

# Cost optimization of Helical Gear of Transmission System Using Additive Manufacturing

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## ABSTRACT

Gears are power transmission components used to transfer power from one shaft to other. Polymer gears find its applications in all the segments of mechanical power transmission system because of its high strength to weigh ratio. They are manufactured using machine cutting technique or by injection moulding which are costly due to mold cost and are more time consuming process. Additive manufacturing technique can be implemented because of its compatibility to produce complex designs and for customized requirements. The literature review shows that 3D printing technology is useful for Product development for fast product delivery. Additive manufacturing the gears will results into product development in short time and at low cost. These types of Gears can be used in any power transmission system and can be manufactured with required load carrying capacity and complex designs. Gear manufactured using additive manufacturing methods 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:** Polymer Gear, Additive Manufacturing, 3D Printing.

## I. INTRODUCTION

Additive Manufacturing (AM) is a term to describe set of technologies that create 3D objects by adding layer-upon-layer of material. Materials can vary from technology to technology. The term Additive Manufacturing holds within such technologies like Rapid Prototyping (RP), Direct Digital Manufacturing (DDM), Layered Manufacturing and 3D Printing. There are different 3d printing methods that were developed to build 3D structures and objects. Some of them are very popular nowadays; others have been dominated by competitors.

FDM is the more preferred method of printing components in additive manufacturing industry

because of its availability and low cost of manufacturing. 3D printing materials such as PLA, ABS, Nylon 12 and PC have been shortlisted among the other materials. Finally PLA is selected for manufacturing because its Properties are matching with actual Properties of the Transmission gear.

In this project work, reverse engineering Method is used to design all the Parameters of the Transmission Gear and 3D Modelling of Gear has been done with CAD Modelling software Solidworks 2015. 3D Printing technique is imparted to produce a power transmission gear of Videocon washing machine. Prepare cost estimation for gear manufacturing and finally develop helical gear with 3D printer.

### Project work Methodology:

- ✓ Transmission Gear Drive application in Videocon washing machine
- ✓ Modelling of Gear using Reverse Engineering
- ✓ Selection of 3D printing filament and Method
- ✓ Prepare cost estimation for gear manufacturing
- ✓ 3D printing and Replacement in actual Washing machine

## II. SELECTION OF GEAR, MANUFACTURING MATERIAL & PROCESS

### A. Selection of Washing Machine

Videocon 6.2 kg Fully Automatic Top Load Washing Machine

Brand: Videocon

Model Name: T7269NDDL

Function Type: Fully Automatic Top Load

Washing Capacity: 6.2 kg

Maximum Spin Speed: 720 rpm

Technology Used: Smart Inverter Technology, Turbo Drum



**Figure 1.** Polymer Gear in Transmission System of Videocon Washing Machine



**Figure 2.** Helical Gear Made of Polymer Material using Injection Molding

### B. Selection of 3D printing method

#### Stereo lithography (SLA)

Stereo lithography (SLA or SL; also known as Stereo lithography apparatus, optical fabrication, photo-solidification, or resin printing) is a form of 3-D printing technology used for creating models, prototypes, patterns, and production parts in a layer by layer fashion using photo-polymerization, a process by which light causes chains of molecules to link, forming polymers.

#### Fused Deposition Modelling (FDM)

3D printing machines that use FDM Technology build objects layer by layer from the very bottom up by heating and extruding thermoplastic filament. The whole process is a bit similar to stereo lithography. Firstly special software “cuts” CAD model into layers and calculates the way printer’s extruder would build each layer. Along to thermoplastic a printer can extrude support materials as well.

#### Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is a technique that uses laser as power source to form solid 3D objects. The main difference between SLS and SLA is that it uses powdered material in the vat instead of liquid resin as Stereo lithography does.

### Selective laser melting (SLM)

Selective laser melting (SLM) is a technique that also uses 3D CAD data as a source and forms 3D object by means of a high-power laser beam that fuses and melts metallic powders together. In many sources SLM is considered to be a subcategory of selective laser sintering (SLS). But this is not as true as SLM process fully melts the metal material into solid 3D-dimensional part unlike selective laser sintering.

### Electronic Beam Melting (EBM)

EBM is another type of additive manufacturing for metal parts. The same as SLM, this 3d printing method is a powder bed fusion technique. While SLM uses high-power laser beam as its power source, EBM

uses an electron beam instead, which is the main difference between these two methods? The rest of the processes are pretty similar. The material used in EBM is metal powder that melts and forms a 3D part layer by layer by means of a computer,

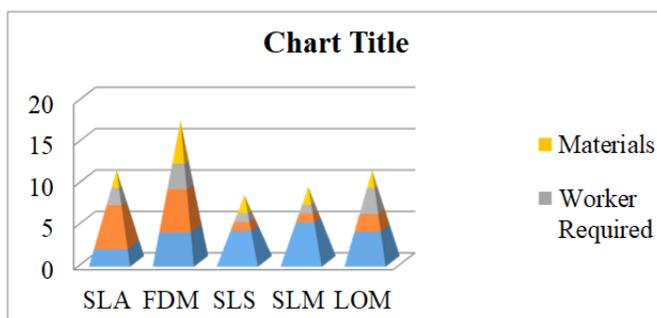
### Laminated Object Manufacturing (LOM)

During the LOM process, layers of adhesive-coated paper, plastic or metal laminates are fused together using heat and pressure and then cut to shape with a computer controlled laser or knife. Post-processing of 3D printed parts includes such steps as machining and drilling.

**Table 1.** Selection of 3D printing method

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

**Table 2.** Comparison chart of 3D printing method



Fused deposition modeling (FDM) 3D printing method is selected for the manufacturing of Spur Gear because its products have high strength; it is most widely used method for 3D printing. It has huge variety of filaments such as nylon, wood, carbon fiber etc. FDM method is simple doesn't require an expert worker. It is also the cheapest 3D printing method. FDM is used for manufacturing of Spur Gear.

### B. Material Selection of 3D printing

The figure below shows the range of materials that are used in 3d printing. Newer materials are being launched with increasing frequency

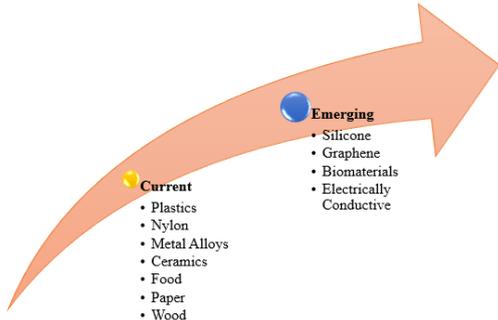


Figure 3. 3D Printing Material

Table 3. Comparison chart of 3D printing method

MTRL	Density (g/cc)	Tensile strength (MPa)		Young's modulus (GPa)	Cost of material filament / Kg	3D Printing methods
		Yield	Ultimate			
PLA	1.29	44.8	50.1	3.76	1625	FDM
ABS	1.05	40.7	41.4	2.10	1625	FDM
NYL12	1.42	45.4	79.4	5.31	7150	FDM
PC	1.20	63.3	60.6	2.36	6175	FDM

Poly lactic acid is the material which is used in the existing transmission gear manufacturing in Videocon washing machine, when PLA is selected for the design and manufacturing of the gear. Nylon or PC can be used to increase the strength of the existing Gear, which also results into increase in Cost because of its high cost of Filament.

### III. CAD DESIGN OF HELICAL GEAR

#### A. Reverse Engineering

Reverse engineering, also called back engineering, is knowledge or design information from a product and reproducing it or reproducing anything based on the extracted information. The process often involves disassembling something and analysing its components and workings in detail.



Figure 4. Reverse Engineering of Helical Gear

#### B. 3D Modelling using Solidworks

Solid works is a solid-modelling computer aided design (CAD) and computer aided engineering (CAE) computer program that runs on Microsoft windows. Solidworks also includes additional advanced modelling features such as gear mating and cam follower mates which allow model gear assemblies to accurately reproduce the rotational movement of the actual gear train.

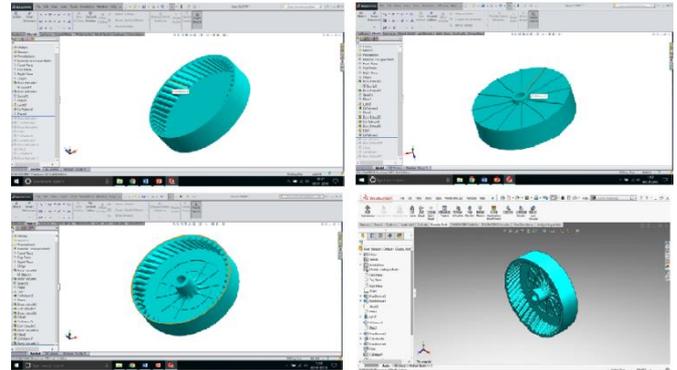


Figure 5. Section Headin3D Model of Transmission Gear in Solidworks

### IV. GEAR DEVELOPMENT WITH 3D PRINTING

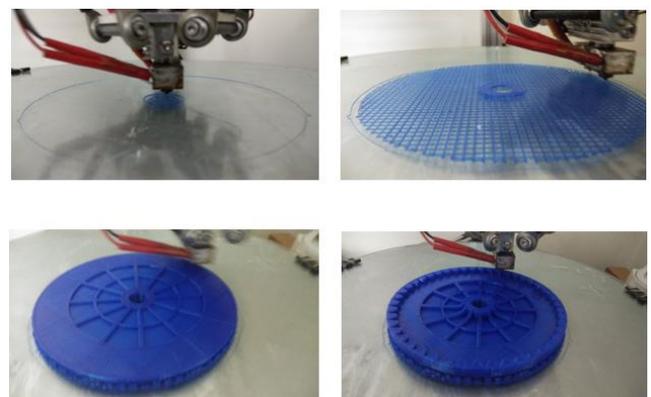


Figure 6. 3D Printing of Transmission Gear in 3D Printer

## V. PRODUCT COST ESTIMATION

Printing cost for 3D printed parts in the market varies from Rs. 15/gram to Rs. 35/gram depending upon the machine used for printing and type of filament used.

The above said cost is for PLA, it may vary slightly for other materials also. This cost is inclusive of filament and machining cost.

**Table 4.** Comparison charts of 3D Printing Material

Materials	Density (g/cc)	Cost of Filament per kg	Mass of product (Grams)	Cost of 3d printing per Gram (Rs.)	Total Cost of 3D printed Product (Rs.)
PLA	1.29	1625	99	25	1485/-

## VI. RESULTS AND CONCLUSIONS

### A. Comparison Interns of Cost of Product

**Table 5.** Comparison Interns of Cost of Product

Existing Method Cost	3D Printing Method Cost
<ul style="list-style-type: none"> <li>• It's Cost around Rs. 10,000/- per component.</li> <li>• Cannot be Manufactured in advance, it will incurred high initial cost.</li> <li>• Requires high cost in Mold mfg</li> </ul>	<ul style="list-style-type: none"> <li>• It will cost Rs.1500/- per Component.</li> <li>• Can be manufactured once the order is confirmed.</li> <li>• No Mold is required.</li> </ul>

### B. Comparison Interns of Manufacturing Process

**Table 6.** Comparison Interns of Manufacturing Process

Existing Manufacturing Method	3D Printing Method
<ul style="list-style-type: none"> <li>• Manufacturing starts with Mold design for component, Injection Molding and Inspection and finalization.</li> <li>• Requires High cost Injection Molding Machines.</li> <li>• Good for Bulk Orders.</li> <li>• Requires skilled man Power to operate the multiple Machines i.e. CNC, Molding machines etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Manufacturing starts with Designing and directly printing it.</li> <li>• Requires 3D Printing Machines and Filaments.</li> <li>• At present, Good for customized Orders and Small orders.</li> <li>• Skill Manpower is required to operate the 3D printing Machine for initial setting.</li> </ul>

Imparting 3D printing manufacturing process for Transmission gear, Customer can save about Rupees when there is a requirement of helical gear for their washing machine.

This also reduces the slack time of repair by manufacturing parts in short time and fixing it in the assembly and to run it without waiting for ordering the part and waiting to deliver it and then fix it.

This method can be implemented for the development of any parts used in day today life in low cost and low manufacturing process time.

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