A

Lab Report

On

## "Synchronized Cam and Follower Mechanism"

Submitted by

#### **DANISH ANWER**

(Roll No- ME21708)

Master of Technology

(Additive Manufacturing)



#### NATIONAL INSTITUTE OF TECHNOLOGY, WARANGAL

Under the Guidance of

Dr A. KUMAR

**Professor** 

#### National Institute of Technology, Warangal

#### DEPARTMENT OF MECHANICAL ENGINEERING



#### **CERTIFICATE**

This is to certify that Project Report entitled "Synchronized Cam and Follower Mechanism" with Additive Manufacturing" which is submitted by Danish Anwer in partial fulfilment of Additive Manufacturing Laboratory in Department of Mechanical Engineering at NIT Warangal. He has undergone intensive hands on project. He has carried out the lab work under my supervision and guidance in academic year 2021- 2022.

Dr. Adepu Kumar

**Head of Department** 

Department of Mechanical Engineering

**NIT Warangal** 

#### **ACKNOWLEDGEMENT**

I take this opportunity to express my sincere gratitude of indebtedness to my Lab coordinator/faculty **Dr. Adepu Kumar** for their valuable guidance & the freedom they gave me to explore my knowledge in the field of Additive Manufacturing. Due to their constant encouragement & inspiration, I am able to present this Lab Work successfully.

I am thankful to the **PhD Scholars and Seniors** for giving me guidance regarding SolidWorks, Cura, Magics & all those who have been instrumental directly or indirectly in the process of completion of this Lab work.

I am thankful to all my **Batch mates** for their help in the completion of this Lab work. I also wish to express my sincere thanks to all those who helped me directly or indirectly in completing my Lab work.

Danish Anwer
M. Tech. (AM)
NIT, Warangal

#### **ABSTRACT**

Additive manufacturing technologies performs layer-wise fabrication of complex parts directly from CAD files without part-specific tooling. Additive manufacturing offers many strategic advantages, including increased design freedom for building complex internal and external part geometries that cannot be made in any other way, the ability to rapidly iterate through design permutations, the ability to build functional parts in small lot sizes for end-user customization or bridge manufacturing.

One of them is Extrusion AM process. Extrusion-based technology is currently the most popular on the market.

By far the most common extrusion-based AM technology is fused deposition modeling (FDM), produced and developed by Stratasys, USA. FDM uses a heating chamber to liquefy polymer that is fed into the system as a filament. The filament is pushed into the chamber by a tractor wheel arrangement and it is this pushing that generates the extrusion pressure.

This project report emphasis upon Synchronized cam and follower mechanism.

This mechanism can be used for transmission purpose in industries instead of belt and conveyor assembly. This will reduce manpower requirement and systemized transmission will be there.

It can be used as a prototype to convey its benefits over belt and conveyer assembly.

## **CONTENTS**

1. Manuf	acturing					1	Additive
	_						2
1.2			and			of	AM
Proces				_			
1.3 process	s	Addit		VS	4	\$	subtractive
2.			AM pro	ocess used6	in	the	project
2.1 Тур	oes of AM pro	ocesses					6
2.2 Fus	sed deposition	n modelling					7
2.3 Wo	rking princip	le					7
2.4 FD	M Machine						8
2.5 Spe	ecification o	f Ultimaker 2	+				9
3. Gene	eric AM proc	ess					10
4. Mate	erial Used						11
5. Can	ıs						12
5.1 Ty <sub>1</sub>	pes of Cams						12
5.2 No	menclature	of Cams					13
6. Foll	ower						14
6.1 Ty <sub>1</sub>	pes of follow	vers					14
6.2 Ty <sub>1</sub>	pes of follow	ver motion					15
6.3 Dis	splacement d	liagrams					15
6.4 Fo	llower motio	on with Unifo	rm velocity				16
7. Sket	tching, mode	elling and par	t fabrication				17
7.1 Fre	ee Hand Sket	tch					17
7.2 Mc	odelling on S	SolidWorks					20
7.3 Co	nversion to S	STL File					26

7.4 Correction of STL Files using Magics software		
7.5 Slicing of STL file on CURA software	33	
8. Displacement Diagram	36	
5		
9. Cost analysis of synchronized cam and follower	38	
10. Break even analysis	41	
11. Post processing.	43	
12. Conclusion.	44	
13. References	45	

# **LIST OF FIGURES**

Fig	1.1	Illustration	of	Additive	VS	Subtractive	Manufacturing
Proce	sses		4				
Fig techno	ology	2.1		Types		of 6	AM
•		Schematic	diagra	am of	Fused	Deposition	Modelling
Fig mach	ines			2.3			FDM
Fig Ultim	aker2+	2.4			Specifi		of
Fig 3.	1 Generi	c AM process					10
Fig 5.	1 Schem	atic of cam					12
Fig 5.	2 Plate o	r disk cam					13
Fig 5.	3 Schem	atic of cam nom	enclature	<b>;</b>			14
Fig 6.	1 Differe	ent kind of follow	vers				15
Fig 6.	2 Follow	er motion (Unif	orm velo	city)			16
Fig 7.	1 Hand s	ketch of cam					17
Fig 7.	2 Hand s	sketch of longer	follower.				17
Fig 7.	3 Hand s	ketch of smaller	follower				18
Fig 7.	4 Hand s	sketch of bigger	support				18
Fig 7.	5 Hand s	ketch of smaller	support.				19
Fig 7.	6 Hand s	ketch of middle	support.				19
Fig 7.	7 Hand s	ketch of slant su	pport				20

Fig 7.8 Hand sketch of cam bar.	.20
Fig 7.9 SolidWorks 2019 page.	.21
Fig 7.10 Part drawing page on SolidWorks.	21
Fig 7.11 Initial Sketch on SolidWorks.	.22
Fig 7.12 Extruding of sketch.	.22
Fig 7.13 Final part drawing of a part.	23
7	
Fig 7.14 Part modelling of Bigger follower.	.23
Fig 7.15 Part modelling of Smaller follower.	.23
Fig 7.16 Part modelling of Bigger support.	.24
Fig 7.17 Part modelling of Smaller support.	.24
Fig 7.18 Part modelling of Middle support.	.24
Fig 7.19 Part modelling of Slant support.	.25
Fig 7.20 Part modelling of Cam bar.	.25
Fig 7.21 Assembled View.	.26
Fig 7.22 STL Conversion of Bigger follower.	.27
Fig 7.23 STL Conversion of Smaller follower.	.27
Fig 7.24 STL Conversion of Bigger support.	.28
Fig 7.25 STL Conversion of Smaller support.	.28
Fig 7.26 STL Conversion of Middle support.	.28
Fig 7.27 STL Conversion of Slant support.	.29
Fig 7.28 STL Conversion of Cam bar.	.29
Fig 7.29 Correction of STL file of Bigger follower in Magics.	.30
Fig 7.30 Correction of STL file of Bigger support in Magics.	.30
Fig 7.31 Correction of STL file of Smaller support in Magics.	.31
Fig 7.32 Correction of STL file of Middle support in Magics.	.31
Fig 7.33 Correction of STL file of Slant support in Magics.	.32

Fig 7.34 Correction of STL file of Cam bar in Magics.	32
Fig 7.35 Slicing of parts in Cura Software	34
Fig 7.36 Whole build three whole assembled parts slicing in Cura	35
Fig 8.1 Design of Cam.	36
Fig 8.2 Rotation reciprocation diagram.	37
8	
<u>LIST OF TABLES</u>	
Table 1.1 Application and advantages of AM processes	3
Table 1.2 Additive vs subtractive manufacturing.	5
Table 4.1 Properties of PLA.	11
Table 9.1 Electricity rates in Warangal	39
Table 9.2 Total Part cost.	40
Table 10.1 Cost function vs Revenue function.	42

#### 1. ADDITIVE MANUFACTURING

Additive manufacturing (AM) is a transformative approach to industrial production that enables the creation of lighter, stronger parts and systems. It is a technological advancement made possible by the transition from analog to digital processes.

The term "additive manufacturing" references technologies that grow three-dimensional objects one superfine layer at a time. Each successive layer bonds to the preceding layer of melted or partially melted material. Objects are digitally defined by computer-aided-design (CAD) software that is used to create STL files that essentially "slice" the object into ultra- thin layers. This information guides the path of a nozzle or print head as it precisely deposits material upon the preceding layer. Or, a laser or electron beam selectively melts or partially melts in a bed of powdered material. As materials cool or are cured, they fuse together to form a three-dimensional object.

Additive manufacturing now enables both a design and industrial revolution, in various industrial sectors such as aerospace, energy, automotive, medical, tooling and consumer goods.

#### 1.1 History

Additive manufacturing first emerged in 1987 with stereolithography (SL) from 3D Systems, a process that solidifies thin layers of ultraviolet (UV) light-sensitive liquid polymer using a laser. The SLA-1, the first commercially available AM system in the world, was the precursor of the once popular SLA 250 machine.

In 1991, three AM technologies were commercialized, including fused deposition modeling (FDM) from Stratasys, solid ground curing (SGC) from Cubital, and laminated object manufacturing (LOM) from Helisys.

Selective laser sintering (SLS) from DTM (now a part of 3D Systems) became available in 1992.

Binder jetting was developed by Ely Sachs and Mike Cima at the Massachusetts Institute of Technology in 1993 and Z Corporation obtained an exclusive license for the process in 1995.

In the 1990s, Powder-sintering methods emerged, and the first major creations fueled a growing interest in additive manufacturing. The first prosthesis was implanted into a human in 1999.

The 2000s are synonymous with expansion and strongly growing accessibility to individuals.

# 1.2 Applications and advantages of AM Processes

Field	Applications	Advantages		
Aerospace and Defense	<ul> <li>a) Functional prototypes</li> <li>b) Tooling</li> <li>c) Lightweight components</li> </ul>	a) Light volume production b) Weight reduction c) Material efficiency Part consolidation d) Maintenance and repair e)		
Automotive	<ul> <li>a) 3D printed custom seats</li> <li>b) Prototypes</li> <li>c) Tooling</li> <li>Spare and replacement parts</li> <li>d)</li> </ul>	i) Faster product development ii Greater design flexibility Customization Creation of iii) complex iv) geometry		
Medical and Dental	<ul> <li>a) Digital dentistry</li> <li>b) 3D printed implants and prosthetics</li> <li>c) Bioprinting Surgical planning and testing</li> <li>d)</li> </ul>	i) Enhanced medical devices ii) Personalized healthcare		
Consumer Goods	<ul> <li>a) Footwear</li> <li>b) Beauty and cosmetics</li> <li>c) Personal care products</li> <li>d) Jewelry</li> <li>e) Bikes</li> </ul>	i) Enhanced product development ii) Faster time-to-market Mass customization		
Industrial Goods	<ul><li>a) End use parts</li><li>b) Tooling</li><li>c) Spare parts</li></ul>	<ul> <li>i) Design complexity</li> <li>ii Shorter lead times</li> <li>) On-demand production</li> <li>iii)</li> </ul>		

#### **Future of 3D printing**

- a. **Process Innovation**: refers to the greater flexibility and agility 3D printing brings to manufacturing and supply chains. It includes the digitization and decentralization of production, as well as the ability to create tools and spare parts on-demand.
- b. **Product Innovation**: refers to the expanded design possibilities to create innovative new parts and products, including complex lattice structures and other geometries,

light weighting, customization, part count reduction and multi-material 3D printing.

Table 1.1 Applications and advantages of AM processes

3

## 1.3. Additive vs subtractive process

**Additive Manufacturing** processes build objects by adding material layer by layer, while subtractive manufacturing removes material to create parts. Though these approaches are fundamentally different, subtractive and additive manufacturing processes are often used side by side due to their overlapping range of applications.

**Subtractive manufacturing** is an umbrella term for various controlled machining and material removal processes that start with solid blocks, bars, rods of plastic, metal, or other materials that are shaped by removing material through cutting, boring, drilling, and grinding.



Fig 1.1 Illustration of Additive vs Subtractive Manufacturing Processes

Additive Manufacturing	Subtractive Manufacturing		
Adds layers to create an object	Removes material from an object		
3D printing, direct digital manufacturing, rapid prototyping, additive fabrication	Manual removal or CNC machining (computer numerical control)		
Uses 3D printers to create prototypes and products	Uses computers to aid machine processes such as drilling or milling.		
End result is a rough surface that needs to be finished by sanding or blowing.	End result can be machined - smooth, stepped etc.		
Ideal for small parts (plastic)	Ideal for bigger parts (metal)		
Slow process (depending on the job)	Relatively fast process		
Parts that require a lot of detail can be built in layers.	Not ideal for parts that require certain intricacies and details.		
The 3D printer can be linked directly to the software	A CNC programmer needs to set the machine. Code is no longer needed with new automated software.		
Cheap process	More expensive process		

Table 1.2 Additive Vs Subtractive Manufacturing Processes

# 2. DETAILS OF AM PROCESS USED IN THE PROJECT

#### 2.1 Types of AM processes

In 2010, the American Society for Testing and Materials (ASTM) group "ASTM F42 – Additive Manufacturing", formulated a set of standards that classify the range of Additive Manufacturing processes into 7 categories (Standard Terminology for Additive Manufacturing Technologies, 2012).

- 1. Vat photopolymerization
- 2. Powder bed fusion
- 3. Material extrusion
- 4. Material jetting
- 5. Binder jetting
- 6. Sheet lamination
- 7. Directed energy deposition

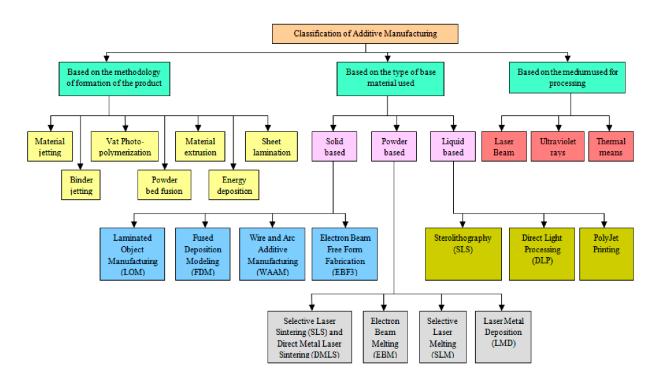


Fig 2.1 Types of AM technology

## 2.2. Fused Deposition Modelling

An FDM printer prints a 3-dimensional object by extruding a stream of heated or melted thermoplastic material, which is carefully positioned into layer upon layer, working from the bottom up.

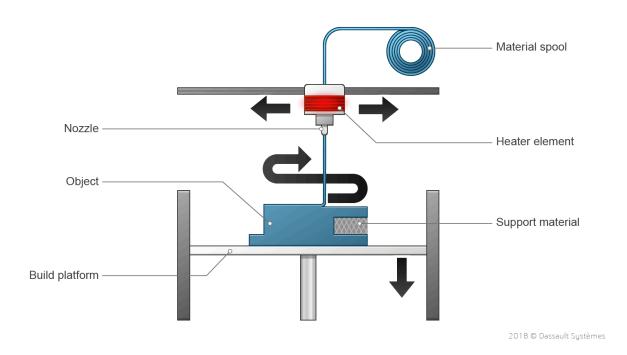


Fig 2.2 Schematic diagram of Fused Deposition Modelling Process

## 2.3. Working Principle

The principle of the FDM is based on surface chemistry, thermal energy and layer manufacturing technology.

The material in filament (spool) form is melted in a specially designed head, which extrudes on the model.

As it is extruded, it is cooled and thus solidifies to form the model. The model is built layer by layer, like the other RP systems.

Parameters which affect performance and functionalities of the system are:

- 1. Material column strength
- 2. Material flexural modulus
- 3. Material viscosity
- 4. Positioning accuracy
- 5. Road widths
- 6. Deposition speed
- 7. Volumetric flow rate
- 8. Tip diameter
- 9. Envelope temperature
- 10.Part geometry.

#### 2.4 FDM Machine





Fig 2.3 FDM machines

In this project to manufacture parts of wall mounted adjustable mobile holder, *UltiMaker 2+* is used.

## 2.5 Specification of Ultimaker 2+

# Ultimaker 2+ Quick Specs

Layer Resolution Up to 20 micron (0.02mm)

 Build Volume
 230 x 225 x 205 mm

 Speed
 30 - 300 mm/sec

Print Surface Heated bed, 20 - 100 C

Nozzle Temperature 180 - 260 C

Nozzle Diameter 0.25, 0.4, 0.6, 0.8mm

Filament Diameter 2.85mm

Supported Filaments PLA, ABS, CPE

Printing Software Cura (Download)

Overall Size 357 x 342 x 388 mm

File Transfer Standard SD card

Print Technology Fused Filament Fabrication (FFF)

What's Included Ultimaker 2+ Printer

Australian power cord

Power supply

USB cable (for firmware upgrades)

0.75kg filament spool

SD card

Glass build plate

Glue stick User manual

Grease & Hex wrench

Filament spool spigot & Filament guide post

Optional Accessories Redstack Front Cover (for ABS printing)

Redstack Ultimaker Advanced Stand

Ultimaker or a second of the s

Fig 2.4 Specifications of Ultimaker2+

## 3. GENERIC AM PROCESS

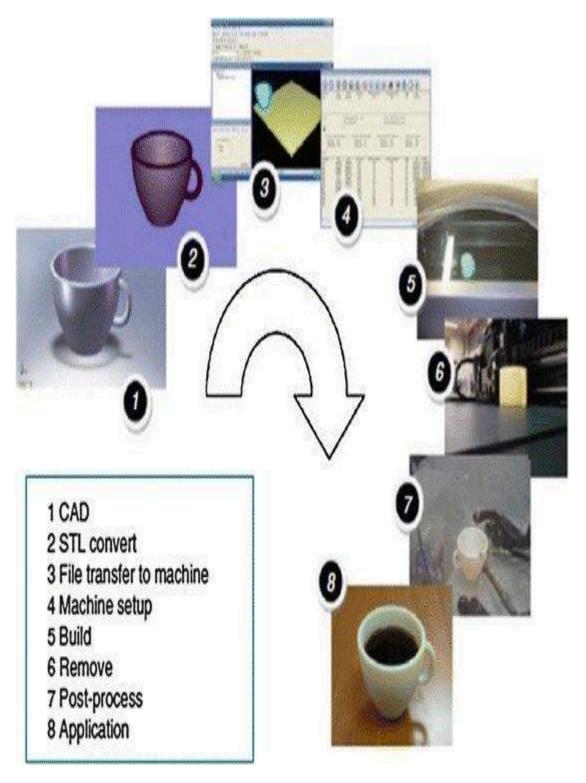


Fig 3.1 Generic AM process

## 4. MATERIAL USED

Material used for manufacturing parts is <u>PLA</u>. Its properties are as given below-

Characteristics	Unit	Amount
Physical: Mw Specific gravity Solid density Melt density  T <sub>g</sub> T <sub>m</sub> Specific heat (Cp) 190 °C 100 °C 55 °C Thermal conductivity 190 °C 109 °C 48 °C	g/mol - g/cm³ g/cm³ °C °C J/kg °C	66,000 1.27 1.252 1.073 55 165 2060 1955 1590 0.195 0.197
Optical: UV light transmission 190 to 220 nm 225 to 250 nm >300 nm Visible light transmission Color L* a* b*		$<5\%$ $85\%$ $95\%$ $90.64 \pm 0.21$ $-0.99 \pm 0.01$ $-0.50 \pm 0.04$
Mechanical: Tensile strength Elongation at break Elastic modulus Shear modulus Poisson's ratio Yield strength Flexural strength Unnotched izod Notch izod impact Rockwell hardness Heat deflection temp Vicat penetration Ultimate tensile strength Percent of elongation Young's modulus	Mpa % MPa MPa MPa J/m J/m HR °C °C MPa % MPa	59 7 3500 1287 0.36 70 106 195 26 88 55 59 73 11.3 1280

Table 4.1 Properties of PLA

"Following sections explains each of these steps in detail used for manufacturing of *Synchronized Cam and Follower* by Fused Deposition Modelling (FDM)".

#### 5. CAMS

The basic idea of a cam is by rotating the cams, bars will have either translational or oscillatory motion.

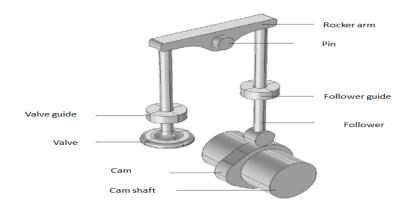


Fig 5.1 Schematic of cam

#### 5.1 Types of Cams

- a) Disk or plate cam
- b) Cylinderical cam
- c) Translating cam

a) Disk or plate cam: The disk (or plate) cam has an irregular contour to impart a specific motion to the follower. The follower moves in a plane perpendicular to the axis of rotation of the cam shaft and is held in contact with the cam by springs or gravity.

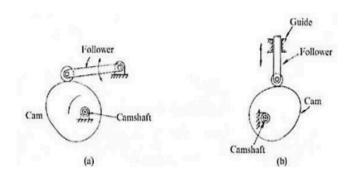


Fig 5.2 Plate or disk cam

#### 5.2 Nomenclature of Cams

**Cam Profile:** The contour of the working surface of the cam.

**Trace Point:** The point at the knife edge of a follower, or the centre of a roller, or the centre of a spherical face.

**Pitch Curve:** The path of the trace point.

**Base Circle:** The smallest circle drawn, tangential to the cam profile, with its centre on the axis of the cam shaft. The size of the base circle determines the size of the cam.

**Prime Circle:** The smallest circle drawn, that can be drawn from the centre of the cam and tangent to the pitch curve.

Prime circle radius: Base circle radius for knife edge and flat faced follower.

Prime circle radius = Base circle radius + radius of roller for roller follower

**Pressure Angle:** The angle between the normal to the pitch curve and the direction of motion of the follower at the point of contact.

**Lift of stroke:** It is the maximum travel of the follower from its lowest position to the topmost position. The maximum rise is called lift.

**Pitch Point:** It is a point on the curve having maximum pressure angle.

**Pitch Circle:** It is the circle drawn from the centre of the cam through the pitch points.

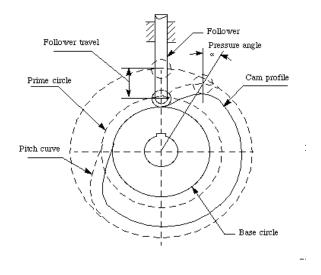


Fig 5.3 Schematic of cam nomenclature

### 6. FOLLOWER

A follower is a rotating or an oscillating element of a machine that follows the motion of cam by direct contact.

### 6.1. Types of followers

Based on surface in contact

- (a) Knife edge follower
- (b) Roller follower
- (c) Flat faced follower
- (d) Spherical follower

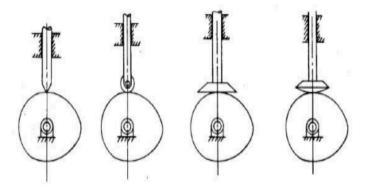


Fig 6.1 Different kind of followers

#### 6.2 Types of follower motion

Cam follower systems are designed to achieve a desired oscillatory motion. Appropriate displacement patterns are to be selected for this purpose, before designing the cam surface. The cam is assumed to rotate at a constant speed and the follower raises, dwells, returns to its original position and dwells again through specified angles of rotation of the cam, during each revolution of the cam.

Some of the standard follower motions are as follows:

They are, follower motion with-

- (a) Uniform velocity
- (b) Modified uniform velocity
- (c) Uniform acceleration and deceleration
- (d) Simple harmonic motion
- (e) Cycloidal motion

#### 6.3 Displacement diagrams

In a cam follower system, the motion of the follower is very important. Its

displacement can be plotted against the angular displacement  $\theta$  of the cam and it is called as the displacement diagram. The displacement of the follower is plotted along they-axis and angular displacement  $\theta$  of the cam is plotted along x-axis. From the displacement diagram, velocity y and acceleration of the follower can also be plotted for different angular displacements  $\theta$  of the cam. The displacement, velocity and acceleration diagrams are plotted for one cycle of operation i.e., one rotation of the cam. Displacement diagrams are basic requirements for the construction of cam profiles.

#### 6.4 Follower motion with Uniform velocity

Fig.3.8 shows the displacement, velocity and acceleration patterns of a follower having uniform velocity type of motion. Since the follower moves with constant velocity, during rise and fall, the displacement varies linearly with  $\theta$ . Also, since the velocity changes from zero to a finite value, with in no time, theoretically, the acceleration becomes in finite at the beginning and end of rise and fall.

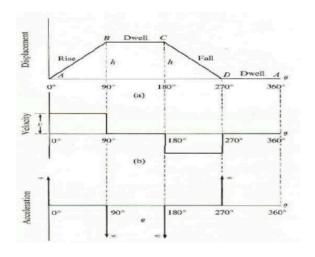


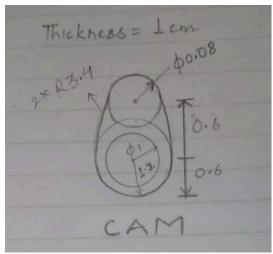
Fig 6.2 Follower motion (Uniform velocity)

"We will go with Disc type Cam and Knife edge Follower working with Uniform velocity".

# 7. SKETCHING, MODELLING and PART FABRICATION

## 7.1 Free Hand Sketch

All dimensions are in cm



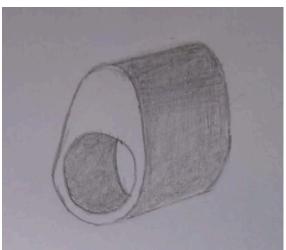
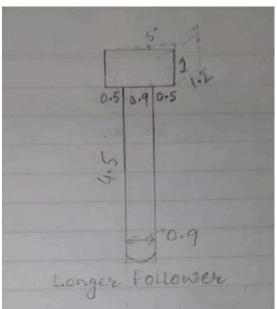


Fig 7.1



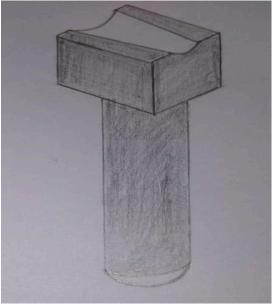


Fig 7.2

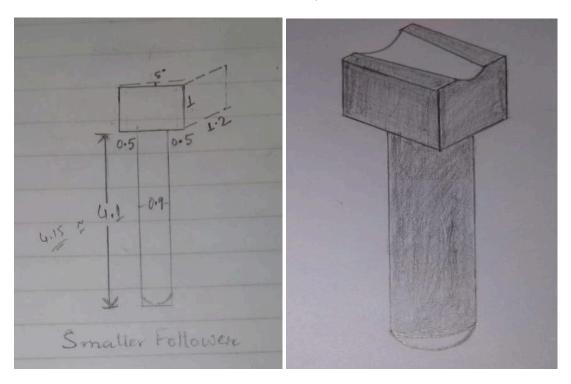
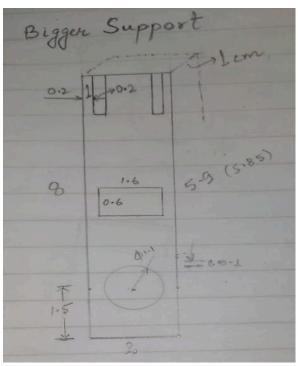


Fig 7.3



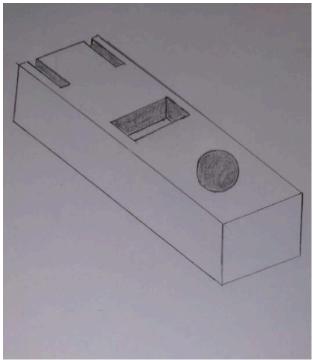


Fig 7.4

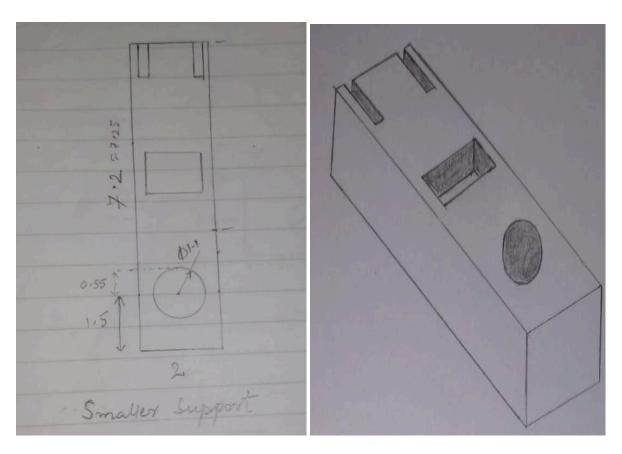


Fig 7.5

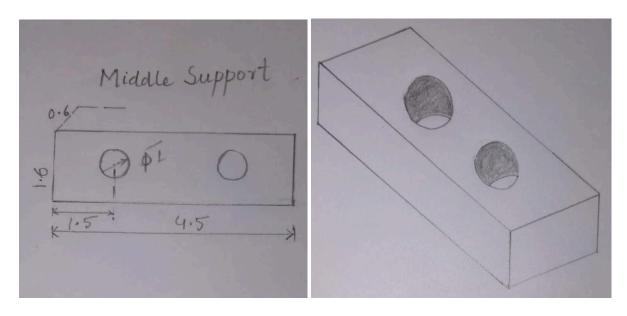
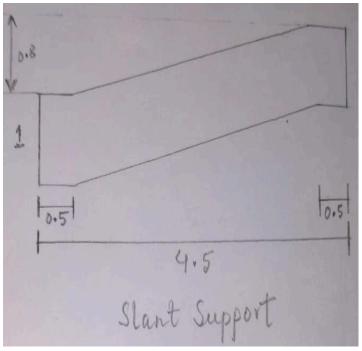


Fig 7.6



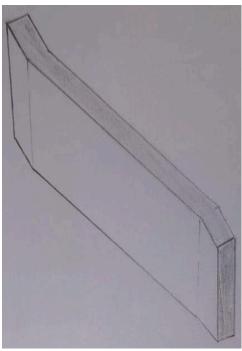


Fig 7.7

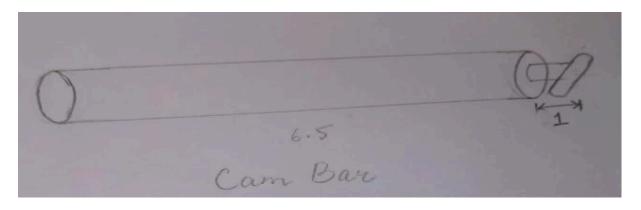


Fig 7.8

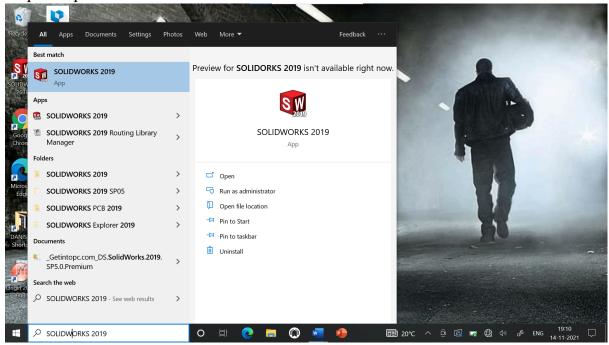
#### 7.2 Modelling on SolidWorks

For modelling and assembling of all the components required for *Synchronized cam and follower*; SolidWorks 2019 software is used.

20

## A. Part Modelling

Step 1: Open SolidWorks 2019



#### Step 2: Choose new part and press OK

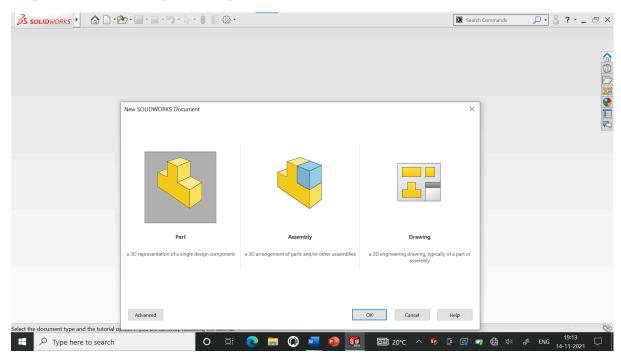


Fig 7.10

21

Step 3: Select right plane > Click on sketch > Draw sketch according to selected dimensions

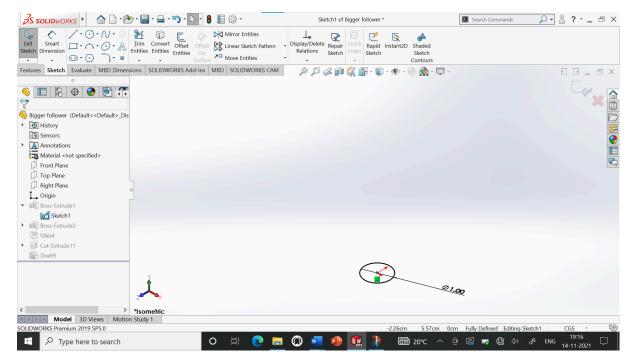


Fig 7.11

Step 4: Extrude the sketch by required dimensions

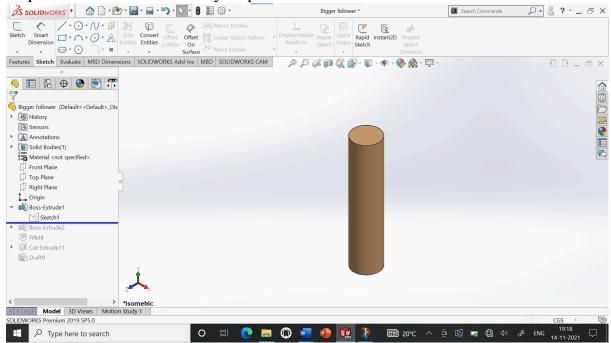


Fig 7.12

22

Step 5: Draw other features as defined and save file as 'Bigger follower'

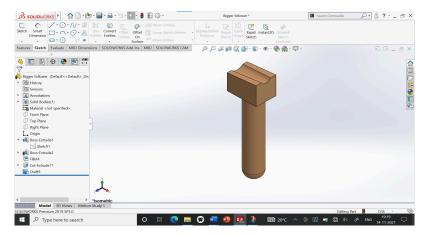


Fig 7.13

# Bigger follower:

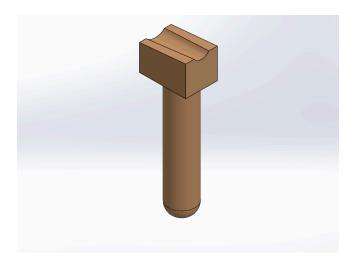


Fig 7.14

### **Smaller Follower:**

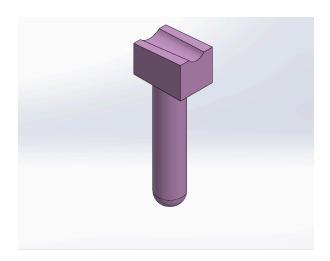


Fig 7.15

# **Bigger Side Support:**

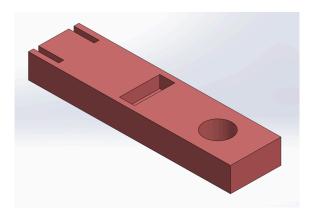


Fig 7.16

# **Smaller Side Support:**

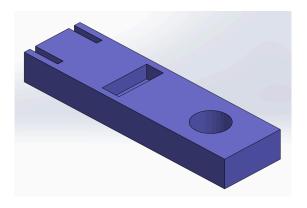


Fig 7.17

# **Middle Support:**

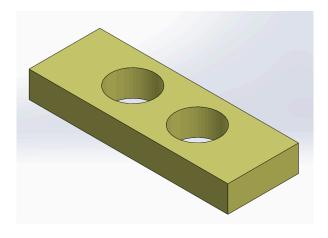


Fig 7.18

## **Slant Support:**

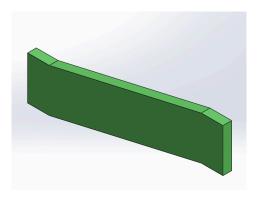


Fig 7.19

#### Cam Bar:

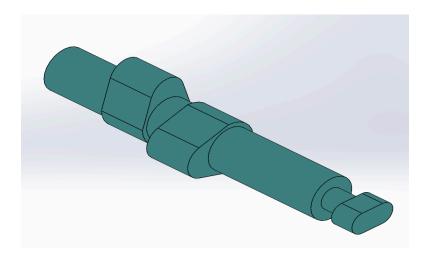


Fig 7.20

## **B.** Assembly

Assembly is done in SolidWorks 2019. This step is not compulsory for AM process but very important in the view of design validation. By doing assembly we can check the final product for fits and interferences. This step helps in reducing errors which might occur due to wrong dimensions of components.

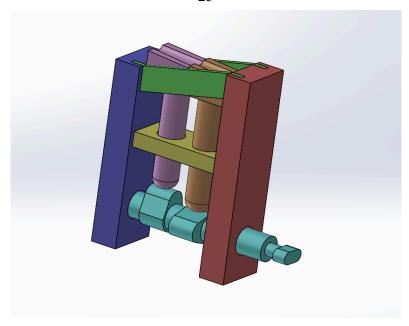


Fig 7.21

#### 7.3 Conversion to STL File

The STL is the standard file format used worldwide for 3D Printing. STL stands form 'Standard Triangle Language' (OR) 'Standard Tessellation Language'. STL files describe only the surface geometry of a three-dimensional object without any representation of color, texture or other common CAD model attributes. An STL file describes a raw, unstructured triangulated surface by the unit normal and vertices of the triangles using a three-dimensional Cartesian coordinate system.

STL file can be represented in both ASCII and Binary format but Binary is more common because they are more compact.

All modern CAD software have ability to convert their native file into STL format.

In SolidWorks 2019, for saving file in STL follow the following process File > Save As > STL

Options > Choose output format > Enter values of Deviation and Angle > OK

#### Selected values of tolerance are:

- a. Deviation = 0.0045 mm
- b. Angle =  $5 \deg$

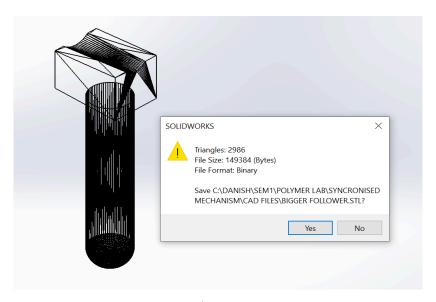


Fig 7.22

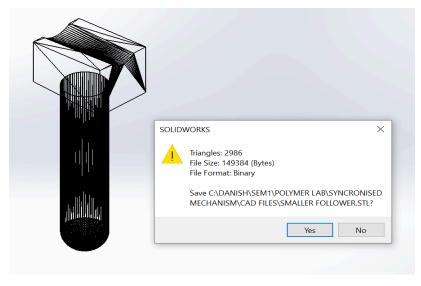


Fig 7.23

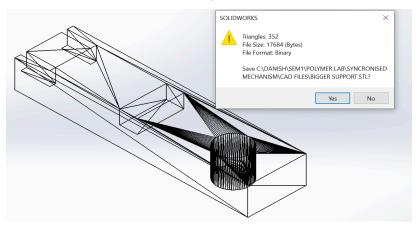


Fig 7.24

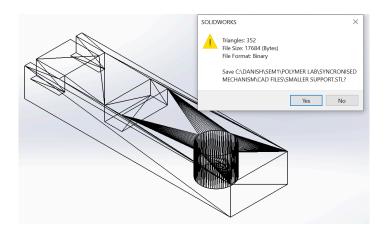


Fig 7.25

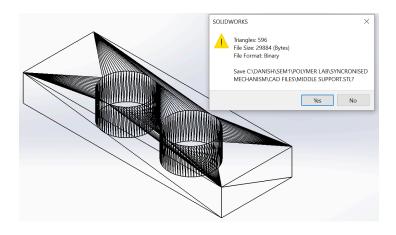


Fig 7.26

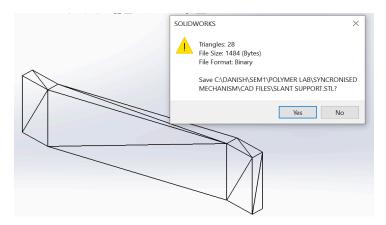


Fig 7.27

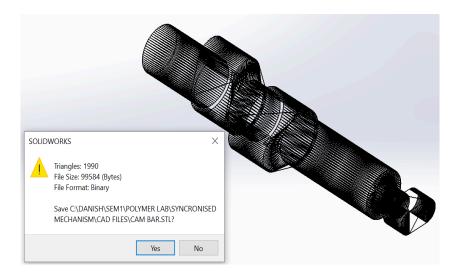


Fig 7.28

## 7.4 Correction of STL Files using Magics software

Magics software has been used for correction of stl files. Using this software we can automatically correct our stl files.

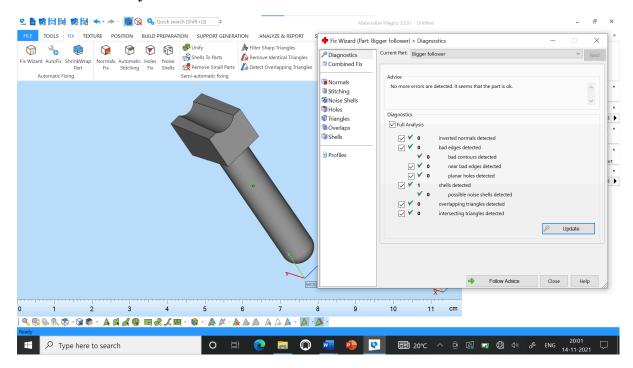


Fig 7.29

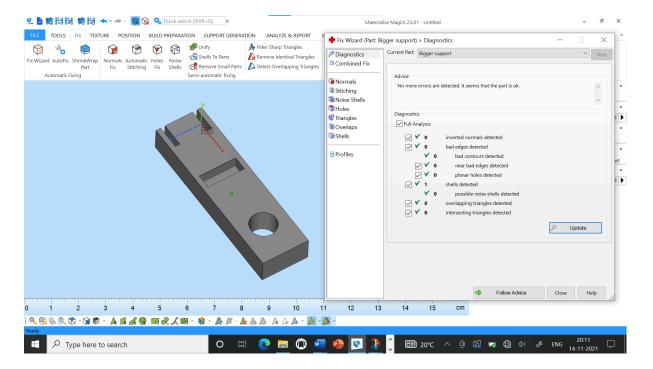


Fig 7.30

30

FILE TOOLS FIX TEXTURE POSITION BUILD PREPARATION SUPPORT GENERATION ANALYZE & REPORT Fix Wizard (Part: Smaller support) > Diagnostics Fix Wizard Autofix ShrinkWrap
Automatic Fixing

Automatic Fixing Current Part: Smaller support Combined Fix Pa Automatic Fixing Semi-automatic fixing **™** Normals No more errors are detected. It seems that the part is ok. Stitching Noise Shells
Holes Triangles ✓ Full Analysis Overlaps Shells ✓ ✓ 0 ✓ ✓ 0 bad edges detected Profiles bad contours detected near bad edges detected planar holes detected ( b shells detected overlapping triangles detected intersecting triangles detected Update Sollow Advice Close Help 16 cm O 🛱 💽 🔚 🔘 🚾 🥬 🛂 🤰 📋 📾 20°C ^ 😉 🐼 💌 🖨 🐠 🖋 ENG 2012 Type here to search

Fig 7.31

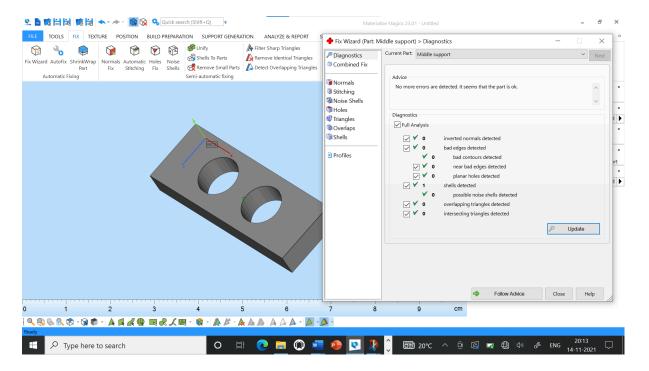


Fig 7.32

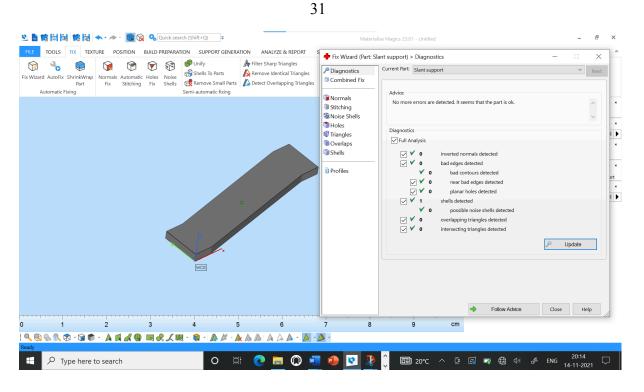


Fig 7.33

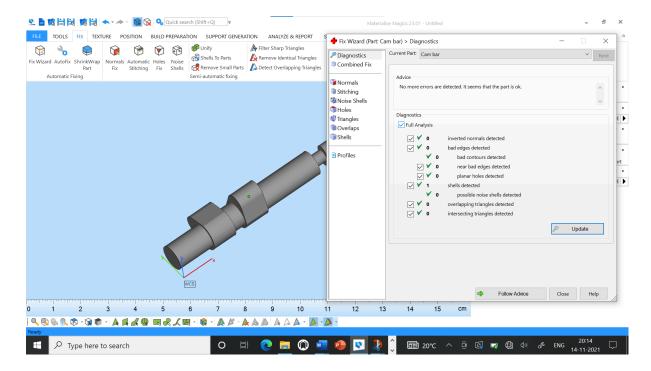


Fig 7.34

32

## 7.5 Slicing of STL file on CURA software

Slicing is the process in which 3D object model in converted to specific instructions for printer. Particularly object in STL format is converted to printer commands in G-Code format.

Slicing software divides object into number of flat layers followed by describing these flat layers in terms of movement of extruder in plane to trace and fill them.

Slicer program allows the calibration of printer settings using following inputs:

Layer Height

Infill Density

Fill Pattern

Print Speed

Travel Speed

Platform Temperature and many others.

In this project CURA software is used for slicing operation. Steps involved are as follow:

Step 1: Open CURA

Step 2: Load > Select STL file of component

Step 3: Process parameters > Input all the parameters

mentioned above as per requirement > OK

33

Parameters selected for this product are:

Layer thickness=0.1mm

Infill density=100%

Print speed=50mm/min

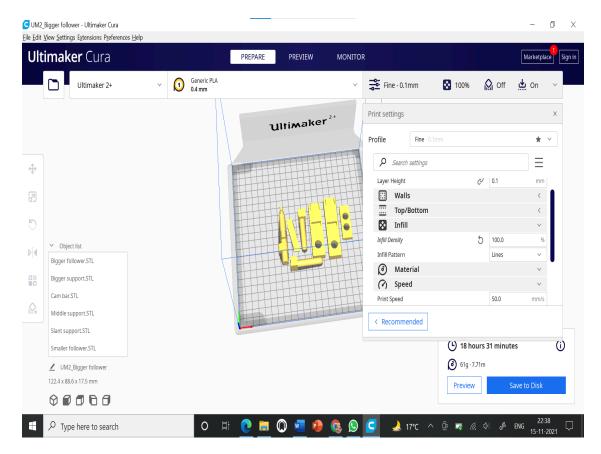


Fig 7.35

So, it will take 18 hrs 31 min to completion of one whole assembly print, and the mass required will be 61 gms.

Also in one build volume a total of whole 3 assembly parts can be printed.

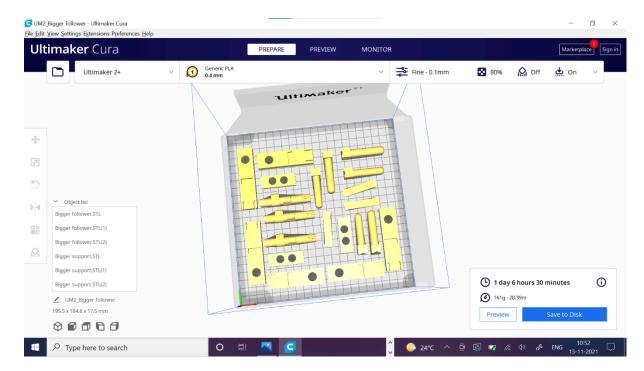


Fig 7.36

#### 8. DISPLACEMENT DIAGRAM

A cam is to give following motion to a knife-edge follower:

- a) Outstroke during 90° of cam rotation.
- b) Return stroke during 90° of cam rotation.
- c) Dwell for remaining 180° of cam rotation.

The stroke of follower is 4mm and minimum radius of cam is 12mm.

Follower moves with uniform velocity during both outstroke and return stroke.

So, using above data-

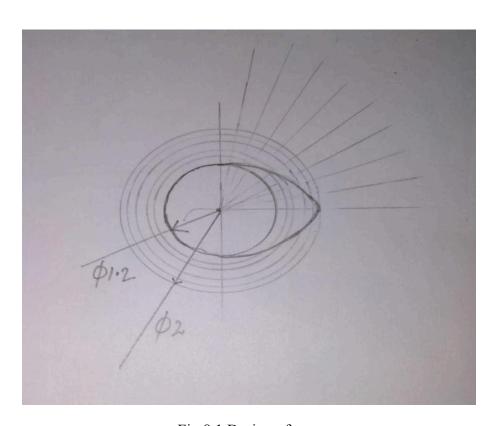


Fig 8.1 Design of cam

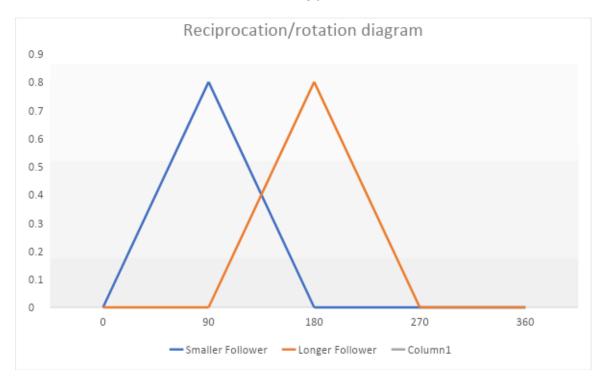


Fig 8.2 Displacement diagram

# 9. COST ANALYSIS OF SYNCHRONIZED CAM AND FOLLOWER

Total Cost = Fixed cost + Variable cost

$$C_{\text{total}} = C_{\text{machine}} + C_{\text{labour}} + C_{\text{material}} + C_{\text{electricity cost}}$$

$$C \ machine = \frac{\frac{E}{10} + M}{\frac{NH}{T}}$$

Where,

 $E = Machine Purchase Cost ( \ge 2 lacs)$ 

 $M = Maintenance Cost Per Year (13\% of E) ( \ge 26000)$ 

H = Machine Working Time In Hours Per Year (4800 hrs)

N = No Of Components In One Build (3)

T = Time For One Build In Hrs (1day 6hrs 30min = 30.5 hrs)

C machine = 
$$\left(\frac{\frac{200000}{10} + 26000}{\frac{3*4800}{30.5}}\right) = \ge 97.43$$

$$Clabour = \frac{W^*(S+P)}{N}$$

W = Minimum Wage Per Hour (≥ 30/hr, 8 hr work day)

S = Setup Time (Usually between 3-4 mins)

P = Post Processing Time (5-10 secs/part)

N = No of Components In One Build

C labour = 
$$\frac{30 \times (1/15)}{3}$$
 =  $\ge 0.67 / \text{part}$ 

 $Cmaterial = (M model \times C model) + (M support \times C support)$ 

Where,

M = Mass of material used

C = Cost per kg of respective material

In our case both support material and model material are same cost will be same for both.

$$Cmaterial = (M model + M support) \times C model$$

C material =  $(0.161 \times 1000) = \ge 161$ 

Material required for one part= ≥ 53.67

C electricity = Power consumed \* Charge per unit

$$= 220 \times 16 \times 30.5 = 107.36 \text{ kWh}$$

HT I(A): Industry General			7 2
11 kV	kVA	390	6.65
33 kV	kVA	390	6.15
132 kV and above	kVA	390	5.65

Table 9.1 Electricity rates in Warangal

C electricity = 
$$107.36 * 6.15 = \ge 660.24$$

Electricity cost for one part= ≥ 220.08

Cost	Value
C <sub>machine</sub>	97.43
$C_{labour}$	0.67
C material	53.67
C electricity	220.08
$C_{ m total}$	371.84

Table 9.2 Total assembly cost

#### 10. BREAK EVEN ANALYSIS

**Total cost function** = Fixed cost + Variable cost

Fixed cost=Equipment cost (E)+Overhead cost (O)(13.5% of E)

Variable cost=Cost per part, CPP

$$TC = E \times \left(1 + \frac{O}{100}\right) + CPP$$

Where,

E = Machine Cost

O% = Overhead Cost (13.5% of Equipment cost)

CPP = U (no of units) X cost of each build (  $\ge$  371.84)

$$TC = 200000 \times \left(1 + \frac{13.5}{100}\right) + U \times 371.84$$

**Total revenue function**= U × Selling Price

Selling price = Cost of part $(1 + \frac{P}{100})$ 

$$39$$

$$TSR = U \times (1 + \frac{P}{100})$$

Fixing price of our product at 500 with approximately 135% profit margin(P)

Where,

P = profit percentage

U = no of units

 $TRF = U \times 500$ 

#### At breakeven point, TRF = TCF

So, from TCF and TRF, we get no of units (U) =  $1771.22 \sim 1772$  units

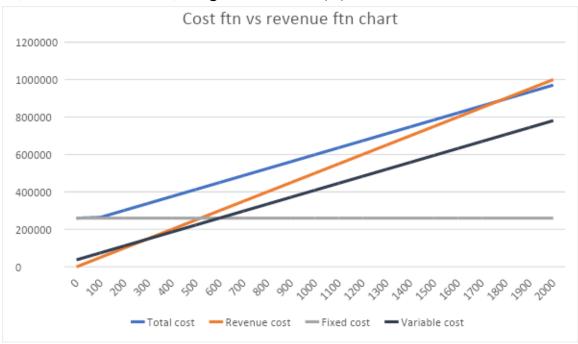


Table 10.1 Cost ft<sup>n</sup> vs revenue ft<sup>n</sup> chart

## 11. POST PROCESSING

- Parts require clean up before they are ready to use.
- Supporting features must be removed which may involve chemical or thermal treatment
- Use of infiltrations or surface coating can be done to improve strength of final part.
- This process might take some time depending upon condition of build part.

# **14. CONCLUSION**

We started with learning Different AM related software and parallelly done brainstorming for Lab related project.
Synchronized Cam and follower is finalized as the project.
It is easier to produce the assembled parts with FDM.
It might be costlier than conventional manufacturing.
Cost analysis and breakeven analysis is done, 1772 units for break even point.
We can display it as a prototype for replacement of conveyor belt assembly for transportation lines in industry.
It can be concluded that Polymer printing can be used for prototyes and low strength materials.

## 15. REFERENCES

- 1. Gibson, I., Rosen, D., & Stucker, B. (2015). Rapid Prototyping to Direct Digital Manufacturing. Additive Manufacturing Technologies
- 2. UltiMaker 2+ Quick Specs
- 3. COVID Key: A Multifunctional Device to Avoid Touch
- 4. Physical and mechanical properties of PLA, and their functions in widespread applications, Shady Farah, Daniel G. Anderson, Robert Langer