A PROJECT REPORT
ON

"Design, Analysis of jar coupler 0f Mixer Grinder and Producing its Prototype Using Additive Manufacturing"

Sybmitted by

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In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE

Of

Prof. SHAIKH MOHAMMED JAWED

DEPARTMENT OF MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the project entitled "**Design, Analysis and Manufacturing of jar coupler 0f Mixer Grinder Using Additive Manufacturing"**

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

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Date: __________

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ABSTRACT

Jar Coupler are power transmission components used to transfer power from one shaft to other. Polymer gears finds its applications in all the segments of mechanical power transmission system because of its high strength to weigh ratio. They are manufactured using injection molding process 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. Jar Coupler used in Bajaj Mixer Grinding machine is considered in this project work and additive manufacturing method is used to produce the product other than conventional method. This Jar Coupler is made of Polyethylene polymer material. 3D modelling is done using Solidworks 2015 software. Finite Element analysis software SOLIDWORKS Simulation is used to study the Strength. Jar Coupler is Manufactured by 3D printing FDM technique with PLA and Nylon filament.

This method of manufacturing the Jar Coupler will results into product development in short time and at low cost. These types of Jar Coupler can be used in any power transmission system and can be manufactured with required load carrying capacity and complex designs. Jar Coupler manufactured using additive manufacturing methods will reduce the manufacturing time, easy to make customized parts instantly, low rate of wear and increase in life of Jar Coupler.

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Chapter 1

Introduction

1.1 Introduction to jar coupler

Jar Coupler are power transmission components used to transfer power from one shaft to other. A polymer gear finds its applications in all the segments of mechanical power transmission system because of its high strength to weigh ratio. They are manufactured using by injection molding 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.

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Fig No 1.1. Polymer Jar Coupler

1.2 Introduction to 3D printing

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. The advantage of this is the rapid verification and development of design ideas.

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.

Additive manufacturing machines complete a build in one step, with no interaction from the machine operator during the build phase. As soon as the CAD design is finalized, it can be uploaded to the machine and printed in one step in a couple of hours. The ability to produce a part in one step greatly reduces the dependence on different manufacturing processes (machining, welding, and painting) and gives the designer greater control over the final product.

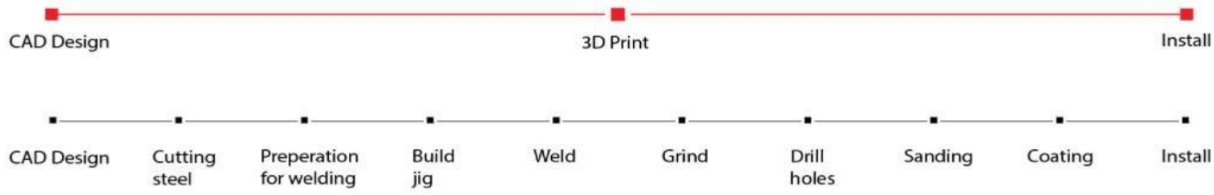


Fig No 1.2. Comparision of Conventional and 3D Printing Manufacturing Process

In this project work, 3D Printing technique is imparted to produce a power transmission Jar Coupler of Bajaj Mixer Grinding machine. This manufacturing Process helps the engineers to produce the component for small orders, Complex designs and in short time. For moderate strength applications, other than going for injection molded Jar Coupler, 3D Printed Jar Coupler can be used which results in less time to delivery, low cost and Customized designs.

Additive manufacturing (AM) also known as 3D printing has been around for over 30 years and is now taking center stage in the medical manufacturing field. Initially computing power hindered the technology but over the years various 3D printing technologies have emerged providing the ability to make complex moving/interlocking products out of a wide range of materials. These new AM processes and materials, when used in the correct application are slowly displacing a percentage of the more traditional subtractive processes like CNC, machining and casting.

1.3 Advantages of 3D Printed Material

- Anatomically Accurate printed parts are developed mostly used in biomedical field.
- Simple mechanism with complex parts can be made easily in low cost.
- 3D printed parts are comfortable & user friendly.
- Waterproof 3D printing materials are available such as PLA, ABS, NYL, PC etc.
- Lightweight products are manufactured without compromising with their strength, Durability etc.
- Products made are hygienic.
- 3D printing materials are Recyclable materials which can be used again and again.
- Aesthetically pleasing looks.

Chapter 2 Literature Reviews

P.B Pawar, Abhay A Utpat [1]: This works concerned with the replacing metallic gear with composite material so as to improve performance of machine and to have longer working life. In this work metallic gears of steel alloy and aluminum silicon carbide composite have been manufactured which provides improved mechanical properties. Gears manufactured from composite provides almost 60% less weight compared to steel gear while power rating of both gears remains almost same. FE analysis also shows less chances of failure in Al-SiC. These gears can be used for transmitting almost 24KW power.

Dr. Ir H.G. H. Van Melick [2]: This paper describes the investigation of a steel and plastic gear transmission, using both numerical (FE) and analytical methods. The aim was to study the influence of the stiffness of the gear material on the bending of the gear teeth, and the consequences on contact path, load sharing, stresses and kinematics. It has been shown that the load sharing of a steel-plastic gear pair changes dramatically compared to the conventional theory of steel gears.

K.Mao, P.Langlois, Z.Hu, K.Alharbi, X.Xu, M.Li, C.J. Spur Geare, D.Chetwynd [3]: This paper concentrate on an extensive investigation of machine cut acetal gear wear and thermal mechanical contact behavior. The results for machine cut acetal gears will be compared to previously published results obtained for polymer gears manufactured through injection molding. It is concluded that the wear rates for the machine cut and injection molded acetal gears tested are independent of the manufacturing process. It is also concluded that machine cut acetal gears can be designed using the existing methods for injection molded acetal gears.

S. Senthilvelan, R. Gnanamoorthy [4]: The aim is to check the effect of gear rotational speed on the performance of unreinforced injection molded nylon 6 & glass fiber reinforced nylon 6 & gears & also check the thermal (temperature) deformation of comparison between these two polymer materials. It contain that, the testing of these two materials at various speed & torque level 5 in a power absorption type gear testing, the tooth temperature of acetal gears using thermal camera & the flank temperature using infrared pyrometer. There tested gear was observed using an optical microscope to understand the failure mechanism. It conclude that the glass fibre reinforced nylon 6 gear shows superior performance over unreinforced nylon 6 gears due to its superior mechanical strength & resistance to thermal deformation.

K. Mao, W. Li, C.J. Spur Geare, D Walton [5]: To investigated of acetal gear on the surface thermal wear on the basis of ambient, bulk, & flash temperature. And to check the parameters like torque, speed, time to failure & wear is measured by bearing block using non contacting capacitive transducer. This paper will concentrate on acetal prediction on the basis of surface temp, has been investigated in details through three components ambient, bulk & flash temperature. Acetal gear performance was found to be entirely dependent on surface temperature. It concludes that, acetal gear has been applied to different loading condition gears with different geometry & good agreement has been achieved between the prediction & test results.

Samy Yousuef, T.A. Osman, Abdel rahman H. Abdalla, Gamal A. Zohdy [6]: The paper deals with the idea to remove barrier between nanotechnology and machine element application by blending carbon nanotubes (CNT) with common types of acetal polymer gears (spur, helical, bevel and worm). It is concluded that the CNT improves wear resistance and reduces the friction coefficient. Nan composite polymer (CNT/acetal) spur, helical, bevel and worm gears were manufactured from injected flanges and short rods. It is also concluded that the average wear resistance of the CNTs/acetal spur, helical, bevel, and worm gears was improved by 28%, 35%, 44%, and 47%, respectively.

Ashish N. Taywade, Dr. V. G. Arajpure [7]: This paper deals with the idea of gear designing and development for automobile application. Low noise, less wear, self-lubrication, economic considerations, light weight, simple designing and manufacturing. The study of molded gear performance is important for economic reasons because it can be mass produced at a fraction of the cost compared to machined gear. The plastic materials have corrosion resistance, low electrical and thermal conductivity, easily formed into complex shapes, wide choices of appearance, colours and transparencies.

Prof. Ajitabh Pateriya, Dipak Parasarm Kharat [8]: This paper deals with the finite element analysis of deformation on spur gear teeth by applying static load on teeth. The feasibility of the project is investigated and the results of the FEM analyses from ANSYS are presented. It is used for checking the whether the design is safe or not. Finite element method has been used to calculate the bending stress between two gears. It has been found that use of ANSYS gives results with enough close to accurate which in the acceptable limits.

Ashutosh, Deepak Singathia [9]: In this paper the maximum stress developed i.e. Von Misses stress in spur gear is determined. In the present the developed stress in the gear is determined using FEA process with the help of ANSYS software. The geometry of the gear includes rim geometry with a solid geometry and defined ratio parameters of the rim thickness to the tooth height more than 2 to 1. From investigations, it is seen that maximum Von misses stress for the different gears are almost same and the effective factor of safety will be criterion for selecting material of gear. It is also observed that, the maximum stress present in gear varies for various material conditions but a little. Strain doesn't have so much impact on the gear; therefore, without considering strain we can concentrate on the factor of safety.

R. Yakut, H. Duzcukoglu, M.T. Demirci [10]: In this paper, usability of PC/ABS composite plastic materials as spur gear was investigated. The purpose of the paper is to examine the load capacity of PC/ABS spur gears and investigation of gear damage. The specific wear rate, the number of revolutions and the increasing load changed each other directly proportional. In this study, it was found that good operating conditions are comprised at low numbers of revolutions and the tooth loads. PC/ABS gear should be preferred at low tooth and unwanted high power transmission.

Chapter 3 Objective and Problem Definition

3.1 Objectives

- To Design the Jar Coupler of Mixer grinding machine using additive manufacturing Process and to study the behavior.
- To replace the existing Jar Coupler used in Mixer Grinding machine.
- To select the affordable 3D printing method to manufacture Jar Coupler.
- To increase the strength of existing Jar Coupler manufacturing by using additive manufacturing process.

3.2 Problem Definition

Jar Coupler used in mixer is made of polymer material. Most coupler endurance limit is less as they are cheap made of nylon or any other material. However some jar coupler with high strength but cost is high. So we can either reduce cost or at same cost we can redesign it by increasing area and choosing alternative material to increase its shear strength and durability.

Chapter 4 Methodology

First of all, we have selected the specific application for 3D Printing in Mixer Grinder i.e. Jar Coupler. Jar Coupler of Bajaj Classic 750 Mixer Grinder is considered. The Jar Coupler is considered as important part of transmission system. To design Jar Coupler, it is required to study various parameters and working condition. It includes Material, Dimensions, Working and Boundary Conditions etc.

Reverse Engineering Method is used to measure all the Parameters of the Jar Coupler. 3D Modeling of Jar Coupler has been done according to the dimensions obtained from Reverse Engineering. Solidworks 2015 is used for 3D designing of the Jar Coupler because of its user Friendly GUI.

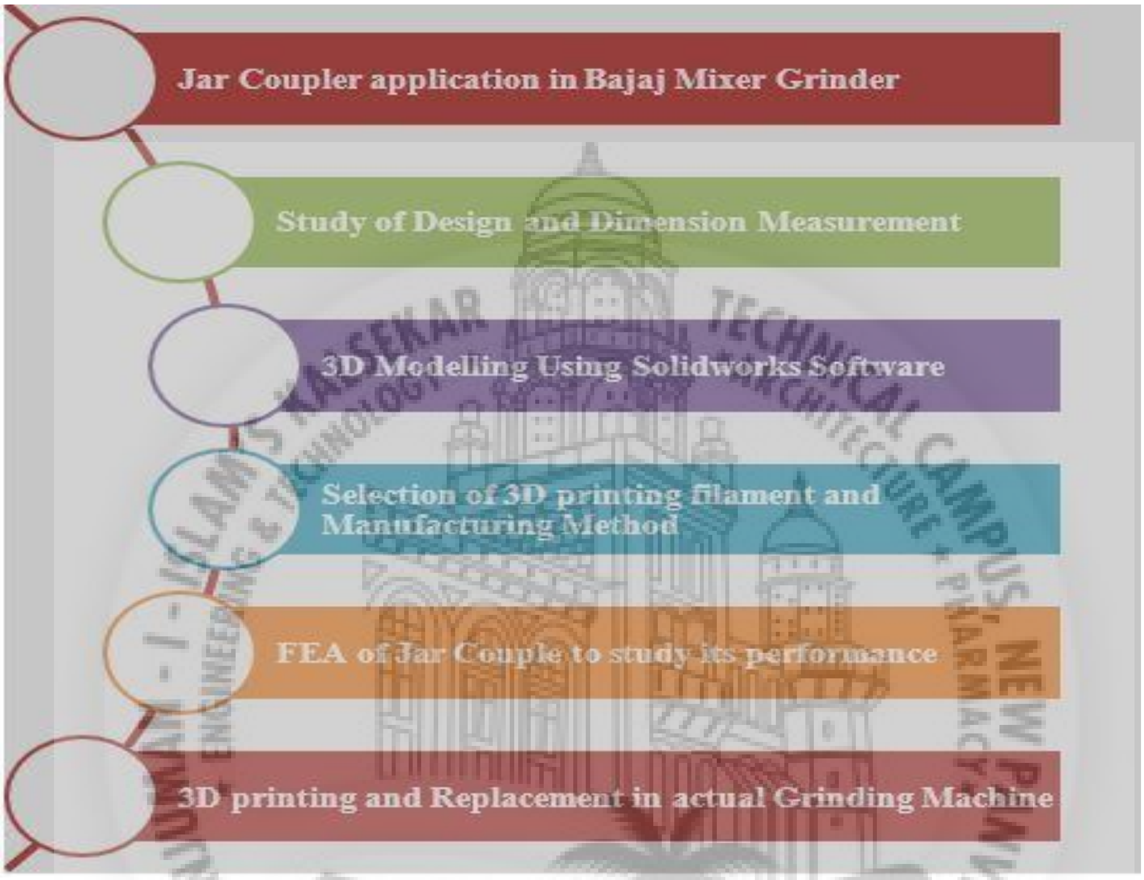


Fig 4.1: Methodology of the project

Selection of 3D printing method is done depending on its strength, durability, cost and availability. 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 and Nylon are selected for manufacturing because its Properties are matching with actual Properties of the Jar Coupler.

Analysis of Jar Coupler is done in Finite element analysis software i.e. SOLIDWORKS Simulation. Stresses, Strain energy and deformations have been calculated. Analysis is done for Jar Coupler made of Polyethylene, PLA and Nylon 3D printed materials. Static structural analysis is used to find the structural strength of the Jar Coupler subjected to Torque and Centrifugal force due to rotation.

Jar Coupler is 3D Printed using FDM technique and final finishing is done using the finishing tools available in the market.

Chapter 5A Selection of Jar coupler

5.1 Selection of Mixer grinder

Bajaj Classic 750 Mixer Grinder is selected.

Brand: Bajaj

Model Name: Classic 750

Function Type: Manual Operated

Power Required: 750 watts, 230 V, 50 Hz

Maximum Speed: 18000 rpm

Fig 5.1: Baja mixer grinder

5.2 Polymer Jar Coupler in Transmission System

Fig 5.2: Polymer Jar Coupler in Transmission system

Generally used material for Jar Coupler is Basic Plastic because of Availability of material in large scale. Different Manufacturers are available in the market to provide readymade jar coupler ranging from 10 rupees per piece to 120 rupees per piece. The Objective of this project work is to manufacturer the same jar Coupler with latest manufacturing process with high strength and Low Cost.

5.3 Requirement

- To Manufacture a Jar Coupler with less Cost To develop the Jar Coupler in 24 Hrs.
- Manufacturing with Advance manufacturing technique without Human error and with automatic system.

- Torsion testing Machine

Chapter 5B

To perform experiment to determine strength and shear stress of existing jar coupler using torque testing machine

It was to be used for Polymer Jar couplers based on several different levels of testing. This method is to be applied on a pair of couplers. To test these materials different speeds of rotation, torque loads and transferred powers to be used.

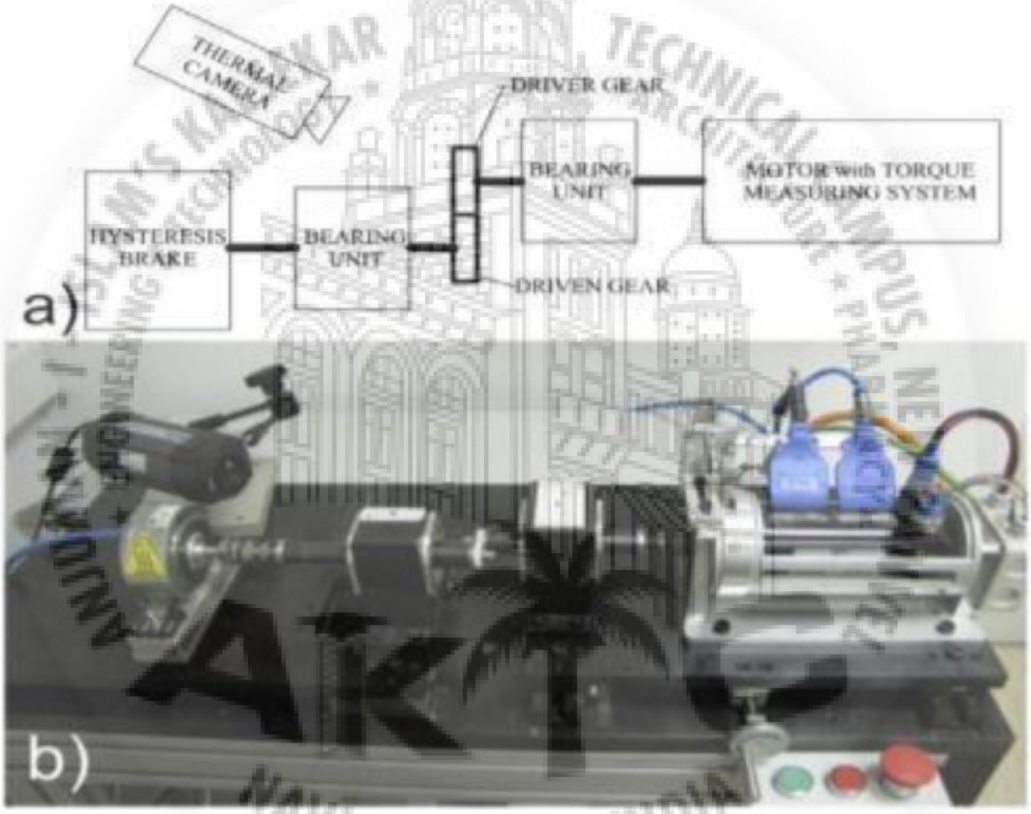


Fig 5.1: a) Block diagram b) Torsion testing Machine

Fig5.2: Pattern of Existing Jar Coupler

To test this experiment jar coupler pattern was made with cast iron as shown in fig 5.2 to apply Torque on polymer Jar coupler. Both the subjects "Jar Coupler And the instrument" to be held up at two extreme points, opposite to each other and by application of torque from torque testing machine, the strength of jar coupler was to be determined.

(The test could not be performed due to occurrence of pandemic).

CHAPTER 6 MATERIAL SELECTION

Common materials which are being used in polymer Jar Coupler are polyoxymethylene (POM), polyamide (PA), polypropylene (PP), nylon 66, etc. Some composite material also can be used like reinforced glass fibre, natural fibre etc. But in 3D Printing Machine composite materials cannot be used. However in manufacturing using composite material solution will give best result in terms of strength as well as durability.eg. A 20% short glass fibre reinforced nylon 6/6 has high shear strength with less Shrinkage.

In polymers Nylon, PLA, ABC materials have good stiffness and mechanical properties. One more advantage is less cost.

Table 6.1: Mechanical Properties of Materials

Materials	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
Stainless steel	7.80	592	863	198	7280	SLS
Gold & silver	Requirement of high end Printing Machines and Costly					SLS/FDM
Titanium	Requirement of high end Printing Machines and Costly					SLM
Ceramic	3.65	275	300	Customized FDM machine is required.		

Table 6.2: Mechanical Properties of Reinforced Composite Material

Material	Specific Gravity	Impact Strength (Izod) (J/m)	Tensile Strength (MPa)	Tensile Elongation (%)	Tensile modulus (MPa)	Flexural Strength (MPa)	Injection Pressure (MPa)	Melt Temperature (C)
PEEK	1.30	53	93	>10	3792	145	83-124	349-399
Nylon 6/6 (PTFE induced)	1.17	53	76	>10	3103	107	69-124	277-299
PMMA	1.18	21	65	3.5-5.5	3448	90	69-103	182-218
Nylon 6/6 (PA) Glass Fibre (13%) Heat Stabilized	1.23	5 kJ/m2	120	3.5	5700	180	70-125	275-300
HDPE	0.98	112	28	>10	1862	29	69-103	193-232
POM	1.41	80	60	>10	2413	76	69-103	182-218
PTFE	2.18	---	35.85	3.6		8.44		
Nylon 6 (PA)	1.23		103	3.0-4.0	6500	165	70-105	245-280

CHAPTER 7

JAR COUPLER DAMAGE MODES

- Deformations: Because of excessive surface stress at area of contact, involute profile of gear is permanently distorted.
- Root fatigue: Stress concentration in roots starts microcracking which propagates and causes the failure in Jar coupler reducing the life.
- Torsion: Shear Stress generate on all teeth results in shear failure.

- Wear: Combination of applied force and speed of sliding causes the material removal on tooth s

Chapter 8 Reverse Engineering and 3D Modeling using Solidworks

8.1 Reverse Engineering

Reverse engineering, also called back engineering, is the processes of extracting 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 analyzing its components and workings in detail.

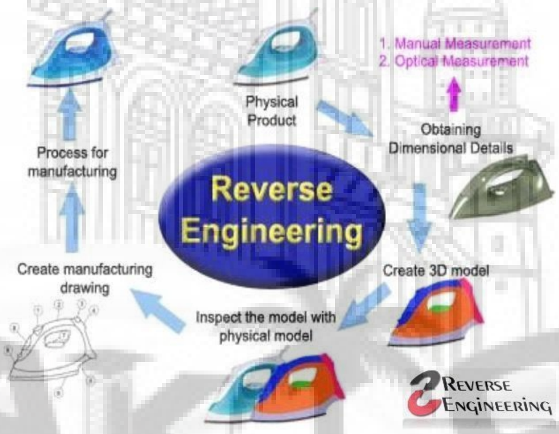


Fig 6.1: Reverse Engineering Process

8.2 Reverse Engineering of Jar Coupler

Reverse engineering of Jar Coupler is started by taking measurement of coupler's dimensions in microns using vainer caliper and recording it in book, as shown in fig. below. These dimensions are used to make 3D model in CAD software.

Fig 6.2: Measuring dimensions of Jar Coupler.

8.3 Introduction to Solidworks

Solid works is a solid-modeling computer aided design (CAD) and computer aided engineering (CAE) computer program that runs on Microsoft windows. Solid works is published by Dassault systems. Solid works currently markets several versions of the Solid works CAD software in addition to e-drawings, a collaboration tool and a draft sight a 2D CAD product. Building a model in Solid works usually stars with a 2D sketch. The sketch generally consists of geometry such as points, arcs, conics (except hyperbolas) and splines. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside the sketch. Follwing Figures are modified design model of Jar coupler by increasing area and its thickness to withstand high torque.

8.4 RENDERED IMAGES OF JAR COUPLER

8.4.1) DESIGN OF EXISTING JAR COUPLER WITH SOME MODIFICATIONS

Jar Coupler is used to transmit power from one shaft to other. Following are the images and Procedure of existing jar coupler with just increasing in thickness of teeth.

Step 1: Double click on the Solidworks icon, Solidworks will open and select Part. Now Solidworks working window will open then first select the dimension standards in millimeters.

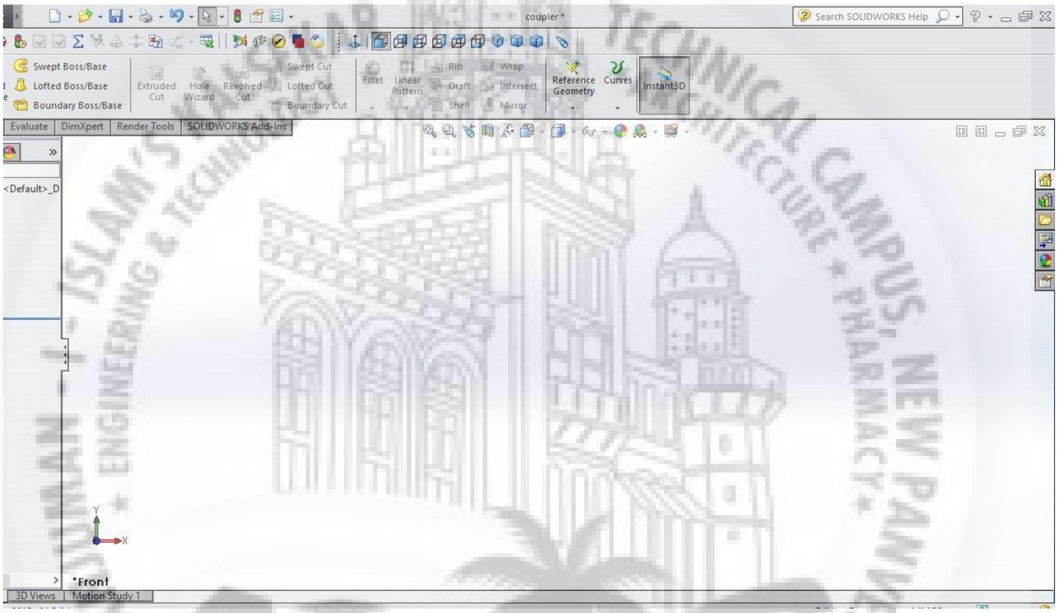


Fig 8.4.1: Working window of Solidworks 2015.

Step 2: Select the plane and sketch according to the dimension and using Sketch command as shown in fig.

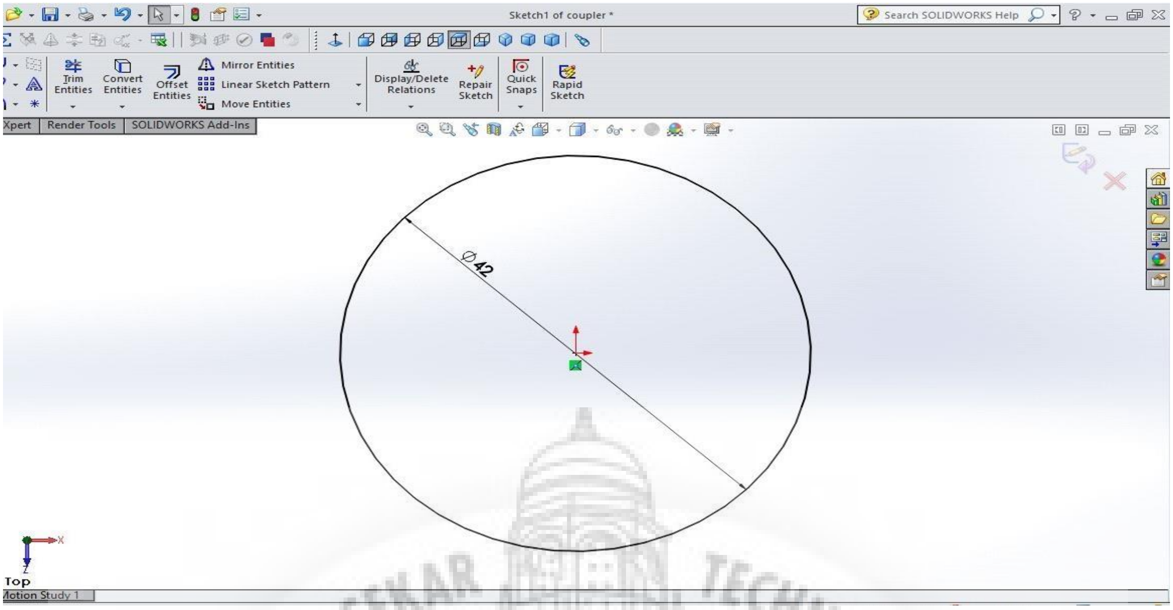


Fig 8.4.2: Sketch of base using command in Sketch tab.

Step 3: Select the sketch and extrude using extrude feature as shown in fig.

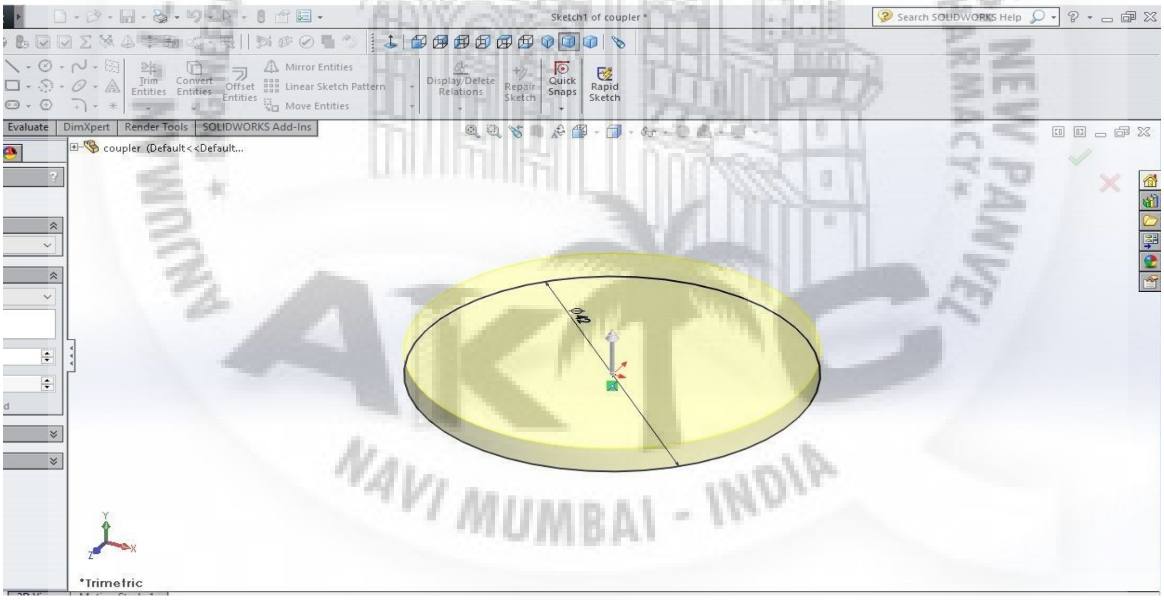


Fig 8.4.3: Base by extrude Command.

Step 4: Select the plane and sketch on that according to the dimension and using the extrude command as shown in fig.

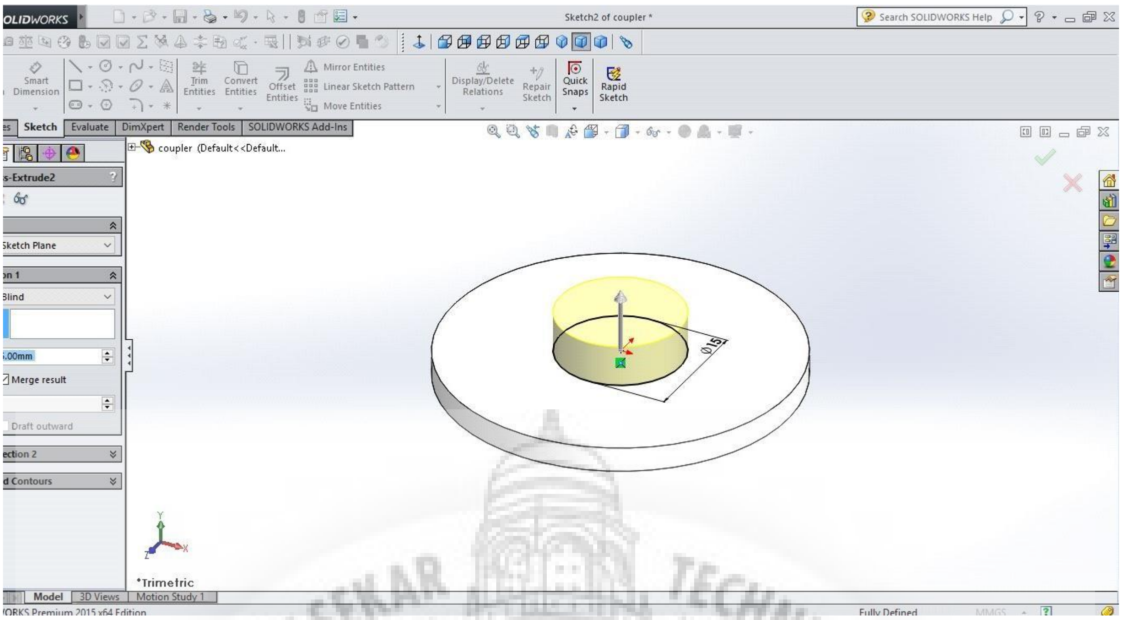


Fig 8.4.4: Extruded portion using Extrude Command.

Step 5: Select the plane and sketch on that then cut using extrude-cut command as shown in fig.

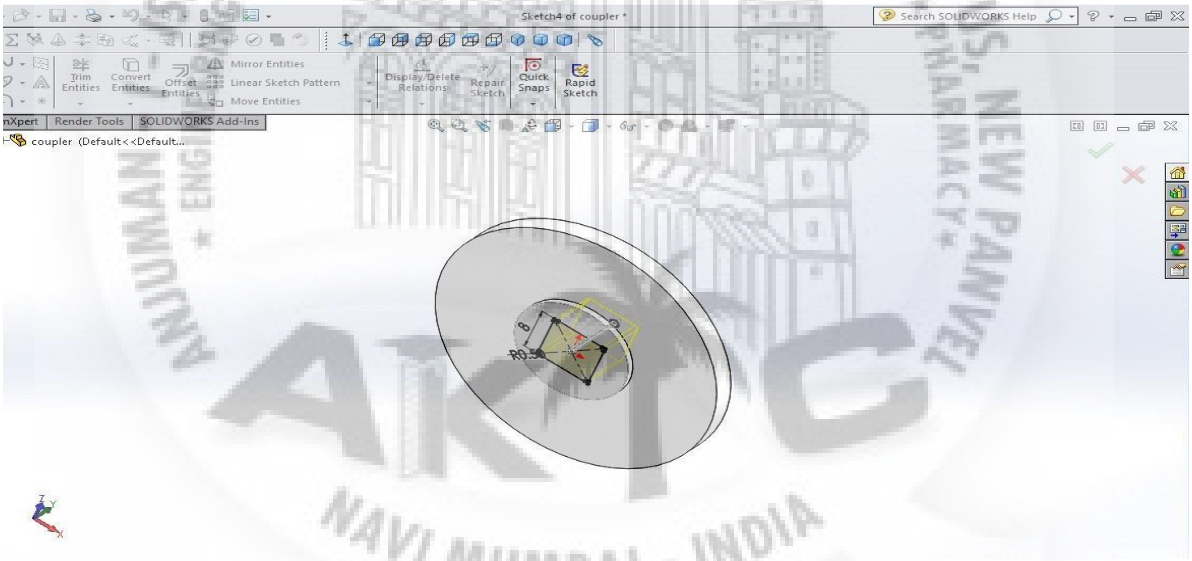


Fig 8.4.5: Slot for insert using Extrude-cut command.

Step 6: Select the edges to curve and use Fillet command as shown in fig.

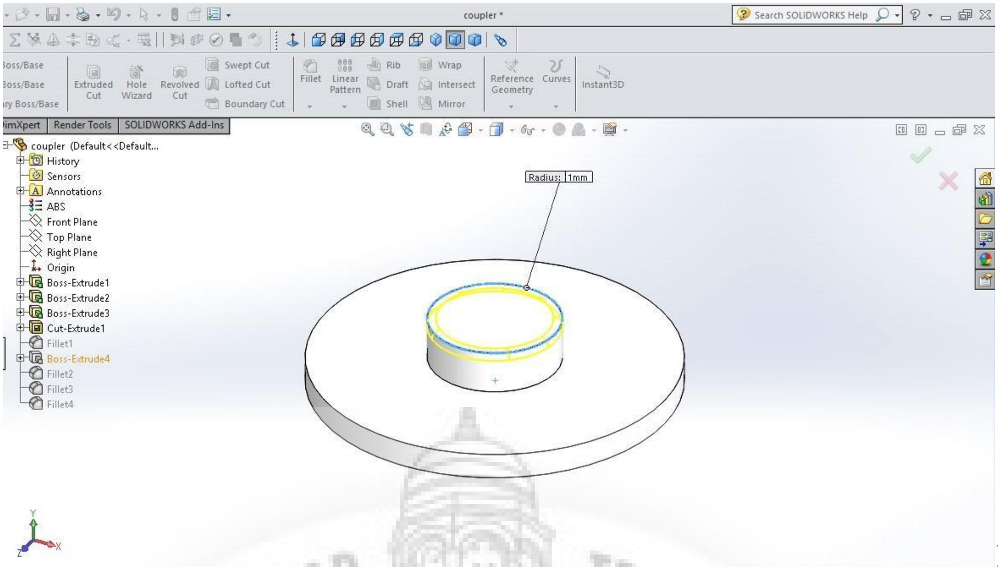


Fig 8.4.6: Curving edges using Fillet command.

Step 7: Select the plane and sketch on that base and extrude using extrude command as shown in fig.

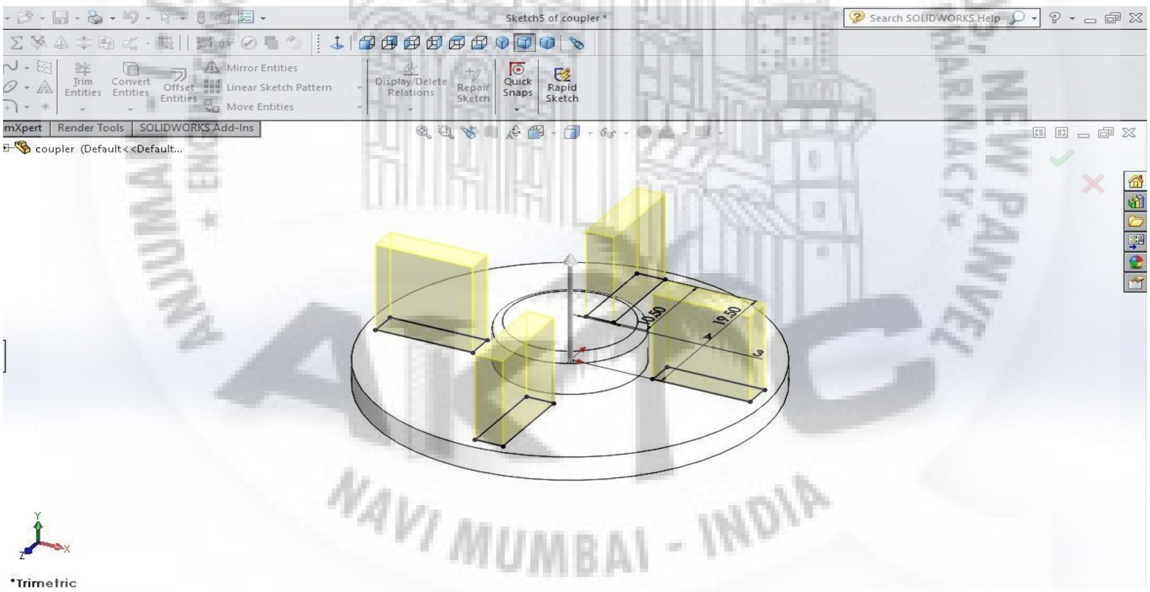


Fig 8.4.7: Teeth of coupler using Extrude command.

Step 8: Curve the edges of part using Fillet option as shown in figure.

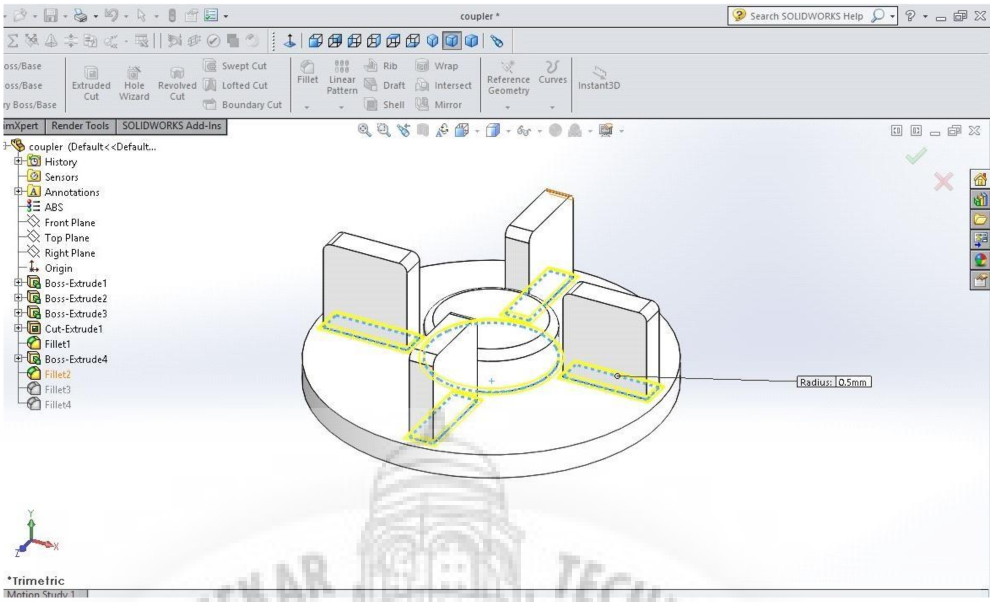


Fig 8.4.8: Curving edges using Fillet command. **Step**

9: Final Coupler 3D Model

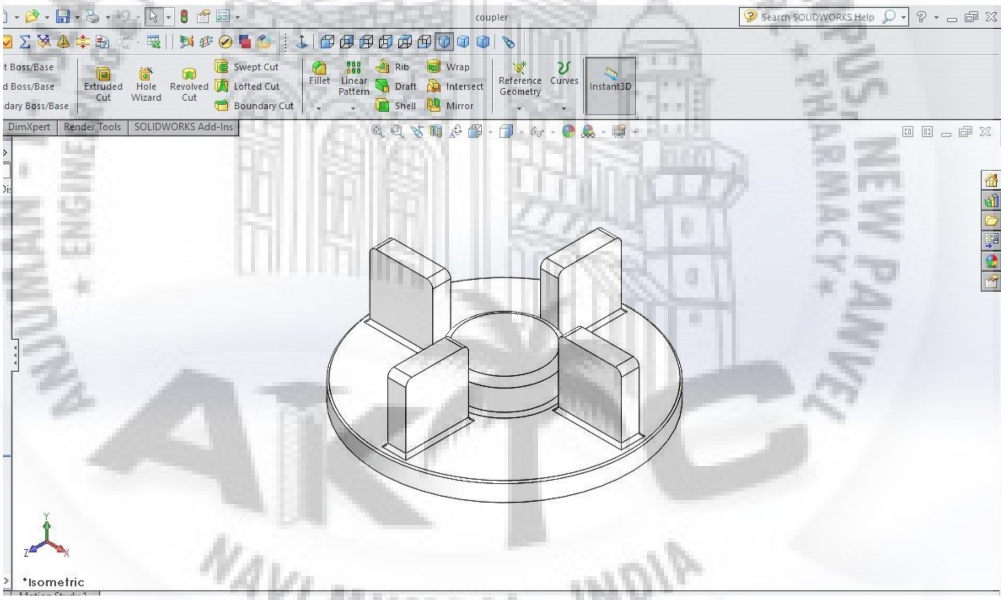


Fig 8.4.9: Design of jar coupler

8.4.2) DESIGN OF COMPLETELY MODIED JAR COUPLER:

In this design, area is increased and width is increased to bare bending stress and maximum twist. Thickness is also increased for torsional moment as shown in follow figure. But varying load can change on the bottom surface.

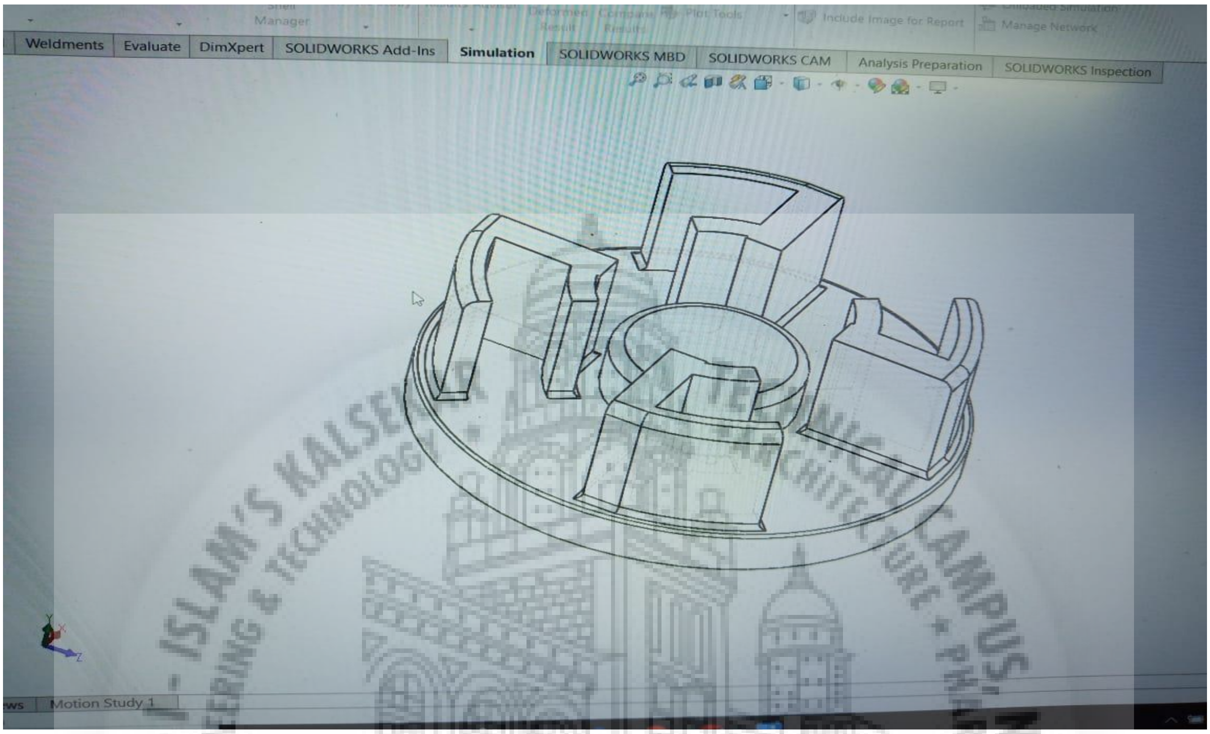


Fig 8.4.10: Design of modified coupler

(Due to pandemic and network issue we could not perform test and did not get more design)

Chapter 9

FEA ANALYSIS OF JAR COUPLER

9.1 FEA of Jar Coupler for Actual Working Conditions

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed. It is called analysis, but in the product development process, it is used to predict what is going to happen when the product is used.

FEA works by breaking down a real object into a large number (thousands to hundreds of thousands) of finite elements, such as little cubes. Mathematical equations help predict the behavior of each element. A computer then adds up all the individual behaviors to predict the behavior of the actual object. Finite element analysis helps predict the behavior of products affected by many physical effects, including:

- Mechanical stress

- Mechanical vibration
- Fatigue
- Motion
- Heat transfer
- Fluid flow
- Electrostatics
- Plastic injection moldings.

9.2 Procedure of FEA

Finite Element Analysis is a mathematical representation of a physical system comprising a part/assembly (model), material properties, and applicable boundary conditions {collectively referred to as pre-processing}, the solution of that mathematical representation {solving}, and the study of results of that solution {post-processing}.

9.2.1 Pre-processing

- Define the geometric domain of the problem.
- Define the element type(s) to be used.
- Define the material properties of the elements.
- Define the geometric properties of the elements (length, area, and the like).
- Define the element connectivity (mesh the model).
- Define the physical constraints (boundary conditions).
- Define the loadings.

9.2.2 Solution

- Computes the unknown values of the primary field variable(s)
- Computed values are then used by back substitution to compute additional, derived

variables, such as reaction forces, element stresses, and heat flow.

9.2.3 Post processing

- Postprocessor software contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution.
- It deals with the representation of result. Typically, the deformed configuration, modes shapes, temperature, and stress distribution are computed and displayed at this stage.

9.3 Design Calculations

- Jar Coupler rotates at 18000rpm and Power of 750Watts, Hence Toque acting on the Jar Coupler is calculated by
- $$P = \frac{2\pi NT}{60X1000}$$
- Where,
- **P = Power in KW**
- N = Rotational Speed in RPM
- T= Torque acting on the Jar Coupler
- $$0.75 = \frac{2\pi x18000xT}{60X1000}$$
- T = 0.4Nm
- This shows that, Jar Coupler Subjected to torque of 0.4Nm.
- **Loading Conditions:**
- Now Jar Coupler has to be tested for Torque of 0.4Nm and Centrifugal Force at 18000rpm.
- **Boundary Conditions:**
- Center Point is fixed and Torque is applied on the Vertical Teeth's of the Jar Coupler. Centrifugal Force is also applied on the Circular ring because of Rotational Motion.

9.4 Simulation Results:

9.4.1) Simulation results of exist jar coupler:

Following figures are the simulation result of existing jar coupler. Three materials are used i.e polyethylene plastic, Nylon, PLA. Various stress and Deformation are considered.

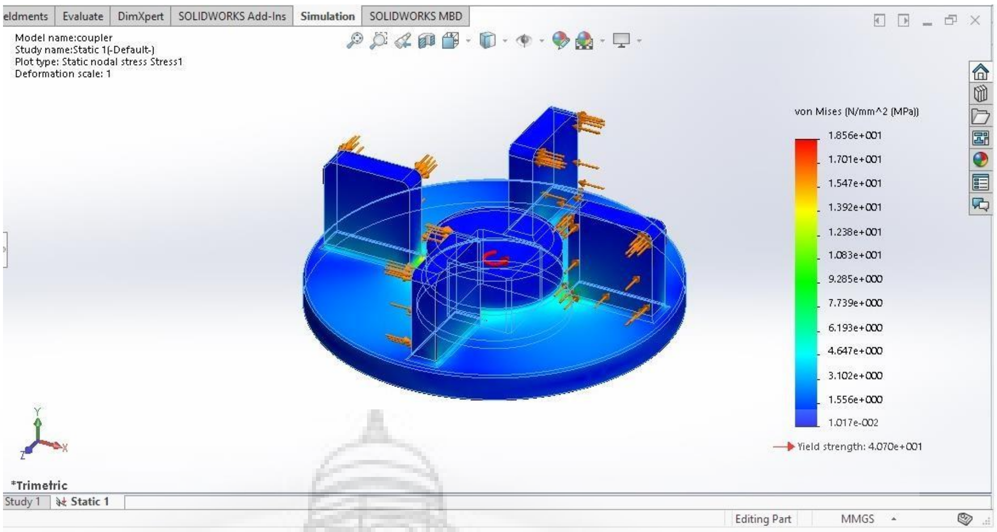


Fig 9.4.1 stress contour of coupler with Polyethylene plastic

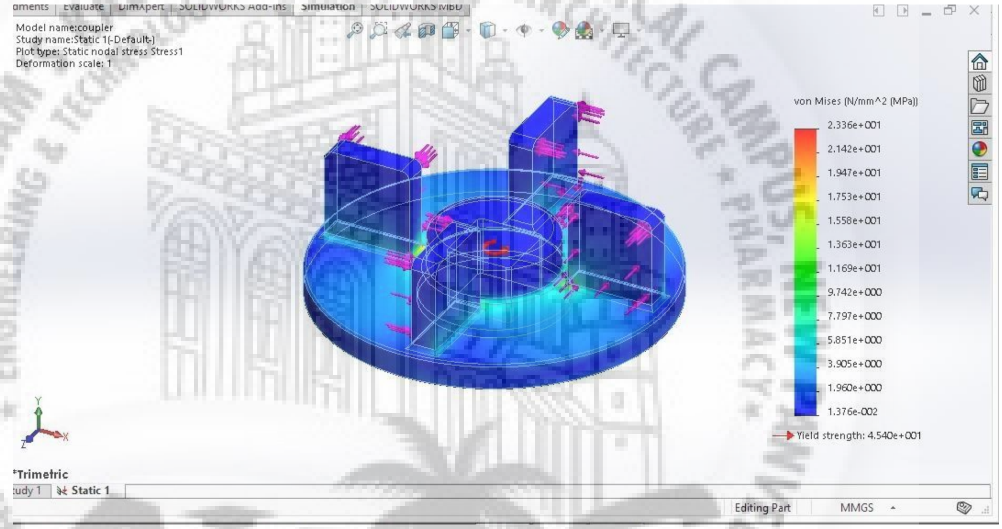


Fig. 9.4.2 Stress contour of Coupler with Nylon Plastic.

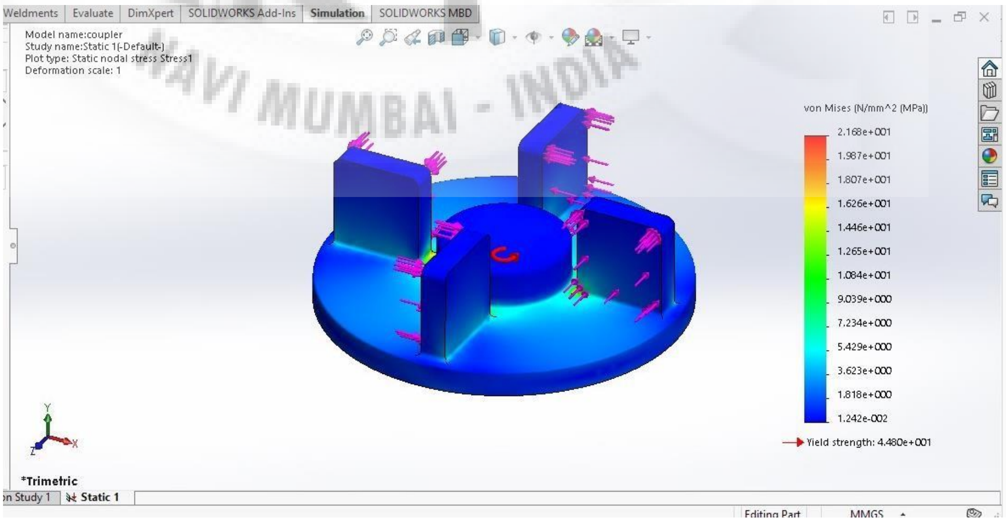


Fig. 9.4.3 Stress contour of Coupler with PLA Plastic.

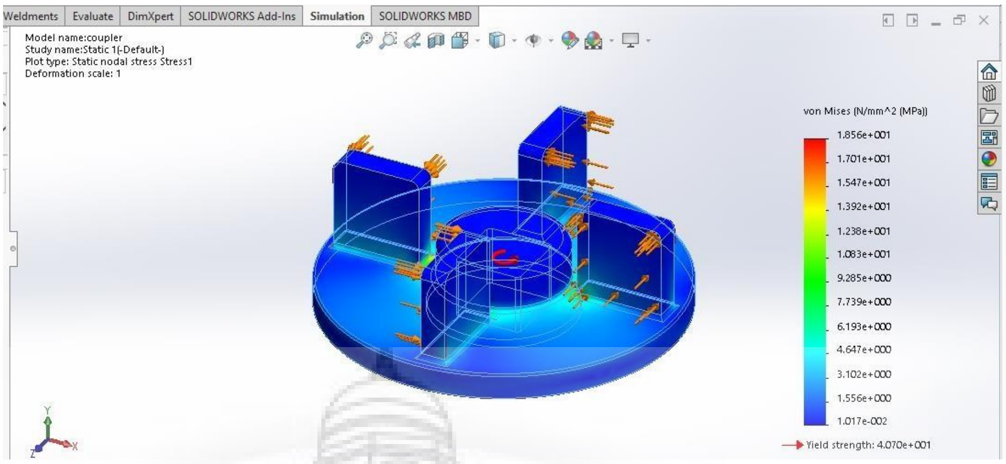


Fig 9.4.4: Deformation of coupler with Polyethylene plastic.

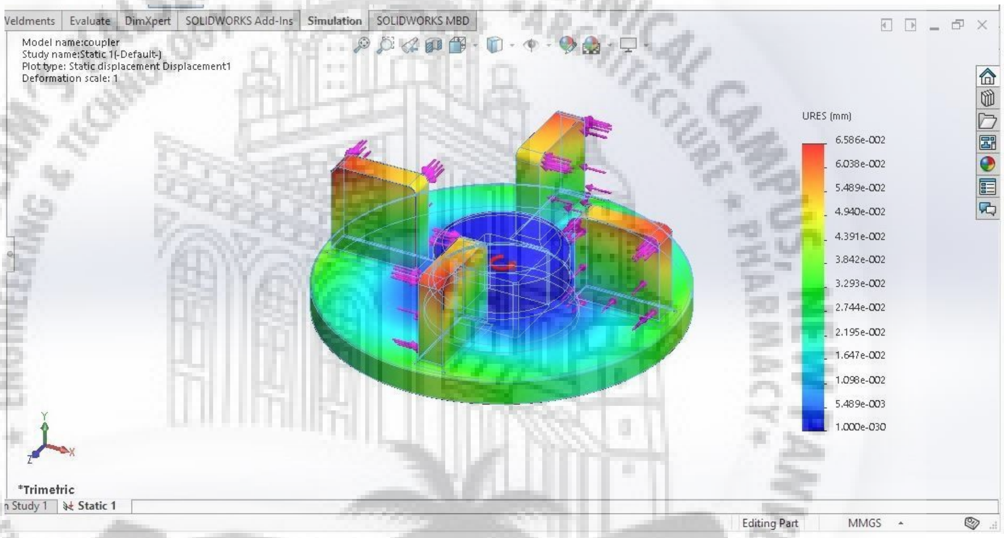


Fig 9.4.5: Deformation of coupler with Nylon plastic.

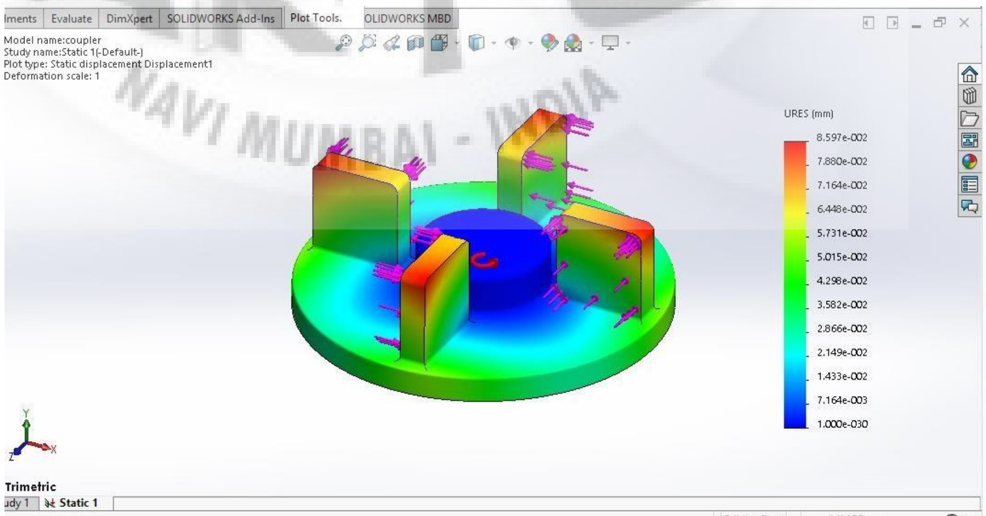


Fig 9.4.6: Deformation of coupler with PLA plastic.

9.4.2) Simulation of modified jar coupler design:
Following simulation fig is of PLA AND Nylon by increasing width support behind teeth.

Fig 9.4.7: Static nodal stress of jar coupler of PLA

Fig 9.4.8 Deformation of Jar coupler using PLA

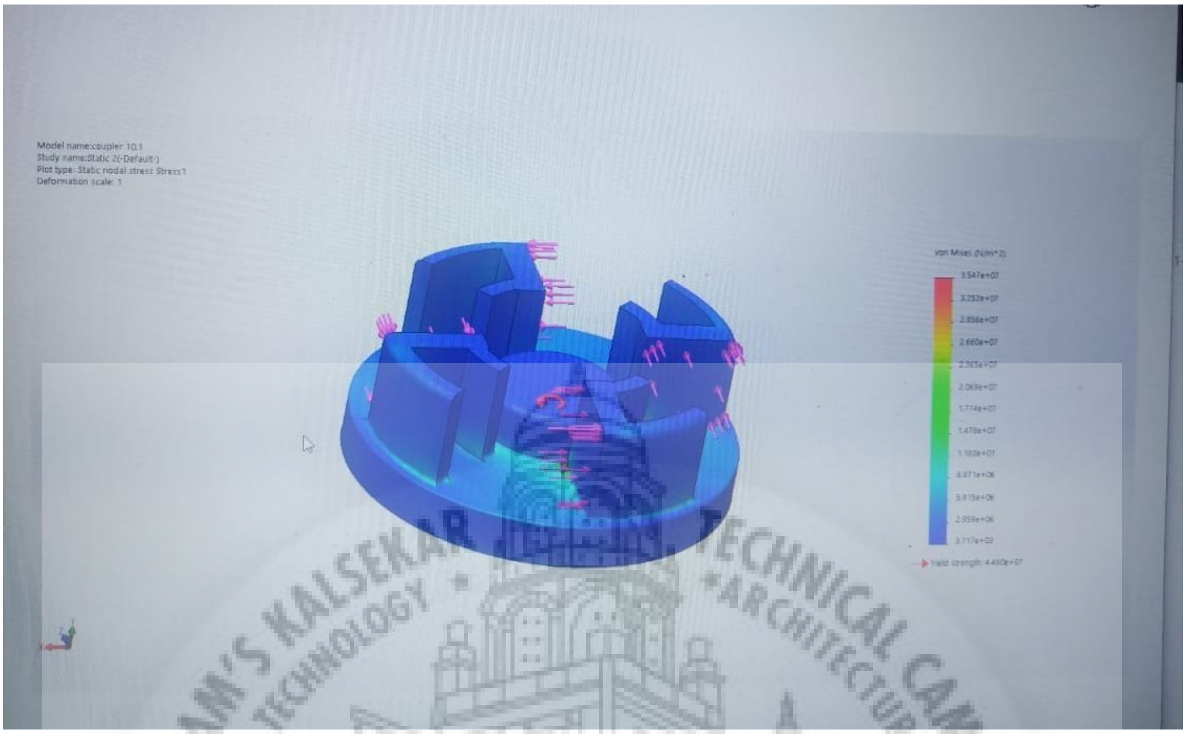


Fig 9.4.9 Static nodal stress of Jar coupler using Nylon

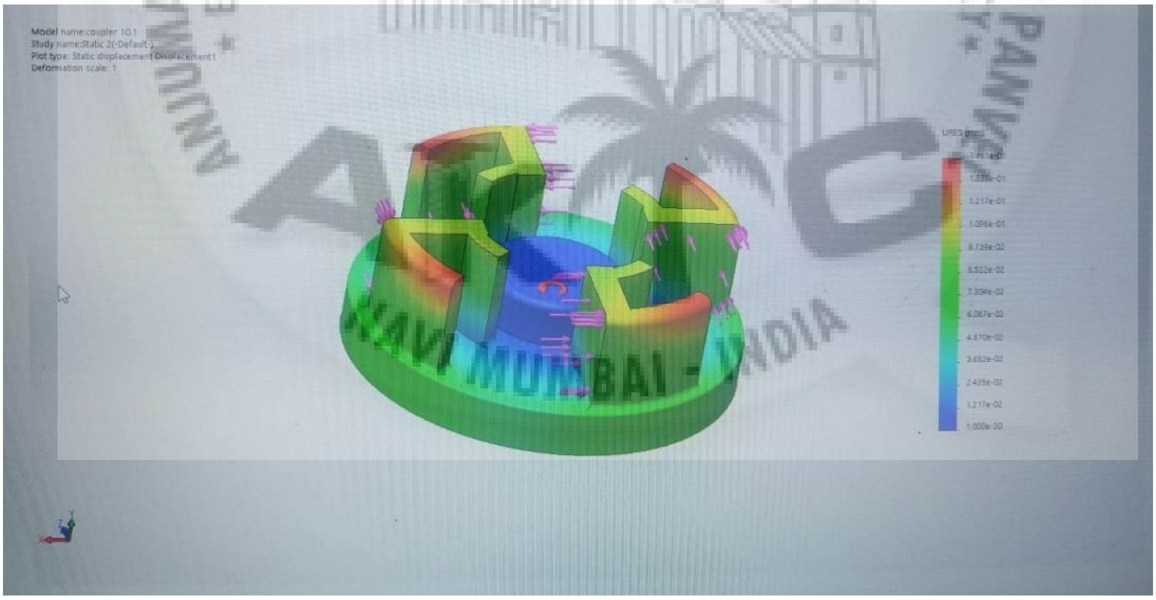


Fig 9.4.10: Deformation of jar coupler using Nylon

Chapter 10 3D printing Filament and Method

10.1 Introduction to 3D Printing

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. But there are some common features for all Addictive Manufacturing, such as usage of computer together with special 3D modeling software.

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.

10.2 3D Printing methods

- **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. Those polymers then make up the body of a three-dimensional solid. Stereo lithography is used to create prototypes for products and in medical modeling, among other uses.

While Stereo lithography is fast and can produce almost any design, it can be expensive.

- **Fused deposition modeling (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. Then the printer heats thermoplastic till its melting point and extrudes it throughout nozzle onto base, which can also be called a build platform or a table, along the calculated path. A computer of the 3d printer translates the dimensions of an object into X, Y and Z coordinates and controls that the nozzle and the base follow calculated path during printing. To support upper layer the printer may place underneath special material that can be dissolved after printing is completed.

- **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. Unlike some other additive manufacturing processes, such as Stereo lithography (SLA) and fused deposition modeling (FDM), SLS doesn't need to use any support structures as the object being printed is constantly surrounded by unsintered powder. The material to print with might be anything from nylon, ceramics and glass to some metals like aluminum, steel or silver. Due to wide variety of materials that can be used with this type of 3d printer the technology is very popular for 3D printing customized products.

- **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 3Ddimentional 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, which controls electron beam in high vacuum. Contrary to SLS, EBM goes for full melting of the metal powder. The process is usually conducted under high temperature up to 1000 °C. Comparing to SLM the process of EBM is rather slow and expensive; also the availability of materials is limited. So the method is not so popular though still used in some of manufacturing processes.

- **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. The LOM process includes several steps. Firstly, CAD file is transformed to computer format, which are usually STL or 3DS. LOM printers use continuous sheet coated with an adhesive, which is laid down across substrate with a heated roller. The heated roller that is passed over the material sheet on substrate melts its adhesive. Then laser or knife traces desired dimensions of the part. Also the laser crosses hatches of any excess material in order to help to remove it easily after the printing is done.

10.3 Selection of 3D Printing method

Table No 8.3: Selection of 3D printing method.

3D Printing Methods	Strength	Cost	Materials 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.

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.

10.4 Materials for 3D Printing

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

- Plastics
- Nylon
- Metal Alloys
- Ceramics
- Food
- Paper
- Wood

- Silicone
- Graphene
- Biomaterials
- Electrically Conductive

Fig 8.4: Materials for 3D Printing.

10.5 Shortlisting of 3D Printing

Materials

Table 8.5: Shortlisted 3D printing materials.

Materials	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
Stainless steel	7.80	592	863	198	7280	SLS
Gold & silver	Requirement of high end Printing Machines and Costly					SLS/FDM
Titanium	Requirement of high end Printing Machines and Costly					SLM
Ceramic	3.65	275	300	Customized FDM machine is required.		

The following 3D printing materials have been shortlisted because of their high tensile strength, durability, availability and low cost which is required for the proper functioning of Spur gear.

- Poly Lactic Acid (PLA)
- Acrylonitrile Butadiene Styrene (ABS)
- Nylon12 (NYL 12)
- Polycarbonate (PC)

10.6 Mechanical properties of shortlisted 3D printing materials

Material Selection is done on the basis of Availability of Printing Machine to print the Component, Cost, and Weight Carrying Capacity and commonly preferred by the industry.

Table 8.6: Mechanical Properties of 3D printing materials.

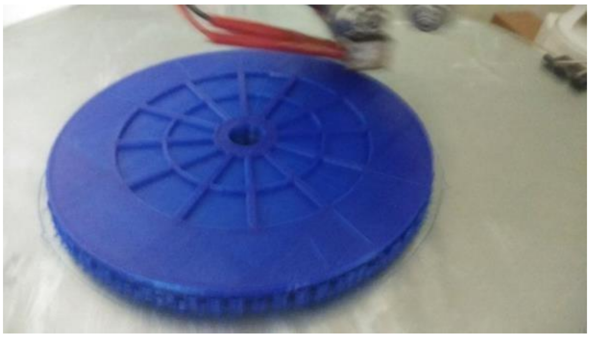
Materials	Density (g/cc)	Tensile strength (MPa)		Young's modulus (GPa.)
		Yield	Ultimate	
PLA	1.29	44.8	50.1	3.76
ABS	1.05	40.7	41.4	2.10
NYL12	1.42	45.4	79.4	5.31
PC	1.20	63.3	60.6	2.36

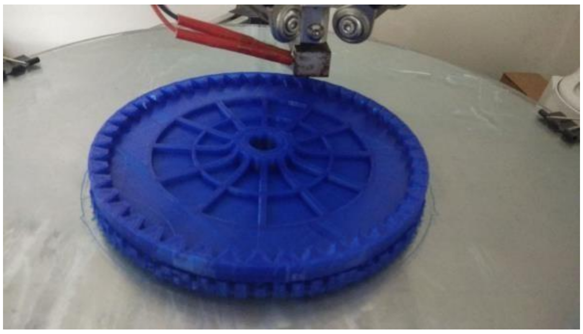
10.7 3D Printing filament for Jar Coupler Manufacturing

Poly lactic acid and **Nylon** can be used to increase the strength of the existing Gear. Use of Nylon results into increase in Cost because of its high cost of Filament.

10.8 3D printing of Jar Coupler using FDM

Fig No 8.8 3D printing of Jar Coupler on Flash forge Printer





10.9 3D Printed Product Cost Estimation

Printing cost for 3D printed parts in the market varies from Rs. 5/gram to Rs. 25/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 8.9: Manufacturing cost Estimation.

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	8	10	80/-
NYL12	1.42	7150	8.8	10	88/-

Chapter 11 RESULTS

As experiment is not performed, we cannot compare on practical basis. Therefore Following Results shown are on the basis of material properties and simulation.

A) Result of Existing Jar Coupler: By increasing slightly thickness in existing jar coupler and changing material by considering torsion factor with either PLA or Nylon gives better strength. Table No 8.1: Simulation Results.

Sr. No.	**Material**	**Max Stress, MPa**	**Deformation, mm**	

1	Polyethylene	1.856	0.131	
2	Nylon	2.336	0.06586	
3	PLA	2.168	0.08597	

The above table shows that, stress is almost same in all the 3 materials, As Stress in independent of the Young's Modulus.

Deformation is Very less in Nylon Material, but we can go for moderate Deformation as in PLA Jar Coupler due to cost concern.

B) Result of Modified Design coupler: Results are not satisfied as we did not perform torsion test. On the basis of simulation results are as follows.

Sr No	**Material**	**Max Stress, Mpa**	**Deformation(mm)**	
1	Nylon	3.546	0.032	
2	PLA	3.96	0.0146	

Results of modified jar coupler are not up to the mark. By replacing material with reinforced composite glass or natural fibre with either Nylon or PLA will give better results but this material cannot be use in 3D printer. However in manufacturing by injection moulding this method can be used. Result A) is best for additive manufacturing. Either using PLA or Nylon will give high torsional strength and durability.

CHAPTER 12

CONCLUSION AND FUTURE SCOPE A) CONCLUSION:

- This type of Component design using advance manufacturing process will result into fast product development. This helps the Manufacturer to manufacture the parts without investing highly into Research and Development. This also helps the designer to design the complex designs without worrying about the manufacturing Process.
- PLA and Nylon materials have good stiffness and better strength so that jar coupler life will increase with minimum cost manufacturing process. Also Jar coupler made with composite glass fibre will give better strength and durability.
- 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.

B) FUTURE SCOPE: In the education segment, 3d printing can bring a number of benefits to students and educators:

- It makes learning more fun.
- Fosters creativity and problem solving skills.
- Vastly improves retention and quality of learning.
- Creates excitement and engagement.
- Can improve rate of learning amongst special needs individuals. E.g. visually challenged, Autistic, etc.
- Not expensive.

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