Design, Analysis And Experimental Investigation of Strength of Spur Rack Manufactured By FDM

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Abstract- *This paper deals with plastic gears which have gone from curiosity to industrial mainstay in the past 50 years. Today they transfer torque and motion in products as diverse as cars, watches, sewing machines, building controls, and missiles. Even with all the ground they've gained, their evolution is far from over as new and more demanding gear applications continue to emerge. Plastic gears are serious alternatives to traditional metal gears in a wide variety of applications. Conventional method of manufacturing is the plastic moulding, but this is only for a substantial batch quantity. In present day situation many times it is required to produce small quantity of products for which plastic moulding is not economical solution. In such cases the method of FDM (Fused deposition modelling) can be used. The FDM method is extremely fast and economical for small batch quantity, the performance of parts produced by this method are yet to be proven for strength and durability. The Dissertation attempts experimentally for spur gear in plastic to investigate the performance of spur rack produced by FDM process and compare it with that produced by ABS & PLM material by development of test rig and by Ansys software.*

Keywords- FDM, ABS and PLM.

I. INTRODUCTION

Plastic gears are serious alternatives to traditional metal gears for wide variety of applications. The use of plastic gears has expand from low-power, precision motion transmission into so demanding power transmission applications. As designers increase the limits of acceptable plastic gear applications, to learn more about a behaviour of plastics in gearing and how to take advantage of their unique characteristics. Plastic materials are widely used for light load, non-precision and noiseless operation. In today's era plastic gears are transferring torque and motion in products as diverse as cars, watches, sewing machines, building controls, and missiles. Now for making plastic gears the method called 3D printing is wildly used. 3D printing is the process of making 3-dimensional solid objects from the digital file. The creation of the 3D printed object can be achieved using additive processes. In an additive process an object can be created by laying down successive layers of material until the entire object should be created. In 3D printing method, the most commonly used method is FDM (fused deposition machine). In the FDM process, the build material will be initially in the raw form of a flexible filament. The feedstock filament is then partially melted and extruded though a heated nozzle within a temperature controlled environment for building of the part. The material is extruded in a thin layer onto the previously built model layer on the build plat forming the form of a prescribed two-dimensional (x-y) layer pattern. The deposited material cools, solidifies, and bonds with adjoining material. After an entire layer is deposited, the build platform moves downward along the z-axis by an increment equal to the filament height (layer thickness) and the next layer is deposited on top of it. The table on which the build sheet is placed lies on the x-y plane. For making the composite spur gear, the composite fiber can be used as a infill material and the number of layers can be used (ie.2-layer, 3- layer, 4- layer etc.) for changing the strength of material. Also the load caring capacity and safety load can be determined by using test rig.

II. PROBLEM STATEMENT

- The composite gears are the solution to plastic gears to improve the capacity of gear but very less research available on it.
- For transmission of high torque spur gears should have sufficient strength, precise, and more powerful. It can be achieved by manufacturing spur gear using FDM technique.

III. OBJECTIVE OF THIS WORK

1. Manufacture spur gear for various layers using FDM process.
2. 2-d drawing and 3-d modeling using uni-graphics, and analysis using ANSYS for spur gear manufactured by FDM process.
3. Determination of load carrying capacity and safety load on test rig for spur gear manufactured by FDM process.

4. Comparative analysis of strength components by both methods.
5. Determine the strength of fdm manufactured gear with increase in layer of composite material

IV. EXPERIMENTATION

A. Specifications of material selected

- Rack type: Spur rack, double sided
- Material of rack = Moulded / ABS polymer
- Rack Dimensions: 1.5 module / 28 Teeth
- Material of Pinion= Moulded / ABS polymer
- Pinion Dimensions: 1.5 module / 38 Teeth

B. Strength Test for spur rack

1. Experimental Procedure:

(a) Assemble the machine parts according to the type of gear to be tested.
(b) Make sure that their snap ring safely mount gear.
(c) With no external load the gears to be tested should be smooth and do not have any surface contaminant.
(d) After this Measure the mass of the driving gear. This measurement is considered the initial point.
(e) Add the spring and mass system. Adjust the mass and the lever hole where the spring can be hung to obtain the desired load. The load can be measured using the LCD (liquid crystal display or digital number display) in the controller.
(f) Keep the load for a certain interval of time and measure the new mass of the gear.
(g) Repeat step (f) several times until the total number of desired cycles is attained.
(h) Now, several points are obtained between the cycles and the weight loss. A curve between these two variables can be plotted to show the wear rate against the motor cycles.

2. Experimental testing:

Failure load for spur rack by plastic moulding 10 kg.

Failure load for spur rack by FDM process in kg.

Durability the equipment will be run for duty cycles till the failure of tooth is seen Under various load condition.

Various load test will be carried out to determine the back lash developed in the system at various loads for given number of duty cycles.

FIG. 1 TEST RIG FOR TEST ON SPUR RACK BY FDM PLASTIC MOULDING PROCESS

C. Test rig set up for testing pinion

Actual deformation is seen to be more than the analytical deformation and having tendency to increase with the increase in load.

The percentage error is well below 8 percent indicating that the analytical and experimental results are well in agreement indicating validation of results.

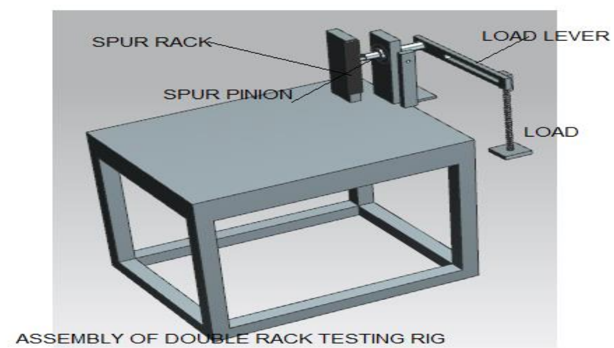


FIG.2 PINION TESTING

V. RESULT AND DISCUSSION

A. Design calculations

1. Theoretical design of spur rack

- Drive as rack and pinion arrangement
- Maximum load = 10 kg (effective load applied by lever mechanism)
- b = 10 m Material of gear ABS POLYMER
- Tensile strength =62 N/mm^2
- The rack and pinion arrangement is such that length of rack is125 mm whereas pinion has 12 teeth of which 1is in simultaneous contact, hence the load on each tooth is 118 N [5]
- $\Rightarrow$Pt = 118N

- Peff = 118 N (as Cv =1 due to low speed of operation)
- Peff = 118N -------------------(A)
- Lewis Strength equation
  WT = Sbym
  Where;
  Y= 0.484 – 2.86Z
- $\Rightarrow$ yr = 0.484 - 2.86 = 0.415 / 40
  Syg = 25.73 N
- W_T = (Syp) x b x m
  =25.73 x 10m x m
- W_T= 257.3 m^2--------------------(B)
- Equation (A) & (B)
- 257.3m^2 = 118
  $\Rightarrow$m=0.67
- selecting standard module = 1.25 mm. Thus the rack is of 1.5 mm module, 50 teeth whereas pinion is of 1.5mm module and 38 teeth.

Below show the ANSYS images of design of spur gear

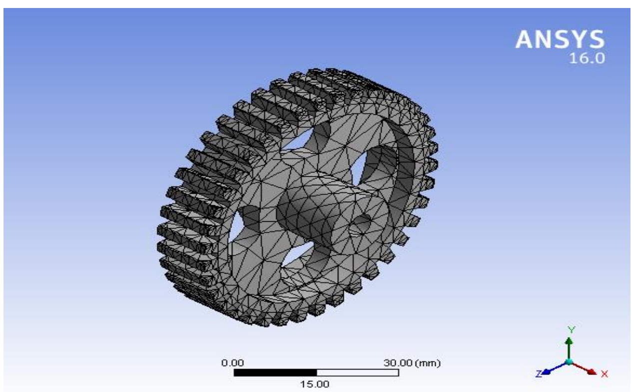


FIG. 3 DESIGN OF SPUR GEAR

Statistics	
Nodes	15809
Elements	7957
Mesh Metric	None

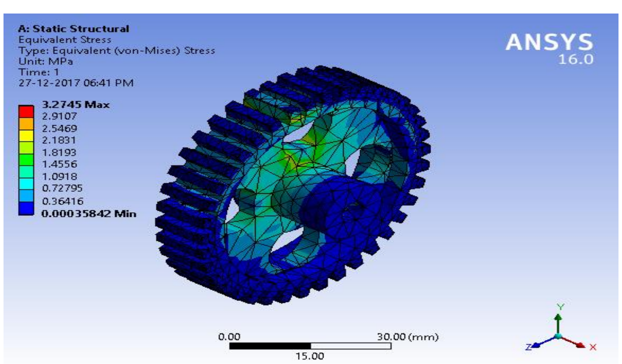


FIG. 4 STATIC STRUCTURE

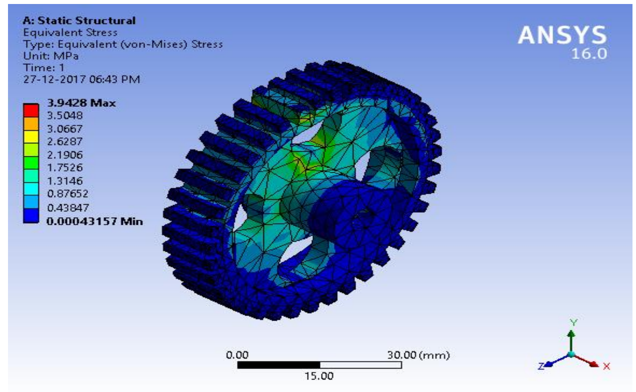


FIG. 5 STATIC STRUCURE WITH LOAD 5KG

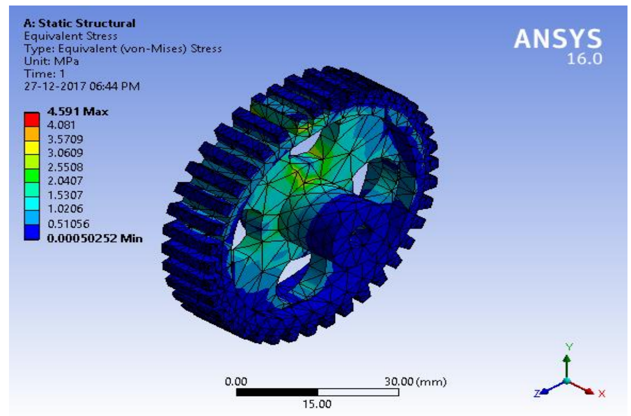


FIG. 6 STATIC STRUCURE WITH LOAD 6KG

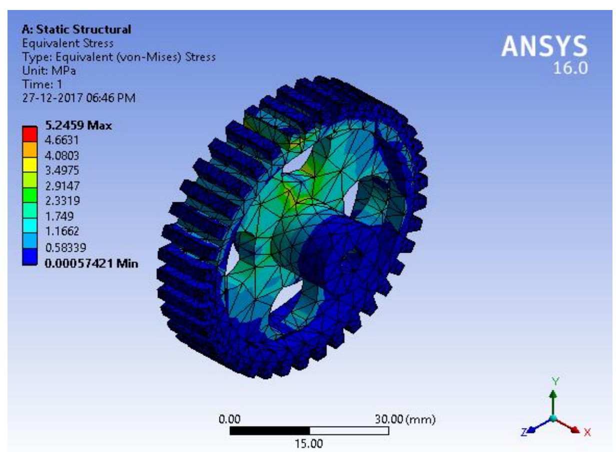


FIG. 7 STATIC STRUCURE WITH LOAD 7KG

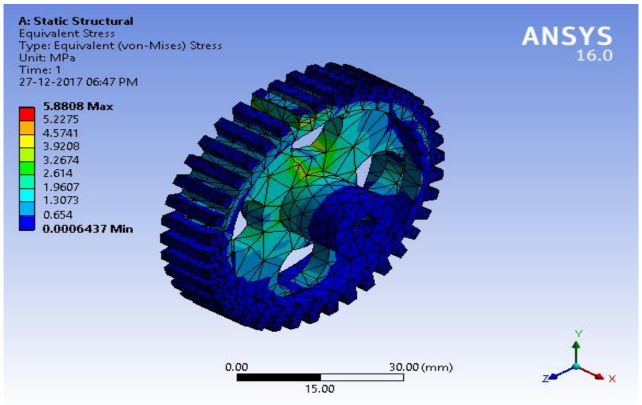


FIG. 8 STATIC STRUCURE WITH LOAD 8KG

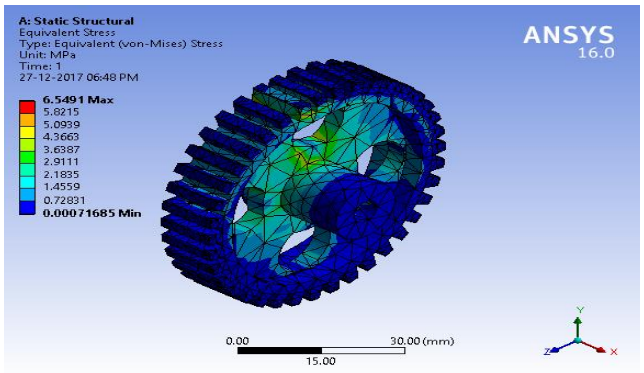


FIG. 9 STATIC STRUCURE WITH LOAD 9KG

2. Analysis of ABS – spur gear

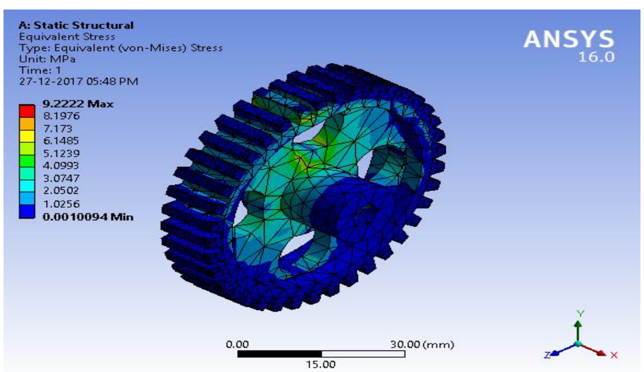


FIG. 10 STATIC STRUCURE WITH LOAD 10KG

TABLE I ANSYS RESULT

VALUE	5 KG	6 KG	7 KG	8 KG	9 KG	10 KG
Von Mises	3.95	4.6	5.25	5.9	6.6	9.3
Deformation	0.2	0.24	0.27	0.3	0.34	0.47

Printing gear 1 (2 layers)

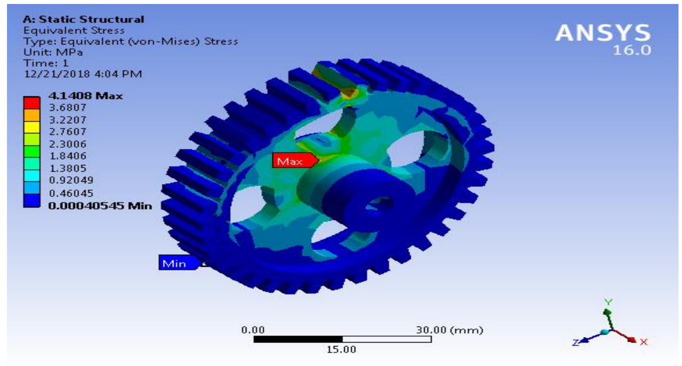


FIG. 11 STATIC STRUCURE WITH 2 LAYERS

The maximum stress induced is 4.14408 Mpa which is far less than the allowable value of 20 Mpa for the Material hence the pinion is safe with 2- layer of printing

Printing gear 2 (3 layers)

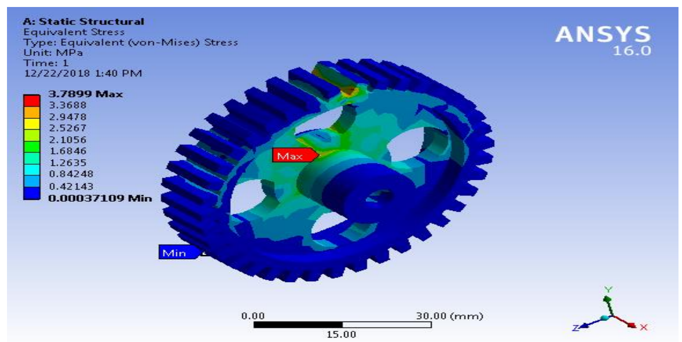


FIG. 12 STATIC STRUCURE WITH 3 LAYERS

The maximum stress induced is 3.7899 Mpa which is far less than the allowable value of 20 Mpa for the Material hence the pinion is safe with 3- layer of printing

Printing gear 3 (4 layers)

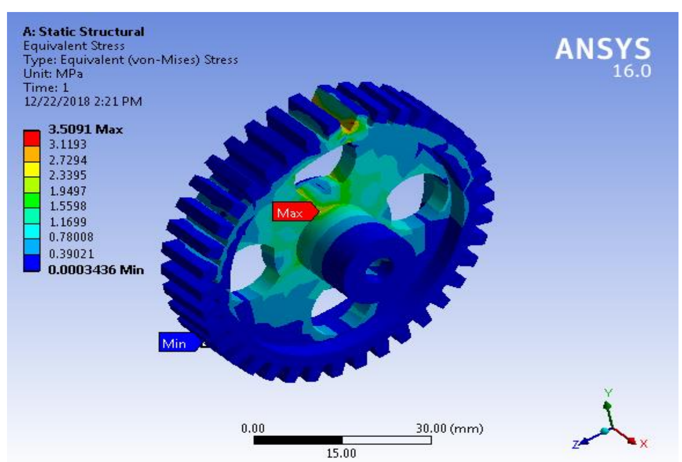


FIG. 13 STATIC STRUCURE WITH 4 LAYERS

The maximum stress induced is 3.5091 Mpa which is far less than the allowable value of 20 Mpa for the Material hence the pinion is safe with 4- layer of printing

Printing gear 4 (5 layers)

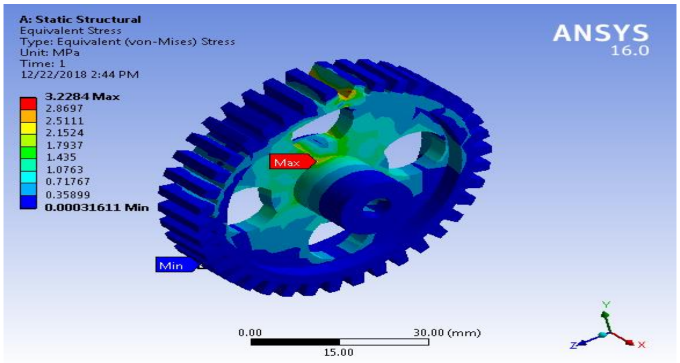


FIG. 14 STATIC STRUCURE WITH 5 LAYERS

The maximum stress induced is 3.2284 Mpa which is far less than the allowable value of 20 Mpa for the Material hence the pinion is safe with 5- layer of printing

Printing gear 5 (6 layers)

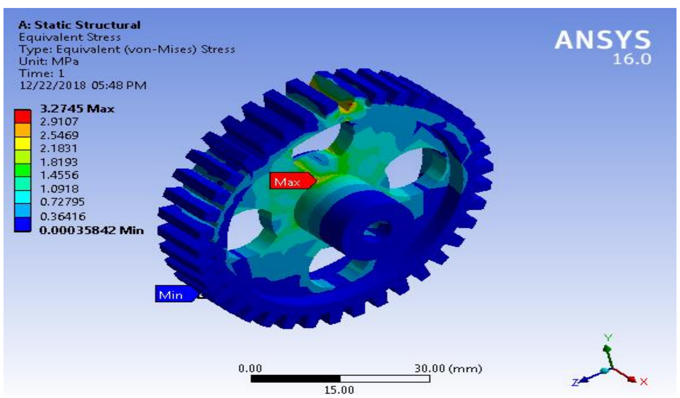


FIG. 15 STATIC STRUCURE WITH 6 LAYERS

The maximum stress induced is 3.2745 Mpa which is far less than the allowable value of 20 Mpa for the Material hence the pinion is safe with 6- layer of printing. But it is greater than 5- layer of printing.

B. Test rig set up for testing pinion

Table II
Deflection value

Load(kg)	Analytical Deflection mm	Actual deflection	Percentage error
5	0.2	0.21	4.761905
6	0.24	0.26	7.692308
7	0.27	0.29	6.896552
8	0.3	0.31	3.225806
9	0.34	0.36	5.555556
10	0.47	0.51	7.843137

Table III
Deflection value of 2 layer

Load(kg)	Analytical Deflection mm	Actual deflection	Percentage error
5	0.21	0.22	4.54
6	0.24	0.26	7.69
7	0.28	0.30	6.66
8	0.31	0.33	6.06
9	0.35	0.38	7.89
10	0.48	0.52	7.69

Table IV
Deflection value of 3 layer

Load(kg)	Analytical Deflection	Actual deflection	Percentage error
5	0.19	0.20	5
6	0.21	0.22	4.54
7	0.26	0.29	3.44
8	0.29	0.32	6.25
9	0.32	0.35	5.71
10	0.45	0.52	3.92

TableV
Deflection value of 4 layer

Load(kg)	Analytical Deflection mm	Actual deflection	Percentage error
5	0.17	0.18	5.55
6	0.19	0.2	5
7	0.23	0.24	4.16
8	0.27	0.29	6.89
9	0.30	0.32	6.25
10	0.44	0.46	4.34

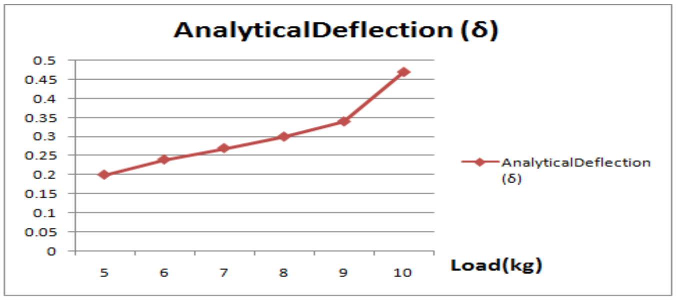
Table VI
Deflection value of 5 layer

Load(kg)	Analytical Deflection mm	Actual deflection	Percentage error
5	0.16	0.17	5.8
6	0.18	0.19	5.26
7	0.21	0.22	4.54
8	0.24	0.26	7.69
9	0.28	0.30	6.6
10	0.38	0.40	5

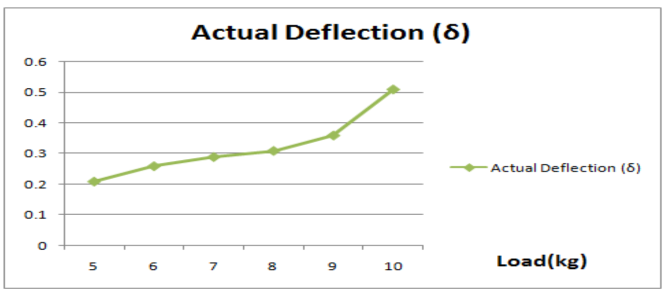
Table VII
Deflection value of 6 layer

Load(kg)	Analytical Deflection mm	Actual deflection	Percentage error
5	0.17	0.18	5.5
6	0.19	0.20	5.1
7	0.23	0.24	4.16
8	0.26	0.27	6.62
9	0.31	0.33	6.31
10	0.42	0.45	4.35

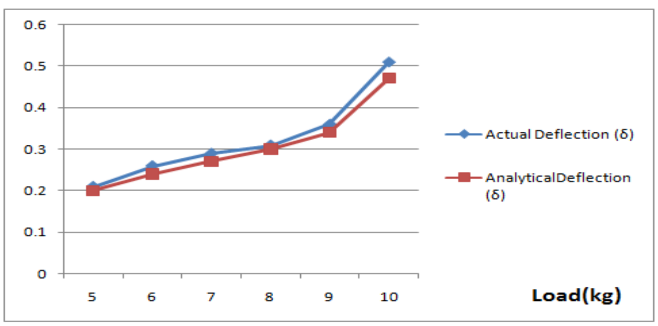
Graph of Analytical Deflection Vs Load



Actual deformation is seen to increase with increase in load



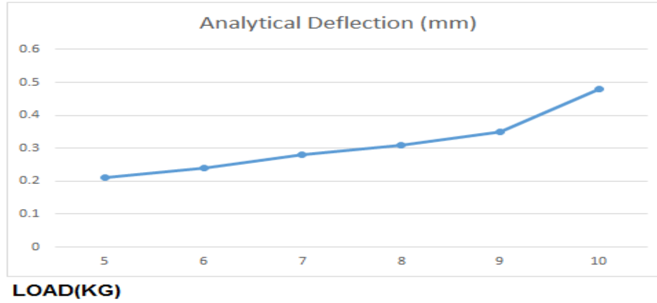
Actual deformation is seen to increase with increase in load



Actual deformation is seen to be more than the analytical deformation and having tendency to increase with the increase in load.

For 2 Layer

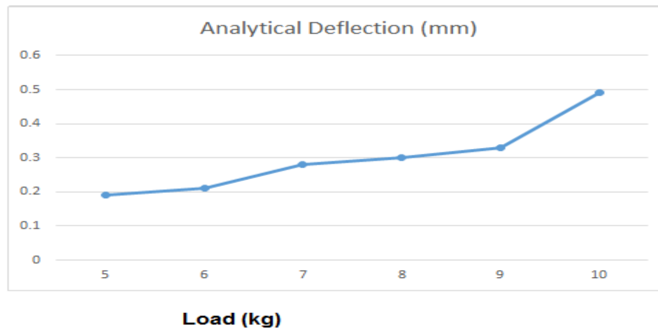
Graph of Analytical Deflection Vs Load



Actual deformation is seen to increase with increase in load

For 3 Layer

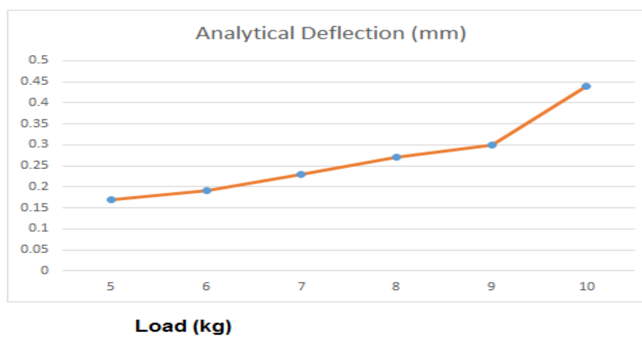
Graph of Analytical Deflection Vs Load



Actual deformation is seen to increase with increase in load

For 4 Layer

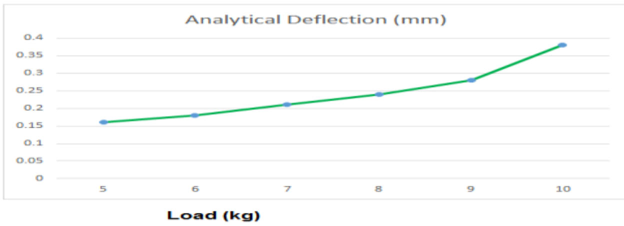
Graph of Analytical Deflection Vs Load



Actual deformation is seen to increase with increase in load

For 5 Layer

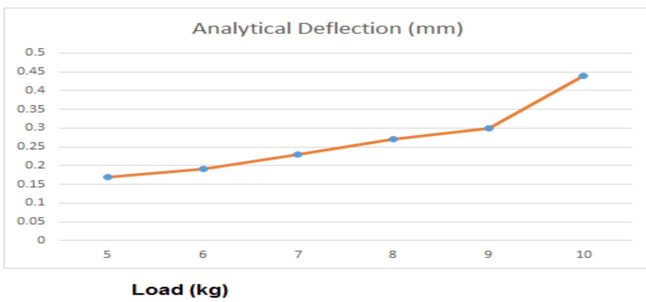
Graph of Analytical Deflection Vs Load



Actual deformation is seen to increase with increase in load

For 6 Layer

Graph of Analytical Deflection Vs Load



Actual deformation is seen to increase with increase in load

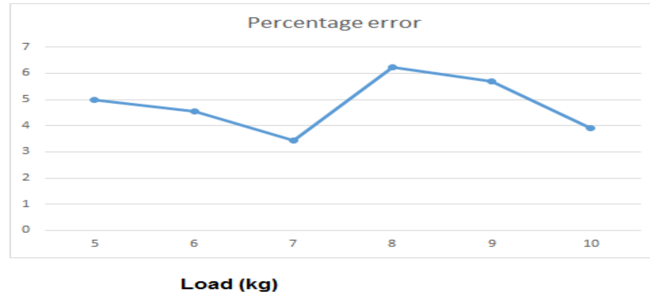
Graph of Percentage Error vs Load

Analytical deformation is seen to increase with increase in load

For 2 Layers

Analytical deformation is seen to increase with increase in load

For 3 Layers

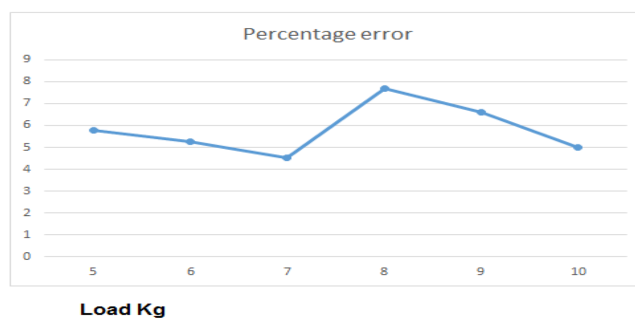


Analytical deformation is seen to increase with increase in load

For 4 Layers

Analytical deformation is seen to increase with increase in load

For 5 layers



Analytical deformation is seen to increase with increase in load

For 6 layers

Analytical deformation is seen to increase with increase in load

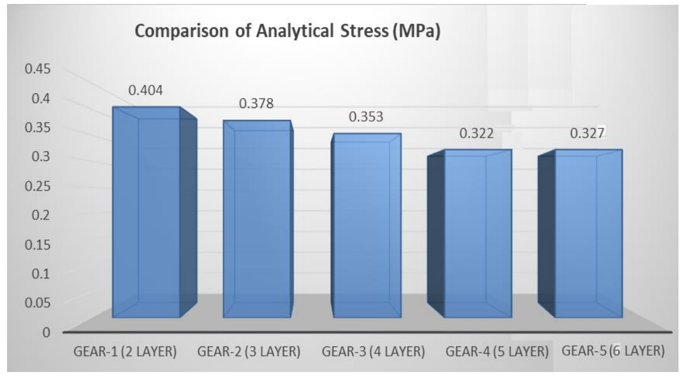
VI. CONCLUSION

Conclusion theoretical and Ansys Analysis

1. The maximum stress is observed in the ABS polymer worm gear, followed by the PLA worm, thus PLA material will be preferred over the ABS material.
2. The maximum deformation is observed in the ABS worm polymer gear, followed by the PLA worm, thus PLA material will be preferred over the ABS material.
3. Though the FDM printed gears show larger values of stress, but they are well below the safety limits hence the FDM manufactured gears can be used as replacement to the Molded gears.
4. Though the FDM printed gears show larger values of deformation, but they are well below the safety limits hence the FDM manufactured gears can be used as replacement to the Moulded gears.
5. Actual deformation is seen to be more than the analytical deformation and having tendency to increase with the increase in load.
6. The percentage error is well below 8 percent indicating that the analytical and experimental results are well in agreement indicating validation of results.

Analytical stress of Specimens with different layers

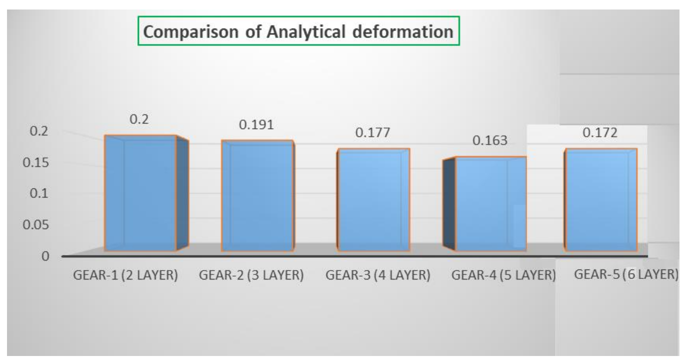
Comparison of Analytical stress of Specimens with different layers of fill density is given below for load of 54 N



From bar chart it is clear that with increase in fill density ie, number of layers the stress induced in the part is reduced thus we can conclude and recommend that fill density of 5 layers is recommended for gears to attain maximum stress and reduce the chances of failure. Then after if there is increase in fill density ie. 6 layers, gears increases the stress induced in part and decreases capacity to attain maximum strength.

Final Conclusion of Project :

The comparison of Analytical deformation of Specimens with different layers of fill density is given below for load of 54 N



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VII. ACKNOWLEDGEMENT

It is a matter of great satisfaction and pleasure to present the Paper on “Design, Analysis and Experimental investigation of strength of spur rack Manufactured by FDM.”

I express my deep sense of gratitude to Prof. V. M. Mhaske for their valuable guidance discussion and constant encouragement for successful completion of this work.

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