International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

Design & Analysis & Performance Evaluation of Self Locking of Worm & Worm Gear Manufactured by Moulding & FDM Process

Laxman naikwadi[1], Alimoddin Patel[2], Vikramsinha Mane[3]

[1]M-Tech Student Dept. Of Mechanical Engg. College of Engineering, Dharashiv, Maharashtra, India
[2]Professor Dept. Of Mechanical Engg. College of Engineering, Dharashiv, Maharashtra, India
[4] Principal College of Engineering, Dharashiv, Maharashtra, India

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Abstract - *Plastic gears 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. The use of plastic gears has expanded from low-power, precision motion transmission into more demanding power transmission applications. The project aims at the design development analysis of self locking gears as worm and worm wheel manufactured by moulding process to be compared with those manufactured by FDM process to prove suitability of the new gears as replacement to the conventional moulded gears.*
Project work will include the design of the gears using Unigraphix NX-8 and analysis of the same using Ansys Workbench 16.0 Testing of the gears will be done to evaluate and confirm the self locking property of gears.

Key Words: Ansys 16.0, Worm Gear, FDM

1. INTRODUCTION

Plastic gears are serious alternatives to traditional metal gears in a wide variety of applications. The use of plastic gears has expanded from low-power, precision motion transmission into more demanding power transmission applications. As designers push the limits of acceptable plastic gear applications, more is learned about the behavior of plastics in gearing and how to take advantage of their unique characteristics.

Non-metals widely used for light load, non-precision and noiseless operation. Polymers (plastics): both thermoplastic and thermosetting type and various composites (metals, graphite, wood dust or ceramic powders dispersed in thermosetting plastics. Plastic gears 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 ground they've gained, their evaluation is far from over as new and more demands gear applications continue to emerge.

The strongest growth area has been the automotive arena. As amenities have become central to competitive success, automakers have sought to power a variety of vehicle subsystems with motors and gears rather than muscle, hydraulics, and cables. This has brought plastic gears into uses ranging from lift gates, seating, and tracking headlights to break actuators, electronic throttle bodies, and turbo controls.

Appliances also make broad use of plastic power gears. Some larger applications, like clothes-washer transmissions, have pushed the limit on gear size, often as a replacement for metal. Plastic gears are present in many other areas, for example, damper drives in HVAC zone controls, valve actuators in fluid devices, automatic flushers in public restrooms, power screws that shape control surfaces on small aircraft, and gyro and steering controls in military applications.

1.1 FDM Process

It is an additive manufacturing technology commonly used for modeling, prototyping, and production applications. It is one of the techniques used for 3D printing.

FDM begins with a software process which processes an STL file (stereolithography file format), mathematically slicing and orienting the model for the build process. If required, support structures may be generated. The machine may dispense multiple materials to achieve different goals: For example, one may use one material to build up the model and use another as a soluble support structure or one could use multiple colors of the same type of thermoplastic on the same model.

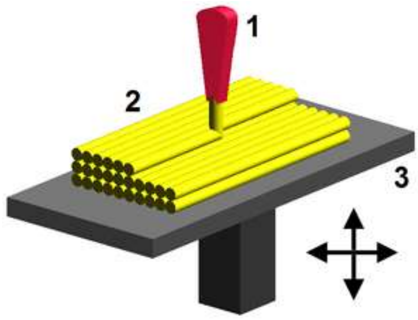

Fig -1: Fused deposition modelling: 1 – nozzle ejecting molten material, 2 – deposited material (modeled part), 3 – Controlled movable table

The model or part is produced by extruding small flattened strings of molten material to form layers as the material hardens immediately after extrusion from the nozzle.A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. There is typically a worm-drive that pushes the filament into the nozzle at a controlled rate.

The nozzle is heated to melt the material. The thermoplastics are heated past their glass transition temperature and are then deposited by an extrusion head. The nozzle can be moved in both horizontal and vertical directions by a numerically controlled mechanism. The nozzle follows a tool-path controlled by a computer-aided manufacturing (CAM) software package,

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and the part is built from the bottom up, one layer at a time. Stepper motors or servo motors are typically employed to move the extrusion head. The mechanism used is often an X-Y-Z rectilinear design, although other mechanical designs such as deltabot have been employed.

2. LITERATURE REVIEW

1. Study and Investigate Effect of Input Parameters on Temperature and Noise in Gearbox Using DOE, Rushil H.

In this research paper, Researcher suggest that before making gearbox, verification of its work, performance, efficiency, which effects gearbox performance is necessary. He used DOE techniques to achieve desired design of gearbox for control the temperature and noise levels in gearbox. He reached to the conclusion that it seems that the input speed, back lash, axial play of Pinion and output shaft, oil viscosity are very crucial for the gearbox noise and temperature of oil. By optimizing input parameter, life of the gearbox will be increase.

2. Research and Analysis of the New Modification Theory of Toroidal Worm gearing Wen qi ngming

In this research paper, Researcher discovers the shortage of the traditional "modification" theory, and then a research method. Accordingly, the principle of curvature modification is established and the effect of the curvature modification theory is also analyzed. During the research and analysis, he find that the curvature modification principle solves the long time unsolved problem in the modification of toroidal worm gearing is get in theory and practice. The new toroidal worm gearing modified on the principle of curvature modification have higher carrying capacity and transmission efficiency than the traditional toroidal worm gearing. Experiment also proves that compared with the traditional modification, it can bring higher bearing ability and transmission efficiency. Including as a technological measure to improve transmission stability, the modification principle of toroidal worm is a theory and technology to study the basic structure of toroidal worm.

3. an Experimental Investigation of Power Losses in Gear box at different operating condition, Prakash D Patel

In this study, Researcher studies the influence of a variety of operating conditions on the power losses and efficiency of an automotive manual transmission was investigated experimentally. An experimental methodology was developed to measure power losses of a manual transmission under both loaded and unloaded conditions while all operation parameters were controlled tightly. A set of fixtures and instrumentation were designed and implemented to apply the experimental methodology to a five speed, manual transmission from a front wheel drive passenger vehicle.

2.1 Problem Statement

Worm gear drives with self locking characteristics are thus needed to prevent backward motion during power transmission to prevent operational failure or to maintain proper tension in case of packaging machines. Conventional gears used are the moulded ones which we plan to replace by those manufactured by FDM process to reduce manufacturing cost as well as able to develop customized gears which would otherwise be extremely costly using moulding process.

2.2 Objective

- To overcome the problem of Backdriving in the gears.
- Design & Analysis of self locking of worm gear manufactured by moulding process to be compared with those manufactured by FDM process.

3. Selection of Material

For FDM process Nylon 12 is used as material. Nylon is used in the aerospace, automotive and consumer goods industries. Nylon 12 gives unparalled toughness, simple and clean process.

CONDITIONED					
MECHANICAL PROPERTIES	TEST METHOD	ENGLISH		METRIC	
		XZ AXIS	ZX AXIS	XZ AXIS	ZX AXIS
Tensile Strength, Yield (Type 1, 0.125", 0.2"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tensile Strength, Ultimate (Type 1, 0.125", 0.2"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tensile Modulus (Type 1, 0.125", 0.2"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Elongation at Break (Type 1, 0.125", 0.2"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Elongation at Yield (Type 1, 0.125", 0.2"/min)	[illegible]	2.4%	2.1%	2.4%	2.1%
Flexural Strength (Method 1, 0.05"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flexural Modulus (Method 1, 0.05"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flexural Strain at Break	[illegible]	No Break	[illegible]	No Break	[illegible]
IZOD Impact - notched (Method A, 23°C)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IZOD Impact - unnotched (Method A, 23°C)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Compressive Strength, Yield (Method 1, 0.05"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Compressive Strength, Ultimate (Method 1, 0.05"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Compressive Modulus (Method 1, 0.05"/min)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

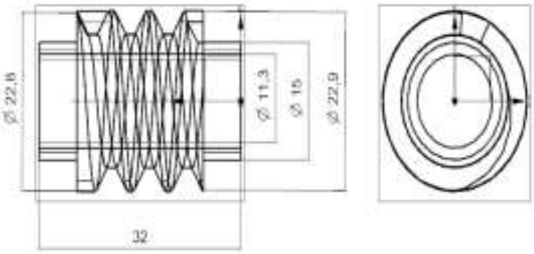
Fig -2: Material Properties

3. EXPERIMENTAL SETUP

Fig -3: Experimental Setup

4. DESIGN & ANALYSIS OF GEAR

4.1 Design of Worm



TORQUE = 0.8 N-m

Assuming 100 percent overload in event of lever blockage

T_{design} = 0.8 x2 = 1.6 N-m

The ABS polymer material is selected with ultimate tensil strength 44 N/mm² and yield strength 32 N/mm².

F_s allowable = 44/2 = 22 N/mm²

T_{design} = 1.23 Nm

CHECK FOR TORTIONAL SHEAR FAILURE OF SHAFT:

$T_d = P/16 \times f_{s\ act} \times (D^4- d^4) /D$

$$f_{s\ act} = \frac{16 \times T_d}{\Pi \times (D^4- d^4) /D}$$

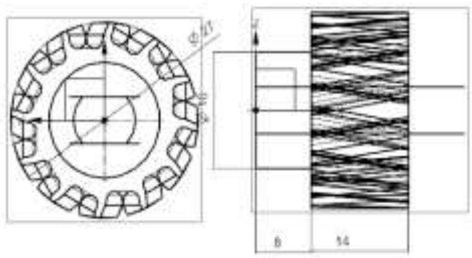
$$= \frac{16 \times 0.8 \times 10^{3} \times 22.8}{\Pi \times (22.8^4- 18^4)}$$

$f_{s\ act}$ = 0.56 N/mm²

As $f_{s\ act} < f_s$ all

The worm is safe under torsional load.

4.2 Design of Worm Gear



CHECK FOR TORTIONAL SHEAR FAILURE OF SHAFT:

$T_d = P/16 \times f_{s\ act} \times (D_4- d_4) /D$

$$f_{s\ act} = \frac{16 \times T_d}{\Pi \times (D^4- d^4) /D}$$

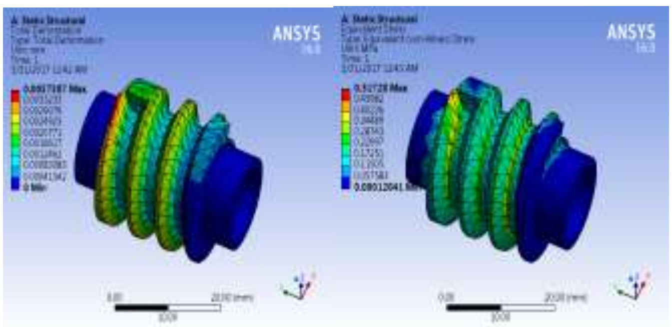
$$= \frac{16 \times 0.8 \times 10^{3} \times 27}{\Pi \times (27^4- 16^4)}$$

Fs act = 0.23 N/mm²

As $f_{s\ act} < f_s$ all

Worm gear is safe under torsional load.

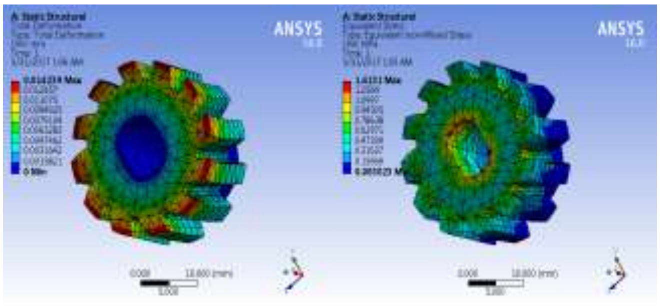
4.3 Analysis of Worm



(a) (b)

Fig -4: (a) Total deformation (b) Equivalent stress

4.4 Analysis of Worm Gear



(a) (b)

Fig -5: (a) Total deformation (b) Equivalent stress

5. RESULT & DISCUSSION

Table-1: Result comparison for Worm

VALUE	ABS WORM	PLA WORM
Von Misses stress	0.65 Mpa	0.61 Mpa
Deformation	0.0047 mm	0.0044 mm

The above observation table shows that the maximum stress is observed in the ABS polymer gear, followed by the PLA worm thus PLA material will be preferred over the ABS material. The maximum deformation is observed in the ABS polymer gear, followed by the PLA worm, thus PLA material will be preferred over the ABS material.

The equivalent stress in the PLA worm is minimum as compared to the ABS polymer material. Similarly the deformation occurred in the PLA polymer is minimum as compared to the ABS polymer material.

Table-2: Result comparison for Worm Gear

VALUE	NYLON WORM	ABS WORM	PLA WORM
Von Misses stress(Mpa)	**3.462**	**5.87**	**4.4602**
Deformation (mm)	**0.00038**	**0.00063**	**0.00046**

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.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.

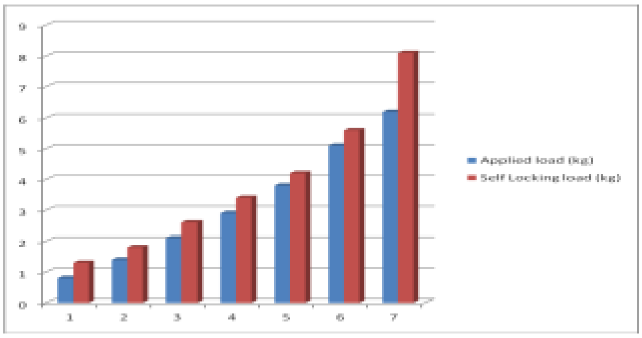
Table-3: Observation Reading

Load meter reading (Applied force) Kg	Spring balance reading (self locking load)	Slip
0.8	1.3	0
1.4	1.8	0
2.1	2.6	0
2.9	3.4	0
3.8	4.2	0

5.1	5.6	0
6.2	8.1	0

From above observation table we conclude that there is no slip of worm & worm gear occur at different readings taken. Hence the worm & worm gear is safe at all applied load readings.

Table-4: Comparative Chart



The Chart shows that the self-locking force well exceeds the gripping force applied at all points thereby confirming that the gripper functions to 100% efficiency at all points Indicating no slipping of the gear pair thus experiment is validated.

6. CONCLUSION

1. The maximum stress & deformation is observed in the ABS polymer gear followed by the PLA worm & worm gear thus PLA material will be preferred over the ABS material.

2. Though the FDM printed gears show larger values of stress & deformation but they are well below the safety limits hence the FDM manufactured gears can be used as replacement to the Moulded gears.
3. Thus a general conclusion can be drawn that the plastic gears display minimum stress and are better than the FDM gears but, FDM gears also show good strength well below the permissible limit hence they can be good replacement to the plastic moulded gears.
4. Thus a general conclusion can be drawn that the plastic gears display minimum deformation and are better than the FDM gears but FDM gears also show good strength well below the permissible limit hence they can be good replacement to the plastic moulded gears.

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