

DESIGN AND FABRICATION OF SPUR GEAR USING 3D PRINTING TECHNOLOGY

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Abstract - Spur gears play a significant role in mechanical engineering and can obtain a high transmission and energy consumption ratio, common elements used in the transfer of motion, and high-intensity control for mechanical drives, i.e. belt drives, chain drives, and cylindrical drives. Such power transmission components are subjected in terms of load and speed to non-conforming working environments, which are often important at high speeds. When a gear tooth embraces a tooth on the other side, the teeth interfere, causing noise from this effect. It raises the tension on the teeth of the equipment too. This project research aims at modeling and developing the spur gear using 3D printing technology. Cheap, quick, and customizable movement transfer solution for 3D printing gears compared to alternative modes of gear production. Variations of both the complexity & 3D are virtually free. In this work, it is proposed to spur gear model of motorcycle. The modeling of a spur gear using CATIA V5 R21 software and analysis is done with ANSYS software. The spur gear model is contrasted with different materials like Poly Lactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS) in terms of strength.

Key Words: Spur gear, Catia, Ansys, Fused Deposition Modelling

1. INTRODUCTION

3D printing develops durable components by stacking layers of material on each other until the required product is obtained. In the 1990s, 3D printing technologies were deemed ideal only for practical or sample development and rapid prototyping became a more fitting concept. Today, the precision, consistency and wider range of materials have strengthened to the extent that 3D printing is considered an advanced engineering technique with the name of Additive manufacturing. 3D printed objects can have a complicated structure or shape and are always managed to make from a digital 3D model or a CAD file. Product development through this approach provides many advantages over conventional production techniques. 3D printing is unlikely to replace many of the conventional manufacturing methods, such as turning, milling, drilling and shaping, which have been around for many years and have helped people create products.

Gears are commonly used under varying loads and velocities in power and motion transmission work. Particularly in machinery, automotive industries, textile machinery etc., these gears are preferred and used successfully. Gearing is an integral part of the machinery, and the gear collision is the main element that induces machinery failure. The spur gear is probably the easiest type of gear formed and is commonly used for the transfer of rotary motion between parallel shafts. Spur gears, when in practice, are subjected to many stresses but, out of all, two forms of stress: bending stress and contact stress are essential from the design perspective. Lewis equation technically analyses the bending stresses, as well as Hertz equation contact stresses. Since spur gear has complicated geometry, the need for better analysis emerges using numerical methods that have more precise solutions than the theoretical approaches. Finite element analysis has become one of the research methods that's been widely utilized in the study of components used in various mechanical systems.

Plastic gears have put themselves in a wide range of applications as significant alternatives to conventional metal gears. The use of plastic gears has grown via light weight, precise motion transmission to more complex applications of power transmission. Within this project research, the bestowed 3D printing technique is used to manufacture spur gear for customized requirements. This method of production allows the manufacturer to produce the part in limited order, complicated designs in a short time. The spur gear is conceived using two separate filaments, i.e., PLA, ABS.

2. PROBLEM STATEMENT

The conventional methods often involve subtraction of material from a wider block for achieving the finished component or making a casting or molding tool, this seems to be a major obstacle of the entire production line. The production of the random requirement in such cases costs enormously. In that case, custom prototypes can be created within a limited period without going to the conventional manufacturing process; 3D printing technology may be applied.

The research work aims to develop new spur gear for HONDA CB Shine. The spur gear should therefore withstand stress and bear a sufficient load. The spur gear size must also be sufficiently large.

Objectives of the study

1. Data collection from journals
2. Developing a 3D model of spur gear in CATIA by using reverse engineering
3. Distinguish the different polymer materials that can be used to manufacture spur gear
4. Mesh the gear to analyze
5. Spur gear analysis using ANSYS software by application of compressive load, safety factor, allowable stress
6. Manufacture by the 3D printer of spur gear using different polymer materials

3. DESIGN AND STRENGTH CALCULATIONS OF SPUR GEAR

In this project work, focus is to redesign a spur gear of 125cc engine.

For that, two wheeler 125cc Honda CB shine is considered.

Model = HONDA CB SHINE

Engine = TATA475 TCIC (BSIII)

Engine capacity = 125cc

Maximum engine output = 10.16HP@7500rpm

Maximum engine torque = 10.3N-m@5500rpm

Fuel tank capacity = 12 liters

Spur gear design parameters

Module (m) = 2.1;

Number of teeth (T) = 29; Involute teeth

Pressure angle (α) = 20deg

Pitch circle radius (Rp) = $m \times (T)/2 = 2.1 \times 29 / 2 = 30.5$ mm

Base circle radius (Rb) = $0.94 \times R_p = 0.94 \times 30.5 = 28.67$ mm

Circular pitch (Pc) = $\pi D / T = (\pi \times 30.5 \times 2) / 29 = 6.608$ mm

Diametrical pitch (Dp) = $T / D = 29 / 61 = 0.475$ mm

Addendum circle radius (Ra) = $R_p + m = 30.5 + 2.1 = 32.6$ mm

Dedendum circle radius (Rd) = RP - (1.25*m) = 27.8mm

Face width (b) = 10mm

Fillet radius = 0.39*m = 0.39*2.1 = 0.819mm

CALCULATIONS

Torque (T) = 10.3N-m@1500rpm

T = 10.3 N-m = 10300 N-mm

N = 1500 rpm

Power (P) = $2 \cdot 3.14 \cdot 1500 \cdot T / 60$

P = $2 \cdot 3.14 \cdot 1500 \cdot 10.3 / 60$

P = 1617 Watt

Power (P) = 1.617 K Watt.

Torque (T) = F*(d/2)

Where,

F-load,

d- Pitch circle diameter (z*m=61mm)

T= F*(d/2)

F = T / (d/2)

F = 10300/30.5

Load (F) = 337.7 N

DESIGN PROCEDURE FOR SPUR GEAR

Apply the Lewis equation as follows:

$W_T = \sigma_w \cdot b \cdot P_c \cdot y = \sigma_w \cdot b \cdot \pi \cdot m \cdot y$

$W_T = (\sigma_o \cdot C_v) \cdot b \cdot \pi \cdot m \cdot y \dots (\sigma_w = \sigma_o \cdot C_v)$

Module (m) = 2.1; number of teeth (T) =29

$P_c = \pi \cdot m = 6.594\text{mm}$

Y= Lewis form factor = 0.12255

b = face width = 10mm

The maximum allowable stress for PLA= 25.05 MPa

Ultimate tensile strength for PLA = 50.1 MPa

The maximum allowable stress for ABS = 20.7 MPa

Ultimate tensile strength for ABS = 41.4Mpa

$$\sigma_w = \sigma_o.C_v = 45 * 0.3816 = 17 \text{ N/mm}^2$$

$$C_v = (0.75/1+v) + 0.25 = (0.75/1+4.7) + 0.25 = 0.3816$$

$$V = \pi D_p N / 60 = \pi * 61 * 1500 / 60 * 1000 = 4.7 \text{ m/sec}$$

$$W_T = \sigma_w . b . \pi . m . y = 17 * 10 * \pi * 2.1 * 0.12255 = 138.8 \text{ N}$$

DYNAMIC TOOTH LOAD

$$W_D = W_T + W_I$$

$$= W_T + [21v (b * C + W_T) / 21v + (b * C + W_T) 1/2]$$

$$= 138.8 + [21(4.7) (0.01 + 138.8) / 21(4.7) + (0.01 + 138.8) 1/2]$$

$$W_D = 276.9 \text{ N}$$

$$\text{Deformation factor (C)} = K * e / [(1/EP) + (1/EG)] = 22.65 \text{ N/mm}^2$$

STATIC TOOTH LOAD

$$W_S = \sigma_e * b * \pi * m * y$$

$$W_S = 65 * 10 * \pi * 2.1 * 0.12255$$

$$W_S = 538.178 \text{ N}$$

WEAR TOOTH LOAD

$$W_W = D_p * b * Q * K$$

$$Q = 2T_G / (T_G + T_P)$$

$$Q = 1.094$$

$$\text{Load stress factor (k)} = 1.4 \text{ N/mm}^2$$

$$W_W = 61 * 10 * 1.09 * 1.4$$

$$W_W = 930.86 \text{ N}$$

POWER TRANSMITTED

$$P = W_T * V$$

$$P = 138.8 * 4.7$$

$$P = 652.36 \text{ Watts}$$

4. 3D MODEL

CATIA is a three dimensional digital technology computer-supported acronym. CAD, i.e., computer-aided design software, is well known, powerful, and widely successful. Dassault systems has been established, developed and operated.

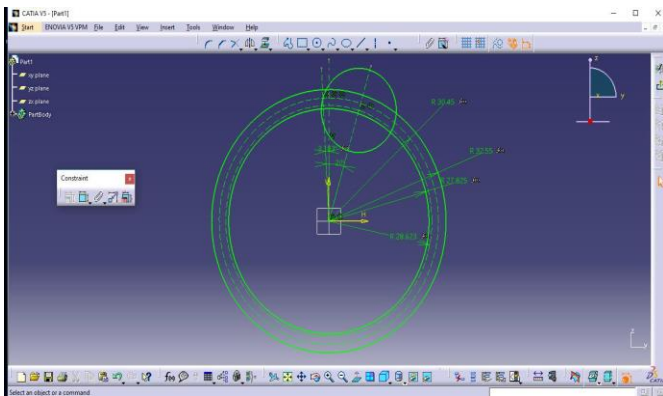


Fig 1: Nomenclature of the spur gear

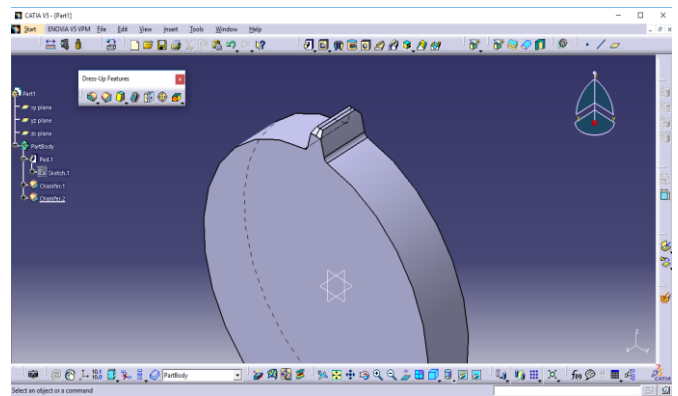


Fig 3: Forming of chamfer on gear tooth

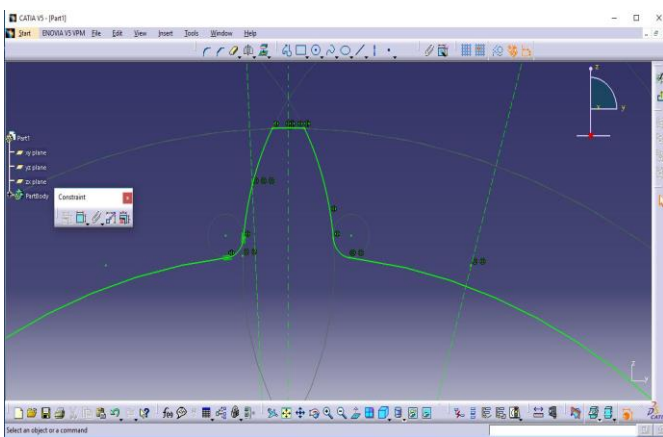


Fig 2: Creating of gear tooth of spur gear

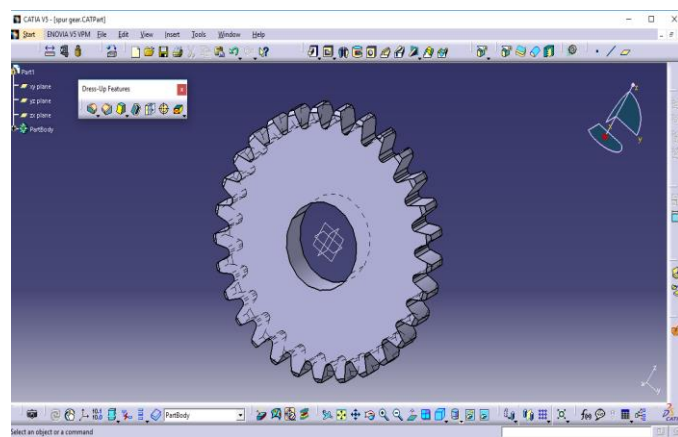


Fig 4: Pocket in gear model

5. FEA SIMULATION OF SPUR GEAR

The structural analysis involves the collection of physical laws and mathematics used to analyze and forecasts the actions of the frameworks. Structural research combines both the fields of mechanics and dynamics and various hypotheses of failure. For engineers, structural analytics is especially important to ensure that they fully understand the load paths and the consequences for their engineering design. It provides designers or engineers with the potential to ensure that a structure or framework is safe to use under the projected loads to be withstanding.

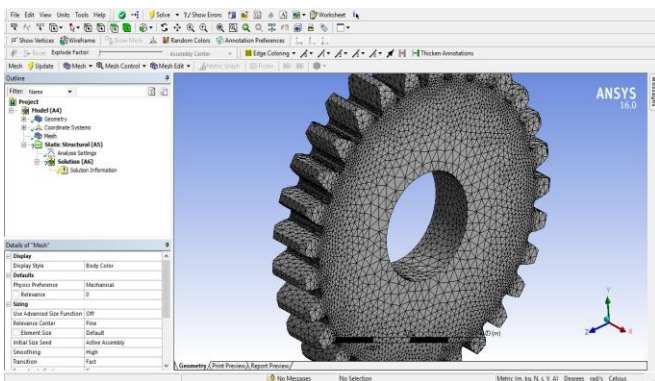


Fig 5: Meshing

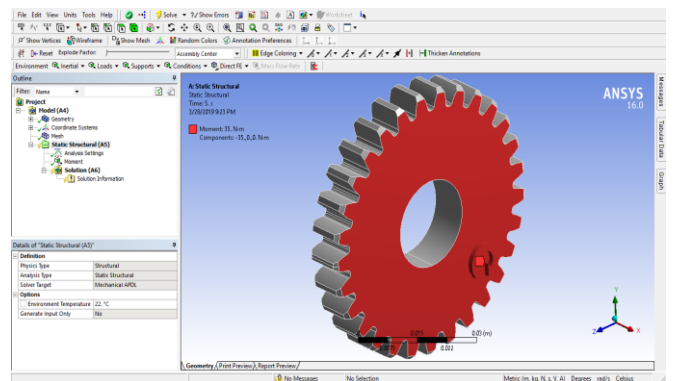


Fig 6: Moment

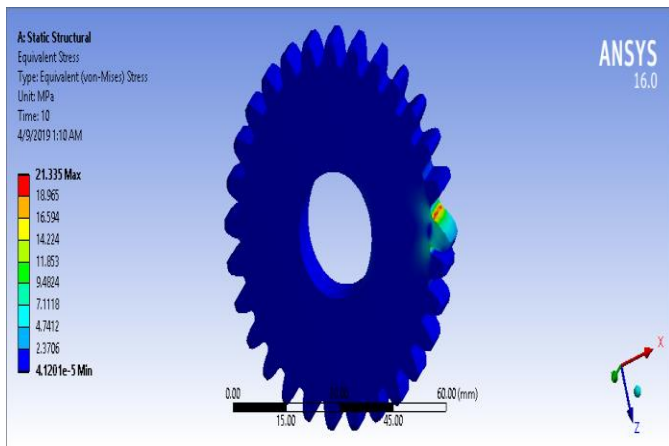


Fig 7: Stress in PLA at tangential load of 133.7 N

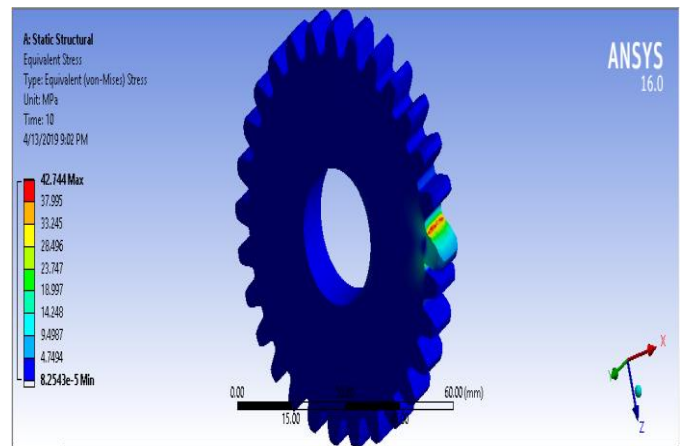


Fig 10: Stress in PLA at tangential load of 268 N

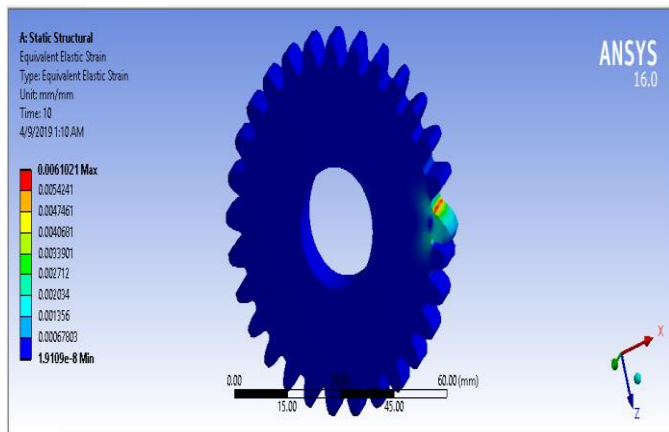


Fig 8: Strain in PLA at tangential load of 133.7 N

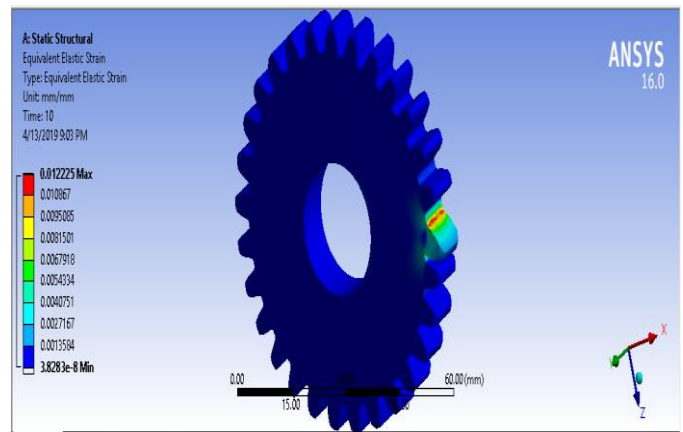


Fig 11: Strain in PLA at tangential load of 268 N

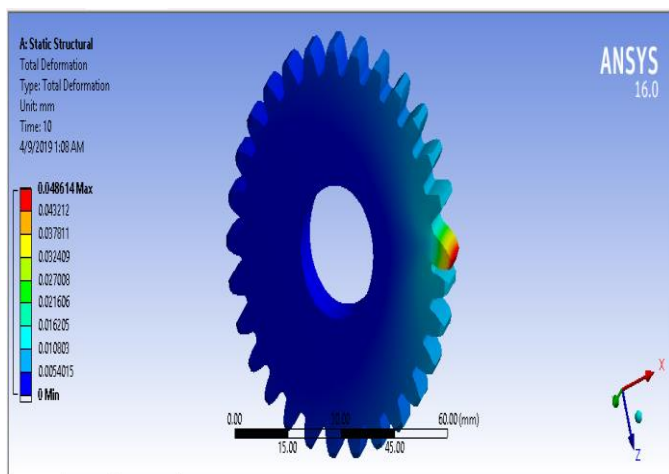


Fig 9: Deformation in spur gear of at tangential load of 133.7 N

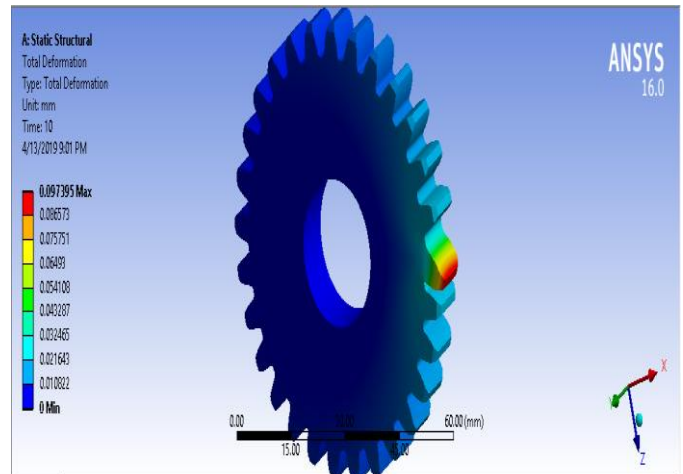


Fig 12: Deformation in spur gear of at tangential load of 268 N

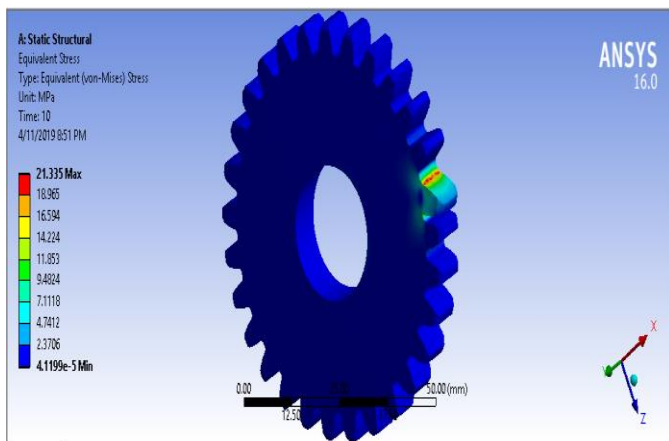


Fig 13: Stress in ABS at tangential load of 133.7 N

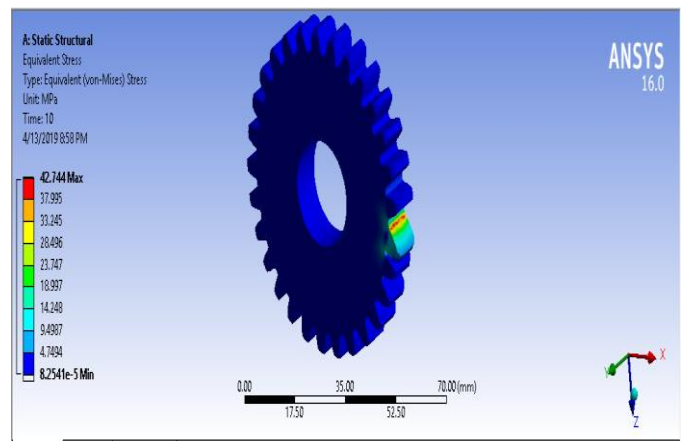


Fig 16: Stress in ABS at tangential load of 268 N

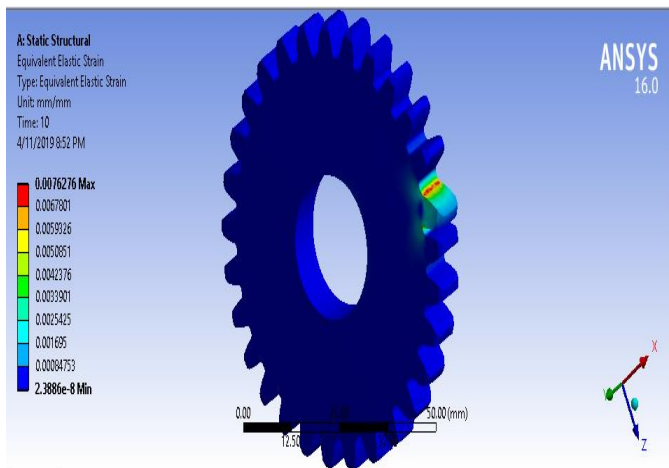


Fig 14: Strain in ABS at tangential load of 133.7 N

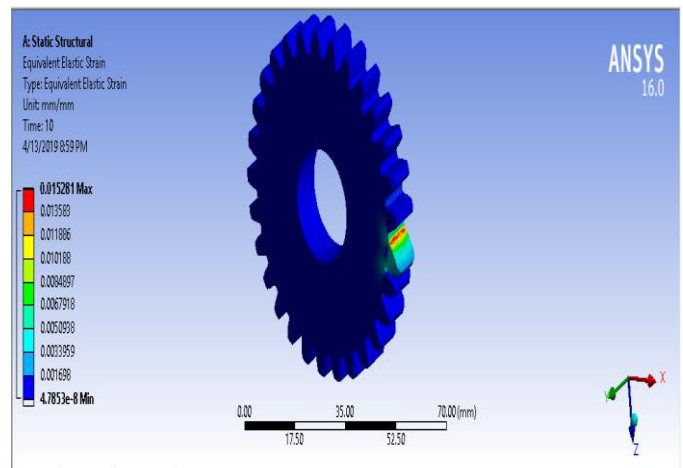


Fig 17: Strain in ABS at tangential load of 268 N

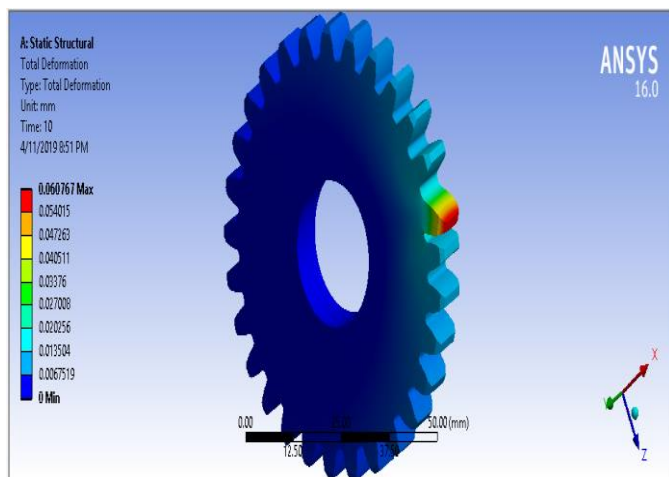


Fig 15: Deformation in spur gear at tangential load of 133.7 N

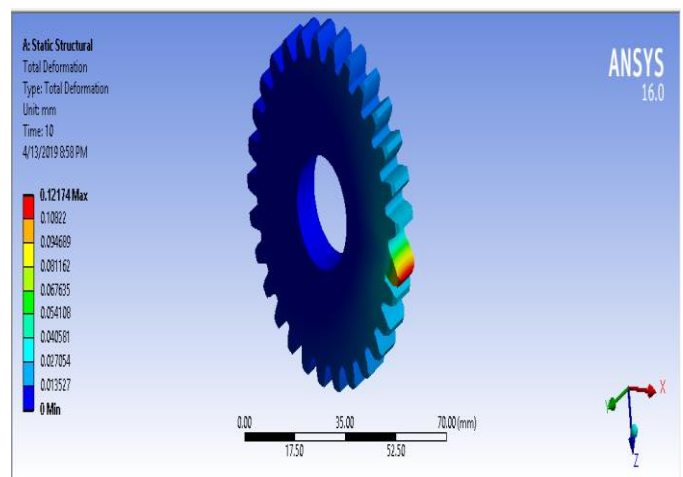


Fig 18: Deformation in spur gear of at tangential load of 268 N

ANALYSIS RESULTS

Table 1: Comparison of PLA & ABS

Materials	Ultimate Stress, (MPa)	Allowable Stress, (MPa)	Tangential Load, (N)	Bending Stress, (MPa)	Power Transmitted, (KW)
PLA	50.1	25.05	138.80	17.172	0.650
ABS	41.4	20.7	110.53	9.105	0.408

Table 2: Ansys comparison values of PLA & ABS

S.No	Materials	Tangential Load (N)	Total Deformation (mm)	Equivalent (von - mises) stress, (MPa)	Equivalent strain, (mm/mm)
1	PLA	133.7	0.04	21.335	0.0061
		268	0.09	42.744	0.0122
2	ABS	133.7	0.06	21.335	0.0076
		268	0.1	42.744	0.0152

6. FDM 3D PRINTER

Creativity Ender 3 is the fast prototyping tool that is used as a 3D printing method for Fused Deposition Modelling (FDM). The Ender 3 3D printer is an open-source 3D printer Creativity that uses the Marlin firmware. The Ender 3 build is very quick and takes most people from beginning to the end of about 2-4 hours. When correctly calibrated the Ender 3 gets good print output.

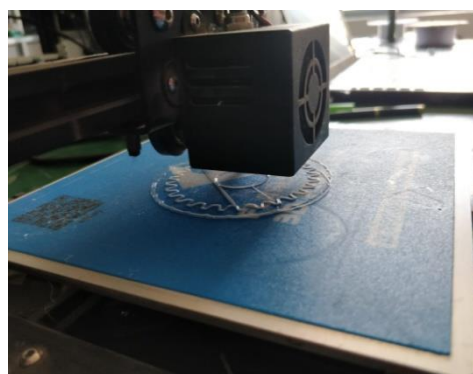


Fig 19: Ender 3

Table 3: Printer Specifications

Printer technology	FDM
File format	.STL, .OBJ, .DAE, .AMF
Nozzle diameter	0.4 mm
Layer thickness	0.1 – 0.4 mm
Filament	PLA, ABS
Slicing software compatibility	Cura/ simplify 3D/ slic3r/ Repetier host
Printing speed	50mm/sec – stable 70mm/sec - Max
Printing size	220*220*250 mm

Software Used

In this research project, we were using software called Cura. It is a 3D printer slicing application used for slicing the objects. It is open-source licensed software and preferred slicer software for Ultimaker 3D printer, as well as other 3D printers too.

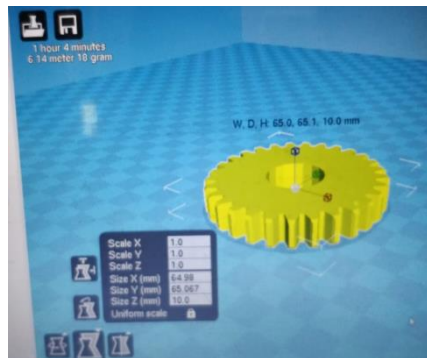


Fig 20: Spur gear in Cura slicing software



Fig 21: Gears are manufactured by 3D printing

7. CONCLUSION

The results of the FEA suggest that PLA, by static structural analysis is a stronger material than ABS. In this project, a table was created to find the best material for our design, based on the design criterion PLA material came out on top among the other material. The results of the study are analyzed for total deformation, equivalent elastic strain, equivalent stress (Von-Mises). The components produced through 3D printing are generally used for small requirements or as prototypes.


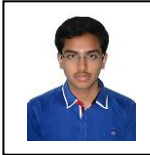

Future scope

Through design considerations and the use of other materials this plastic spur gear can be more optimized. Despite the fact that the automobile industry was among the first to embrace 3D printing, 3d printing technology has been limited to low-volume prototyping applications for decades. The use of 3D printing in automobiles today progresses from fairly basic prototype models for fit and finishes testing and design verification, to practical components used in production cars, engines, and platforms. Additive manufacturing is not only used in the manufacture of prototypes but is also well developed in the medical industry, such as the development of human tissues or organs.

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BIOGRAPHIES

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