast iron, steel, nylon, bronze whose manufacturing cost is high due to mold casting, quenching processes etc. In such cases, it cost highly for producing the random requirement. 3D printing technology can be implemented where customized designs can be manufactured in short time without going to conventional manufacturing process. So there is need to design a 3D printed spur gear which can be made quickly and easily, with moderate strength, durability and performance.

Methodology

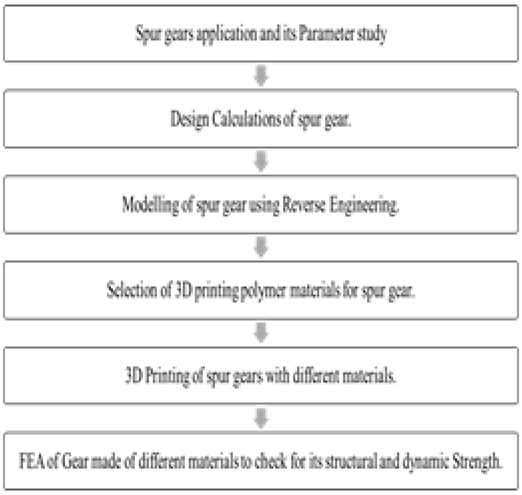

Figure 1. Methodology

II. DESIGNING & STRENGTH CALCULATION

A. Application Selection: I.C Engine of TATA Ace

In this project work, focus is to redesign a spur gear of 1405cc Engine.

For that, four wheeler 1405cc Tata Super Ace is considered.

Consider a 1405cc engine

Displacement = 1405CC

Maximum Power = 70hp at 4500rpm

Maximum Torque = 13.8kg-m at 2500rpm

B. Parameters of Tata ACE

Parameters of gears used in Tata ACE is capable to transmit power of 35KW and 2500rpm is as follow.

- Module (m) = 10 mm
- Number of teeth (Z) = 18 mm
- Pressure angle (α) = 20º Full depth
- Face Width = 54 mm

In this project work, all the parameters are scaled to 4:1 Ratio to make printing cost as low as possible.

- Module (m) = 2.5 mm
- Number of teeth (Z) = 18 mm
- Pressure angle (α) = 20º Full depth
- Face Width = 13.5 mm

C. Spur gear design parameters

Tooth parameters are calculated by involutes teeth standards

1. Pitch circle diameter (PCD) = module x number of teeth
2. PCD = 2.5 x 18 = 45 mm
3. Circular pitch (Pc) = πD/Z= (πX 45)/18=7.85 mm
4. Diametrical pitch (D.P) = Z/D= 18/180=0.1 mm
5. Addendum (ha) = m = 2.5 mm
6. Dedendum (hf) = 1.25m = 3.12 mm
7. Tooth thickness = 1.5708m = 3.92 mm
8. Fillet radius = 0.4m = 1 mm
9. Working depth (hk) = 2m = 5 mm
10. Whole depth (h) = 2.25m = 5.62 mm
11. Addendum circle diameter = 2 x Addendum + PCD = 2 x 2.5 + 45 = 50 mm
12. Dedendum circle diameter = PCD – 2 x Dedendum = 45 – 2 x 3.12 = 38.76mm
13. Clearance depth = 0.25m = 0.62 mm

D. Theoretical Strength Calculation

Table 1. Strength Calculation

Materials	Ultimate Stress, MPa	Allowable Stress, MPa	Tangential Load, N	Bending Stress, MPa	Power Transmitted, KW
PLA	50.1	25.05	133.767	11.019	0.493
ABS	41.4	20.7	110.538	9.105	0.408
NYL12	**79.4**	**39.7**	**211.998**	**17.463**	**0.781**
PC	60.6	30.3	161.802	13.328	0.596

III. 3D MODELLING USING SOLIDWORKS

Introduction to Solidworks

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systems. According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013 Advantages: Cheap and vary reliable for academics and industry, Toolbar is well oriented and simple, Quick learning is possible, wildly used in academics and industry.

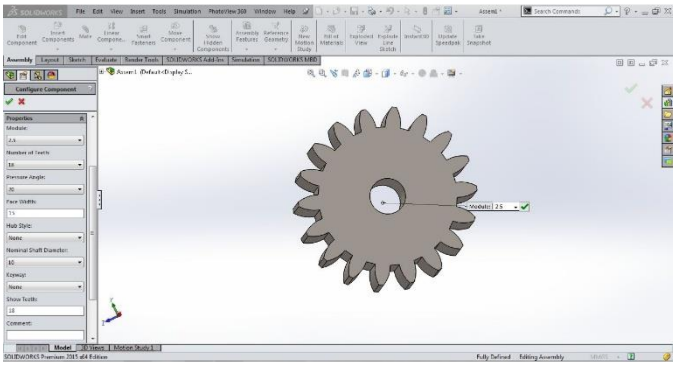

Figure 2. 3D model of Spur Gear in solidworks

IV. FILAMENT MATERIAL SELECTION

A. Selection of 3D printing method

Table 2.3d Printing Method

3D Printing Method	Strength	Cost	Worker Required	Materials
SLA	Low	Low	Beginner	Plastics
FDM	High	Low	Moderate	Thermoplastics, wood, Nylon, Carbon fiber, etc.
SLS	High	Very High	Expert	Metals
SLM	Very High	Very High	Expert	Metals
LOM	Low	High	Moderate	Papers, metal sheets etc.

Fused deposition modeling (FDM) 3D printing method is selected because its products have high strength and it is most widely used method for 3D printing. It is compatible with huge variety of filaments such as nylon, wood, carbon fiber etc. FDM method is simple doesn't require an expert worker. This Method is used for manufacturing of Spur gear.

B. Mechanical properties of shortlisted 3D printing material

Table 3. 3d Printer Material

Materials	Density (g/cc)	Tensile strength (MPa)		Young's modulus (GPa)
		Yield	Ultimate	
PLA	1.29	44.8	50.1	3.76
ABS	1.05	40.7	41.4	2.10
NYL12	1.42	45.4	79.4	5.31
PC	1.20	63.3	60.6	2.36

V. FEA SIMULATION OF SPUR GEAR

- ✓ ANSYS Workbench 15.0 is used for FEA.
- ✓ Spur Gear is tested for static loading condition and is assumed to be fixed at shaft end and subjected to surface load at the Curve face of gear tooth.
- ✓ Mesh size is 2 mm.
- ✓ Sweep method is used for meshing.
- ✓ Spur Gear made of four different materials are tested using FEA.

Working and Boundary Conditions

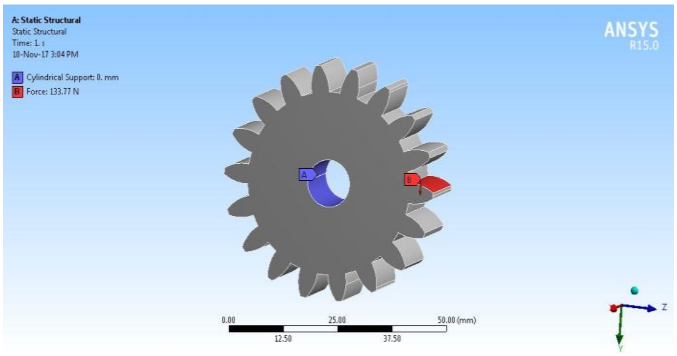

Figure 3. Boundary Conditions of Spur Gear

VI. ANALYSIS RESULTS

A. STRESS

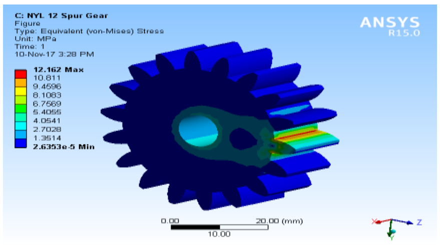

Figure 4. Stress in NYL 12 at tangential load of 211.99 N

B. DEFORMATION

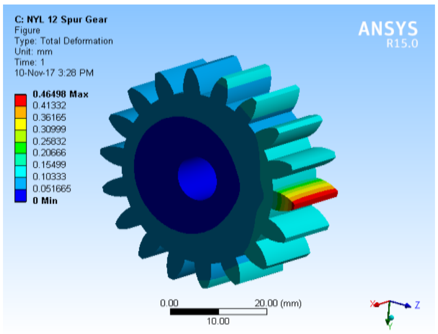

Figure 5. Deformation in Spur Gear of 0.464 mm

VII. GEAR MANUFACTURING AND TESTING

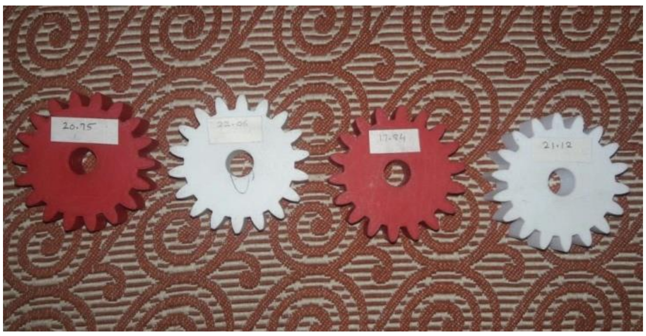

Figure 6. Actual Manufactured Gears

By using 3D print machine we printed four gears i.e. PLA, ABS, NYL12, PC. On the Universal Testing Machine we tested all four 3D printed gears for bending stress.

VIII. RESULTS

Table 4. Fea Results

Sr. no.	Materials	Weight (Kg)	Stress (MPa)	Deformation (mm)	Tangential Load (N)
1	PLA	0.028	7.67	0.414	133.77
2	ABS	0.022	6.34	0.613	110.53
3	NYL12	0.030	12.16	0.464	211.99
4	PC	0.026	9.28	0.798	161.80

Table 4. Comparison Of Testing Results, Fea & Theorotical Calculation

Sr. No.	**Materials**	**Bending Stress(MPa)**			**Tangential Load (N)**		
		Theoretical	**FEA**	**Testing**	**Theoretical**	**FEA**	**Testing**
1	PLA	11.019	7.67	-	133.767	133.77	-
2	ABS	9.105	6.34	-	110.538	110.53	-
3	NYL 12	17.463	12.16	10.37	211.998	211.99	203.14
4	PC	13.328	9.28	11.24	161.82	161.80	183.05

It was concluded that Spur gear made with Nylon 12 3D printing filament can carry tangential load of 211.99 N with a deformation of 0.464 mm.

IX. CONCLUSION

FEA results shows that Nylon is strong when subjected to tensile or compressive loading. These types of 3D printed components can be used when there a small amount of requirement. This will results into reducing the time of Production, complex designs can be manufactured and avoids the cost of molding. This concept of Advance manufacturing can be used for different mechanical parts manufacturing like gears and Mold manufacturing for composite materials. These types of manufacturing can be used in Biology where 3D printed body parts can significantly enhance learning. Feeling the texture of a brain is different from seeing it in a book or on screen. Complex structures of protein molecules in DNA can be very easily appreciated with 3d prints.

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