A

MINI PROJECT

On

DESIGN OF FLEXIBLE GRIPPER WITH SOLIDWORKS SOFTWARE AND PROTOTYPE WITH 3D PRINTING

A dissertation submitted in partial fulfilment of the

Requirement for the award of the degree of

BACHELOR OF TECHNOLOGY

In

MECHANICAL ENGINEERING

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AURORA'S TECHNOLOGICAL AND RESEARCH INSTITUTE

(Accredited by NAAC with 'A' Grade)

(Approved by AICTE and Affiliated to JNTU, Hyderabad)

Parvathapur, Uppal, Hyderabad-500 098

(2023-24)

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CERTIFICATE

This is to certify a mini project of report entitled **"DESIGN OF FLEXIBLE GRIPPER WITH SOLIDWORKS SOFTWARE AND PROTOTYPE WITH 3D PRINTING"** has been submitted by **Mr. K.MANJUNATH (21845A0302), K.RAJESH (21845A0313), P.MAHESH (21845A0314), and V.REVANTH (21845A0315).** In partial fulfillment of the degree of Bachelor of Technology in Mechanical Engineering to the Jawaharlal Nehru Technological University Hyderabad during the academic year 2023-24.

Date:

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Head of Department   Principal
Mr. B. Anil Kumar   Dr.A.Mahesh Babu

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ABSTRACT

Additive Manufacturing (AM) marks a significant departure from traditional manufacturing methods, as a single device handles the entire creation process, offering personalized customization. In contrast, traditional manufacturing involves multiple steps utilizing various machines; for instance, metalworking integrates turning, milling, and drilling to craft a finalized metal part. This project leverages the advantages of additive manufacturing by focusing on the design of a flexible gripper using SolidWorks software, followed by 3d printing for prototyping. The engineered gripper is designed to seamlessly adapt to diverse object shapes and sizes, enhancing its versatility in handling a wide range of items. SolidWorks is chosen for its robust modeling capabilities, facilitating precise design iterations. The use of 3d printing expedites the creation of physical prototypes, enabling practical testing and refinement of the gripper's functionality. This interdisciplinary approach harmonizes digital design and additive manufacturing to create an adaptable and efficient gripping mechanism. Following the design phase in SolidWorks, the components are assembled, the file is selected, and the design is exported as an stl file. the next step involves preparing for 3d printing by transferring the design to the 3d printer. post-printing, necessary post-processing is conducted, resulting in the production of the final, functional product.

Key Words: Additive Manufacturing (AM), Solid works, 3D printer, Prototype.

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CHAPTER 1

COMPANY OVERVIEW

1.1 INTRODUCTION ABOUT COMPANY

National Small Industries Corporation (NSIC), is an ISO 9001:2015 certified Government of India Enterprise under Ministry of Micro, Small and Medium Enterprises (MSME). NSIC has been working to promote, aid and foster the growth of micro, small and medium enterprises in the country. NSIC operates through countrywide network of offices and Technical Centers in the Country. In addition, NSIC has set up Training cum Incubation Centre managed by professional manpower.

MISSION & VISION

"To promote and support Micro, Small & Medium Enterprises (MSMEs) Sector" by providing integrated support services encompassing Marketing, Technology, Finance and other services.
"To be a premier Organization fostering the growth of Micro, Small and Medium Enterprises (MSMEs) Sector".

SCHEMES OF NSIC, MARKETING SUPPORT & CONSORTIA AND TENDER MARKETING

NSIC facilitates Micro, Small and Medium Enterprises with a set of specially tailored scheme to enhance their competitiveness. NSIC provides integrated support services under Marketing, Technology, Finance and other Support service. Marketing has been identified as one of the most important tool for business development. It is critical for the growth and survival of MSMEs in today's intensely competitive market. NSIC acts as a facilitator and has devised a number of schemes to support enterprises in their marketing efforts, both domestic and foreign markets. These schemes are briefly described as under .Small Enterprises in their individual capacity face problems to procure & execute large orders, which deny them a level playing field vis-a'-vis large enterprises.

SINGLE POINT REGISTRATION FOR GOVERNMENT PURCHASE

NSIC enlists Micro & Small Enterprises (MSEs) under Single Point Registration scheme (SPRS) for participation in Government Purchases. The units enlisted under Single Point Registration Scheme of NSIC are eligible to get the benefits under Public Procurement Policy for Micro & Small Enterprises (MSEs) Order 2012 as notified by the Government of India, Ministry of Micro Small & Medium Enterprises, New Delhi vide Gazette Notification dated 23.03.2012 and amendment vide order no. S.O. 5670(E) dated 9th November 2018. The enlistment under SPRS is completely online. Login: www.nsicspronline.com

Issue of the Tender Sets free of cost.

Exemption from payment of Earnest Money Deposit (EMD),

In tender participating MSEs quoting price within price band of L1+15 per cent shall also be allowed to supply a portion up to 25% of requirement by bringing down their price to L1 Price, where L1 is non MSEs.

Consortia facility for Tender Marketing.

MSME GLOBAL MART B2B WEB PORTAL FOR MSMES

Information today is becoming almost as vital as the air we breathe. We need it every minute of our working lives. With increase in competition and melting away of international boundaries, the demand for information is reaching new heights. NSIC, realizing the needs of MSMEs, is offering Infomediary Services which is a one-stop, one-window bouquet of aids that will provide information on business, technology and finance, and also exhibit the core competence of Indian SMEs through digital presence. The corporation is offering Infomediary Services through its MSME Global Mart www.msmemart.com; which is a Business to Business (B2B) web portal. The services are available through Annual Membership.

- Create your Company's Web Page in minutes Display Products & Services 24*7
- Connect with Buyers & Suppliers Globally
- Information’s on Events & Exhibitions
- Keyword based Unlimited Tender Alert

Figure 1.1:- Logo of NSIC

- Request For Quotations
- Trade Leads
- Platform to Buy/Sell Used Machinery
- Service Available in Multiple Language
- Free Membership for SC/ST Entrepreneurs for one year

MARKETING INTELLIGENCE, EXHIBITIONS AND TECHNOLOGY FAIRS, BUYER-SELLER MEETS OF NSIC

Collect and disseminate both domestic as well as international marketing intelligence for the benefit of MSMEs. This cell, in addition to spreading awareness about various programmers' schemes for MSMEs, will specifically maintain database and disseminate information.

To showcase the competencies of Indian MSMEs and to capture market opportunities, NSIC participates in select International and National Exhibitions and Trade Fairs every year. NSIC facilitates the participation of the small enterprises by providing concessions in rental etc. Participation in these events exposes MSMEs to international practices and enhances their business prowess.
Bulk and departmental buyers such as the Railways, Defense, Communication departments and large companies are invited to participate in buyer-seller meets to enrich small enterprises knowledge regarding terms and conditions, quality standards, etc. required by the buyer. These programmers are aimed at vendor development from MSMEs for the bulk manufacturers.

CREDIT SUPPORT

NSIC facilitates credit requirements of small enterprises in the following areas:

Financing for procurement of Raw Material (Short term)

NSIC's Raw Material Assistance Scheme aims at helping Small Enterprises by way of financing the purchase of Raw Material (both indigenous & imported). The salient features

Financing for Marketing Activities (Short term) AND Credit Facilitation Through Bank
NSIC facilitates financing for marketing actives such as Internal Marketing, Exports and Bill Discounting. To meet the credit requirements of MSME units, NSIC has entered into a Memorandum of Understanding with various Nationalized and Private Sector Banks. Through syndication with these banks, NSIC facilitates MSME in accessing credit support (fund based or non-fund based limits) from the banks. NSIC assists MSMEs in completion of the documentation for submitting the proposals to the banks and also does the follow up with the banks. These handholding support are provided by NSIC without any cost to the MSMEs.

Technology Support

Technology is the key to enhancing a company's competitive advantage in today's dynamic information age. Small enterprises need to develop and implement a technology strategy in addition to financial, marketing and operational strategies and adopt the one that helps integrate their operations with their environment, customers and suppliers.

NSIC offers small enterprises the following support services through its Technical Services Centre and Extension Centers:

- Advise on application of new techniques
- Material testing facilities through accredited laboratories
- Product design including CAD
- Common facility support in machining, EDM, CNC, etc.
- Energy and environment services at selected centers
- Classroom and practical training for skill upgradation

Software Technology cum Business Parks

NSIC has established Software Technology cum Business Parks at New Delhi and for providing the space to small and medium enterprises in software development and to IT/ITES/MSME units not regd. with STPI or the units that are falling under the overall Definition of MSME as per the guidelines of Ministry of Micro, Small and Medium Enterprises. Units other than MSME such as Banks/PSUs/Financial Institutions, corporate sector etc. would also be considered for allotment on a case-to-case on merit with the approval of Competent Authority. NSIC Software Technology cum Business Parks, New Delhi is located in a prime location at Okhla Industrial Area adjacent to NSIC Bhawan with a total built up area of approx.53000 sq.ft. This location is in the near vicinity to Nehru Place. (The commercial Centre of computer industry). NSIC Software Technology cum Business Parks, Chennai is located in a prime location at Guindy Industrial Estate.

Name of the Centre	Focus area
Chennai	Leather & Foot ware
Howrah	General Engineering
Hyderabad	Electronics & Computer Application
New Delhi	Machine Tools & related activities
Rajkot	Energy Audit & Energy Conservation activities
Rajpura (Pb)	Domestic Electrical Appliances
Aligarh (UP)	Lock Cluster & Die and Tool making
Neemka (Haryana)	Machine Tools & related activities

Table 1.1 :- NSIC Technical Services Centres are located at the following place.

International Cooperation

NSIC facilitates sustainable international partnerships. The emphasis is on sustainable business relations rather than on one-way transactions. Since its inception, NSIC has contributed to strengthening enterprise-to-enterprise cooperation, south cooperation and sharing best practices and experiences with other developing countries, especially those in the African, Asian and Pacific regions. The features of the scheme are:
.Exchange of Business / Technology missions with various countries.

Facilitating Enterprise to Enterprise cooperation, JVs, Technology Transfer & other form of sustainable collaboration.
Explore new markets & areas of cooperation:
Identification of new export markets by participating in sector- specific exhibitions all over the world.
Sharing of Indian experience with other developing countries

International Consultancy Services

For the last five decades, NSIC has acquired various skill sets in the development process of small enterprises. The inherent skills are being networked to offer consultancy services for other developing countries. The areas of consultancy are as listed below:

- Capacity Building
- Policy & Institutional Framework
- Entrepreneurship Development
- Business Development Services

Figure 1.2 :- NSIC

CHAPTER 2

OVERVIEW OF GRIPPER

2.1 GRIPPER SYSTEMS

Flexible grippers represent a groundbreaking advancement, purposefully designed to skillfully grasp and manipulate objects with diverse shapes, sizes, and properties. Departing from conventional rigid grippers, these state-of-the-art devices possess a distinctive ability to conform precisely to the contours of the objects they manipulate, eliminating the requirement for predetermined grasping positions. This innate adaptability renders them remarkably versatile for applications in environments where objects exhibit unpredictable shapes or variations. Crafted from pliable and compliant materials like elastomers or polymers, flexible grippers leverage their material composition to seamlessly adapt to the specific shape of the targeted object. The pivotal feature of compliance enables them to absorb variations and uncertainties in the position and shape of objects, making them exceptionally well-suited for tasks in settings where precise positioning may pose challenges. These grippers can discern the shape and force applied to the grasped object, supplying crucial sensory feedback for closed-loop control and facilitating meticulous manipulation.

Flexible grippers find broad applications across diverse industries, excelling in pick-and-place scenarios by adeptly lifting objects from one location and delicately placing them in another. In assembly tasks, particularly those involving components with intricate shapes or variations, flexible grippers demonstrate their exceptional capabilities. Industries such as food processing, dealing with items of irregular shapes and sizes, benefit from the gentle handling prowess of these grippers. Despite their adaptability advantages, it's crucial to recognize that flexible grippers may have limitations in terms of precision and speed compared to their rigid counterparts. The selection of the gripper hinges on the specific demands of the task at hand.

Various design variations of flexible grippers, including multi-fingered designs, soft pneumatic grippers, and compliance features, are tailored to address distinct challenges. Significantly, these grippers play a pivotal role in collaborative applications, seamlessly integrating into scenarios where they work alongside humans. Their compliant nature substantially mitigates the risk of injury in case of accidental contact, underscoring their contribution to bolstering safety in collaborative settings. In summary, flexible grippers emerge as indispensable tools across diverse applications, providing the adaptive capabilities required to handle objects with varied shapes and sizes in industries ranging from manufacturing to healthcare and beyond.

2.2 CHALLENGES IN TRADITIONAL GRIPPER DESIGNS

Traditional gripper designs, while effective in certain applications, encounter specific challenges due to their inherent rigidity and fixed configurations. One major limitation is their limited adaptability; these grippers are typically designed with a specific shape or configuration in mind, making them less versatile when handling objects with varying shapes and sizes. In scenarios where objects deviate from predefined shapes, traditional grippers may struggle to achieve a secure and reliable grasp, posing a significant drawback in environments with unpredictable or variable objects.

Another challenge lies in the requirement for precise grasping positions. Unlike flexible grippers that can conform to the shape of the object, traditional grippers need accurate and predefined grasping positions. This need for precision becomes a limiting factor, especially in applications where the location or orientation of objects is not precisely known or may change over time.

The rigid structure of traditional grippers also presents difficulties in handling delicate or fragile items. The lack of compliance in their design limits the gripper's ability to adjust the force exerted during grasping. This rigidity can lead to excessive pressure, potentially causing damage to sensitive materials or components, highlighting a challenge when dealing with fragile items.

Irregular geometries further exacerbate the limitations of traditional grippers. Objects with non-standard shapes or complex geometries may be challenging for these grippers to securely manipulate. This inefficiency becomes a hindrance in applications such as manufacturing or assembly processes involving components with diverse geometries.

Moreover, traditional grippers are often constructed from rigid materials, limiting their suitability for handling a broad range of materials. In industries where flexibility is crucial, such as the food industry or when dealing with deformable materials, the rigidity of traditional grippers becomes a significant limiting factor.

The lack of compliance and adaptability in traditional gripper designs also increases the risk of damage to both the gripper and the objects being manipulated. In scenarios requiring a delicate touch, traditional grippers may lack the finesse needed to handle items without causing harm.

As industries evolve and demand increased versatility and precision from robotic systems, addressing these challenges becomes essential. Innovations in gripper design, such as the development of flexible and adaptive grippers, aim to overcome these limitations and enhance the capabilities of robotic manipulation across diverse applications.

Figure 2.1:- Traditional Gripper

2.3 ADVANCES IN FLEXIBLE GRIPPER TECHNOLOGY

Advances in flexible gripper technology have revolutionized the field of robotics, introducing innovative solutions that address the limitations of traditional rigid grippers. One significant development is the use of advanced materials, such as soft elastomers and polymers, in the construction of flexible grippers. These materials provide a level of compliance and adaptability that was previously unattainable, allowing the gripper to conform to the shape of objects with varying sizes, shapes, and properties.

In addition to materials, there have been substantial strides in the design and engineering of flexible grippers. Multi-fingered designs, inspired by the dexterity of the human hand, enable more intricate and versatile manipulation of objects. The increased number of fingers enhances the gripper's ability to grasp objects from various angles, improving overall adaptability.

Sensing and control mechanisms have also seen notable advancements in flexible gripper technology. Integration of sophisticated sensors, such as force and tactile sensors, provides real-time feedback on the grip strength and contact forces applied during manipulation. This sensory information enables precise control and adjustments, enhancing the gripper's ability to handle delicate or irregularly shaped objects with greater finesse.

The development of soft pneumatic grippers is another noteworthy advancement. These grippers utilize pressurized air to achieve compliant and flexible movements, offering a high degree of adaptability. Soft pneumatic grippers excel in applications where gentle handling and compliance are crucial, such as in the food industry or industries dealing with fragile items.

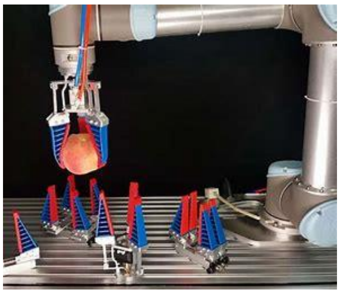


Figure 2.2:- Flexible Gripper Technology

Collaborative robotics has benefited significantly from advances in flexible gripper technology. The compliant nature of these grippers reduces the risk of injury in human-robot collaboration scenarios. The ability to work alongside humans safely opens up new possibilities for applications in shared workspaces, where robots and humans collaborate on tasks that require adaptability and precision.

Moreover, advancements in control algorithms and artificial intelligence have enhanced the autonomy of flexible grippers. These grippers can now learn and adapt to the properties of the objects they manipulate, making them more versatile and capable of handling a wider range of tasks without explicit programming.

In conclusion, the continuous advances in flexible gripper technology have ushered in a new era of robotic manipulation capabilities. The combination of advanced materials, intelligent sensing, innovative designs, and collaborative features has significantly expanded the range of applications for flexible grippers, making them indispensable tools in various industries, from manufacturing to healthcare and beyond.

2.4 RELEVANCE OF 3D PRINTING IN PROTOTYPING

The relevance of 3D printing in prototyping has become increasingly pronounced, transforming the product development landscape by offering numerous advantages. One key benefit lies in the speed and efficiency of the prototyping process. Traditional prototyping methods can be time-consuming and costly, involving the creation of molds or tooling. In contrast, 3D printing allows for the rapid production of prototypes directly from digital models, reducing lead times and enabling iterative design changes with minimal delays.

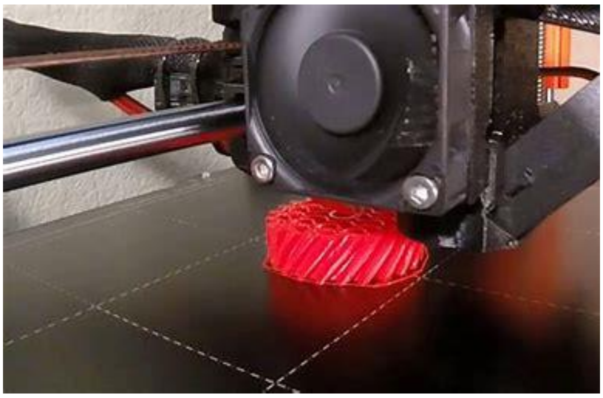


Figure 2.3:- 3d Printing In Prototyping

Additionally, 3D printing provides unparalleled design freedom. It allows engineers and designers to create intricate and complex geometries that would be challenging or impossible to achieve using conventional manufacturing methods. This flexibility empowers innovators to explore creative and optimized designs, pushing the boundaries of what is achievable in product development.

The cost-effectiveness of 3D printing in prototyping is another significant advantage. While traditional prototyping methods may incur high costs for tooling and material waste, 3D printing allows for the use of only the necessary amount of material, minimizing waste and reducing overall expenses. This cost-effectiveness is particularly beneficial for small-scale production runs and startups with limited budgets.

Furthermore, 3D printing facilitates easy design modifications. Since prototypes can be quickly and digitally modified, designers can experiment with various iterations to fine-tune their designs before committing to mass production. This iterative process enhances the overall quality of the final product, as design flaws and improvements can be identified and addressed in the early stages of development.

The technology's versatility is evident in its ability to work with a wide range of materials, including plastics, metals, and even advanced composites. This adaptability ensures that prototypes created through 3D printing closely resemble the properties of the final product, allowing for more accurate testing and validation.

In industries such as aerospace, automotive, and healthcare, where precision and customization are paramount, 3D printing in prototyping proves invaluable. Engineers can produce scale models, functional prototypes, and even patient-specific medical devices with a level of detail and accuracy that is unparalleled.

As technology continues to advance, the relevance of 3D printing in prototyping is poised to expand further. Integration with other digital technologies, such as computer-aided design (CAD) and simulation software, enhances the overall product development process, fostering innovation and accelerating time-to-market. In conclusion, the adoption of 3D printing in prototyping represents a transformative shift, offering efficiency, cost-effectiveness, design freedom, and versatility that significantly contribute to the success of product development endeavors across various industries.

CHAPTER 3

OBJECTIVES AND DESIGN SOFTWARE

3.1 PROBLEM STATEMENT

The current landscape of manufacturing and automation demands adaptable and flexible solutions to accommodate various shapes and sizes of objects. Traditional grippers often lack the versatility required to handle a diverse range of products efficiently. Therefore, there is a need for a flexible gripper design that can be easily customized and adapted to different tasks, providing improved functionality and performance.

3.2 OBJECTIVES

To develop a flexible gripper design capable of adapting to a diverse range of object shapes and sizes.

3.3 DESIGN TOOLS AND SOFTWARE

Design tools and software play a crucial role across creative disciplines, offering specialized solutions for diverse tasks. Adobe Creative Cloud, encompassing Photoshop, Illustrator, and InDesign, dominates graphic design with powerful image editing and page layout capabilities. Web designers often turn to Sketch, Figma, or Adobe XD for interface design, while Autodesk Maya and Blender excel in 3D modeling and animation. UI/UX designers benefit from tools like In Vision and Axure RP for prototyping. AutoCAD and SolidWorks are staples for CAD and engineering design. Video editing finds its champions in Adobe Premiere Pro and Final Cut Pro, while After Effects shines in motion graphics. Light room and Capture One cater to photographers, and desktop publishing relies on Adobe InDesign and QuarkXPress. The choice of tools depends on the specific design requirements, with many professionals integrating a variety of software to achieve optimal results.

3.3.1 AUTODESK PRODUCT DESIGN SUITE

Figure 3.1:- Autodesk

Autodesk is best known for its 3D design and engineering software and services. We like Autodesk Product Design Suite because it is a comprehensive 3D product design solution that offers everything design engineers need, from simulation, to collaboration, to visualization, to digital prototyping tools. Complete your entire engineering process with Autodesk Product Design Suite.

Key Feature

- Use 2D AutoCAD drawings as a base for inventor layouts.
- Quickly and easily make product design changes

- Integrate electrical and mechanical design.
- Get to market faster by reducing rework and reusing design data.
- Reduce manufacturing costs by creating accurate design documentation and evaluating product manufacturability.

3.3.2 CATIA

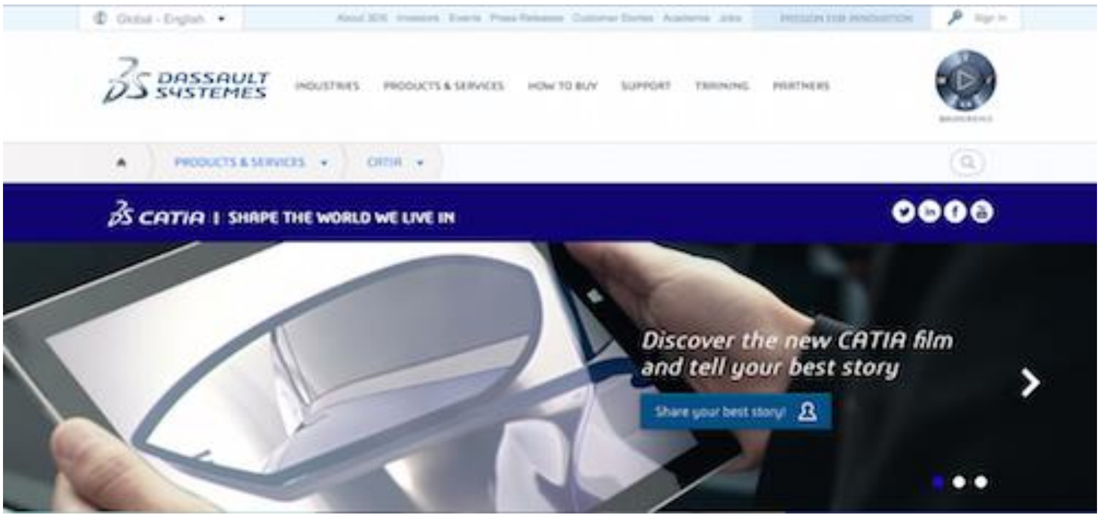


Figure 3.2:- Catia

A Dassault Systems pioneer brand, CATIA is the world’s leading solution for product design and innovation. This engineering design tool is used by leading organizations and is applicable in multiple industries. With CATIA, design engineers have the ability to model products in the context of real-life behavior, allowing them to “design in the age of experience.”

Key Features

- Social design environment accessible through powerful 3D dashboards that drive business intelligence, real-time concurrent design, and collaboration across all stakeholders
- Provides an instinctive 3D experience with world-class 3D modeling and simulation capabilities that optimize the effectiveness of each user
- Delivers an inclusive product development platform that easily integrates with existing processes and tools, to enable multiple disciplines to leverage powerful and integrated specialist applications across all phases of the product design.

3.3.3 ANSYS DESIGN SPACE

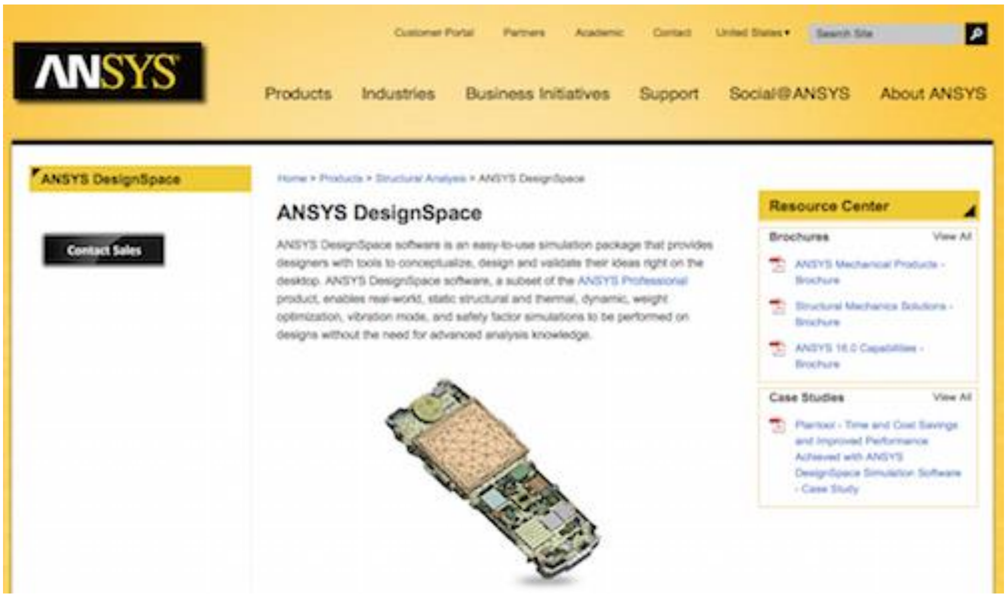


Figure 3.4:- ANSYS

ANSYS, Inc. offers engineering simulation software, and ANSYS Design Space is the easy-to-use simulation tool that provides design engineers with the tools necessary for conceptualizing, designing, and validating their ideas right on their desktops. Even without advanced analysis knowledge, design engineers are able to perform real-world, static structural and thermal, dynamic, weight optimization, vibration mode, and safety factor simulations on designs when utilizing ANSYS Design Space.

Key Features

- Auto contact detection makes it easy to work with large assembly models
- Superior CAD interface and robust meshing
- Advanced numerical methods for nonlinear problems
- Powerful solver capabilities
- Advanced post-processing
- Reporting

3.3.4 SOLIDWORKS

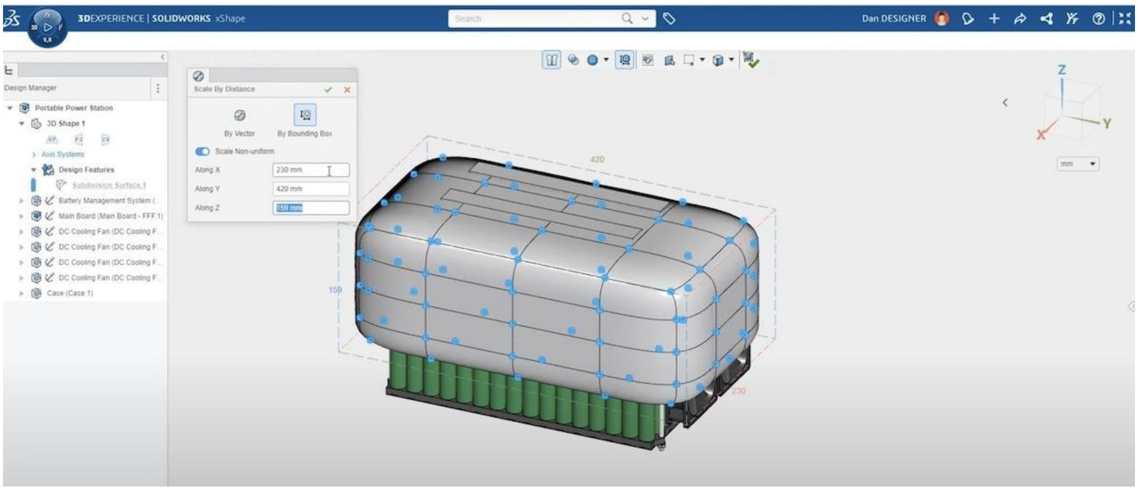


Figure 3.5:- SolidWorks

SolidWorks is one of the most popular product design tools in the world. It’s not a single product, but a gigantic suite of products you combine to manage design, data management, manufacturing, marketing, and simulations in one platform.

SolidWorks is popular for engineering applications, so if you need help modeling electrical systems or 3D structures, this is the tool for you. Mockup designs with your team to reduce back-and-forth emails and iterate more quickly.

Key Features

- Share 3D designs with your team via the cloud.
- Track all feedback and design approvals.
- Store all versions and product data in the cloud.
- Manage data, approvals, and project tasks in one place.

3.3.5 CREALITY SLICER SOFTWARE

Creality Print is a self-developed FDM slicing software produced by Shenzhen Creality 3D Technology Co., Ltd. It's a practical and easy-to-use tool that can help you remote control and monitor your 3D printer and help print directly from your computer.

With Creality Print, you can access your Creality Cloud account to operate the printing process, including searching, uploading, importing, editing models, setting printing and slicing parameters, remote controlling your 3D printing, etc. It allows you to save the G-code on your computer and send it to the printer through a USB serial port or Wi-Fi connectivity, or to import and export the G-code from Creality Cloud and print directly from the Creality Cloud APP.

Required OS

Minimum System Requirements

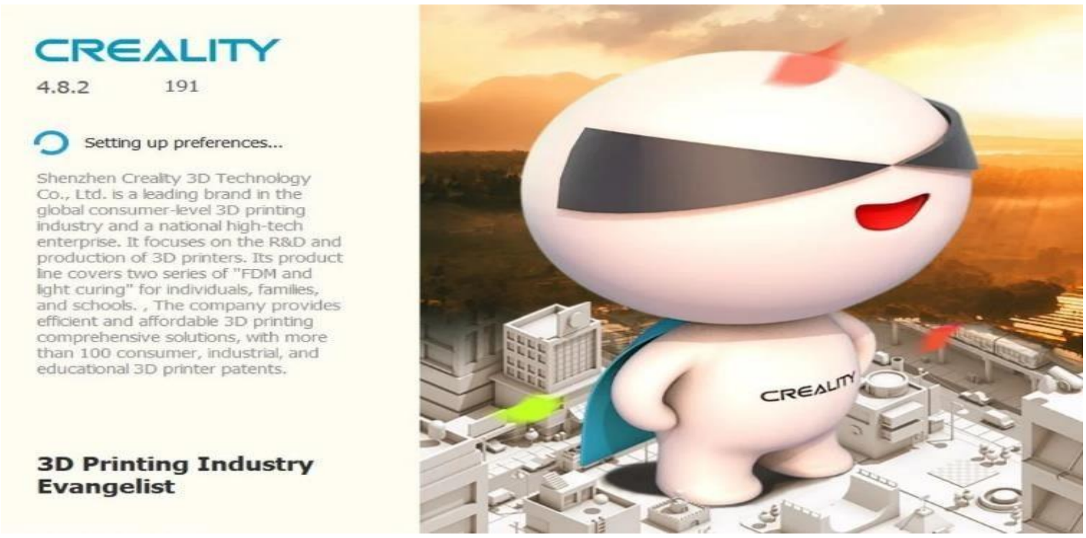


Figure 3.6:- Creality slicer

OpenGL 2 compatible graphics card, OpenGL 4.1 for 3D layer view Display resolution 1024 x 768, Intel Core 2 or AMD Athlon 64 550 MB available hard disk space 4GB RAM memory.

Recommended System Requirements

OpenGL 4.1 compatible graphics card for 3D layer view
Display resolution 1920 x 1080
600 MB available hard disk space 8GB RAM memory
Common file format

Import file format

Creality Print can import the following file types: Model files (.STL, .OBJ)
Picture files (.BMP, .JPG, .JPEG, .PNG) Project file (.CX3D)
G-code file (.G-code)

Export file format

Creality Print can export the following file types: Print file (.G-code)
Project file (.CX3D)

SPECIFICATION OF CREALITY ENDER 5 S1 3D PRINTER

Moulding Technology	: -	FDM Nozzle
Diameter Standard	: -	0.4mm
Build Volume	: -	220*220*280mm
Layer Height	: -	0.05-0.35mm
Product Dimensions	: -	425*460*570mm
File Transfer	: -	SD card, USB Type-C cable
Supported Filaments	: -	PLA, PETG, ABS, TPU, PC, ASA,
HIPS File Formats	: -	STL, OBJ, AMF
Filament Diameter	: -	1.75mm
Printing Accuracy	: -	±0.1mm
Slicing Software	: -	Creality Slicer, Creality Print, Cura, Repetier-Host.
3D UI Language	: -	English, Spanish, Figure German, French,

Figure 3.7:- CREALITY ENDER 5 S1 3D PRINTER

CHAPTER 4

METHODOLOGY

4.1 SOLIDWORKS FEATURES

SolidWorks (stylized as SOLIDWORKS) is a brand within Dassault Systems that develops and markets solid modeling computer-aided design, computer-aided engineering, 3D CAD design and collaboration, analysis, and product data management software. SolidWorks 2023 displaying a 3D assembly.The SolidWorks brand was founded as Winchester Design Systems by Massachusetts Institute of Technology graduate Jon Hirschtick on December 30, 1993.[3] Jon and cofounders Dr. Constantine Dokos, Scott Harris, Bob Zuffante, Mike Payne, and Tommy Li aimed to create 3D design software that was affordable, easy to use, and available on a Windows NT personal computer.

The SOLIDWORKS CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

Concepts

Parts are the basic building blocks in the SOLIDWORKS software. Assemblies contain parts or other assemblies, called subassemblies. A SOLIDWORKS model consists of 3D geometry that defines its edges, faces, and surfaces. The SOLIDWORKS software lets you design models quickly and precisely.

3D Design

SOLIDWORKS uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies. When designing a model using SOLIDWORKS, you can visualize it in three dimensions, the way the model exists once it is manufactured.

Figure 4.1:- SOLIDWORKS 3D part & assembly(3d printing industry.com)

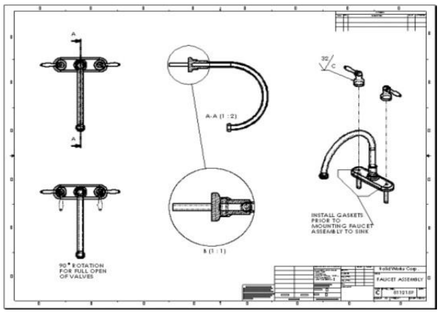


Figure 4.2:- SOLIDWORKS 2D drawing generated from 3D model

Component Based

One of the most powerful features in the SOLIDWORKS application is that any change you make to a part is reflected in all associated drawings or assemblies.

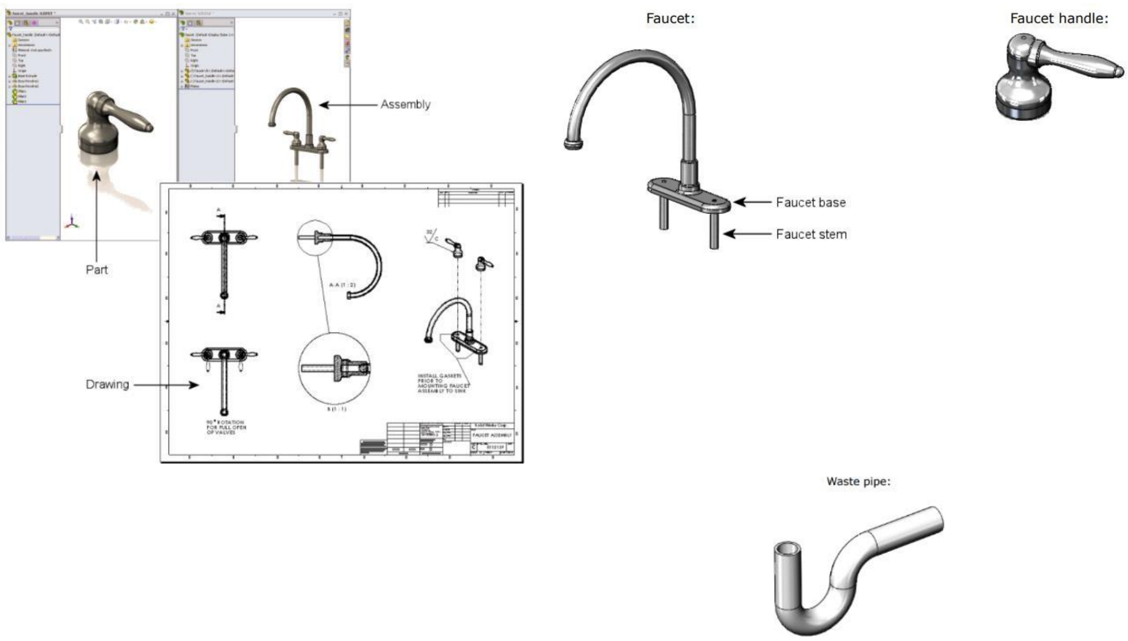


Figure 4.3:- component based

Terminology Origin

Appears as two blue arrows and represents the (0, 0,0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0, 0,0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin.

Plane

Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, or a neutral plane in a draft feature.

Axis

Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The SOLIDWORKS application creates temporary axes implicitly for every conical or cylindrical face in a model.

Face

Boundaries that help define the shape of a model or a surface. A face is a selectable area (planar or nonplanar) of a model or surface. For example, a rectangular solid has six faces.

Edge

Location where two or more faces intersect and are joined together. You can select edges for sketching and dimensioning.

Vertex

Point at which two or more lines or edges intersect. You can select vertices for sketching and dimensioning.

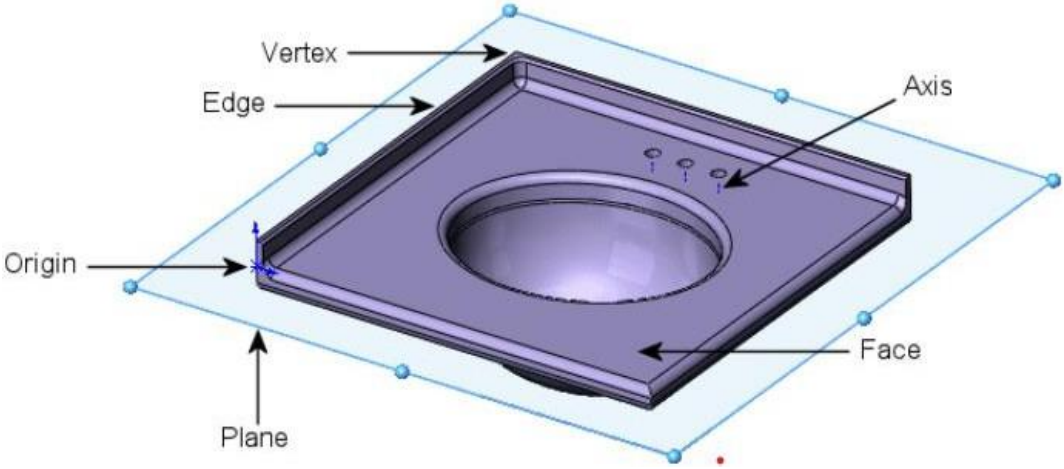


Figure 4.4:- Terminology

User Interface

The SOLIDWORKS application includes user interface tools and capabilities to help you create and edit models efficiently, including:

Windows Functions

The SOLIDWORKS application includes familiar Windows functions, such as dragging and resizing windows. Many of the same icons, such as print, open, save, cut, and paste are also part of the SOLIDWORKS application.
Feature Manager® design tree

Displays the structure of the part, assembly, or drawing. Select an item from the Feature Manager design tree to edit the underlying sketch, edit the feature, and suppress and unsuppressed the feature or component, for example.

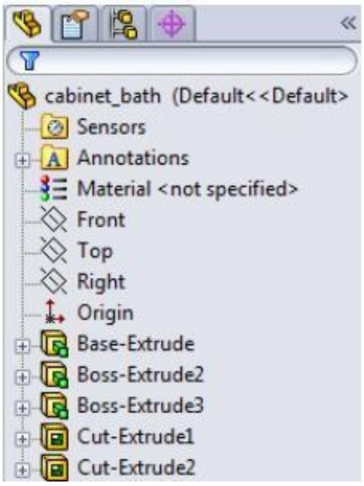


Figure 4.5:- Feature Manager Design Tree

Property Manager

Provides settings for many functions such as sketches, fillet features, and assembly mates.

Figure 4.6:- Property Manager

Configuration Manager

Let's you create, select, and view multiple configurations of parts and assemblies in a document. Configurations are variations of a part or assembly within a single document. For example, you can use configurations of a bolt to specify different lengths and diameters.

Figure 4.7:- Configuration Manager

You can split the left panel to display more than one tab at a time. For example, you can display the Feature Manager Design tree on the top portion and the Property Manager tab for a feature you want to implement on the bottom portion. The right panel is the graphics area, where you create and manipulate a part, assembly, or drawing.

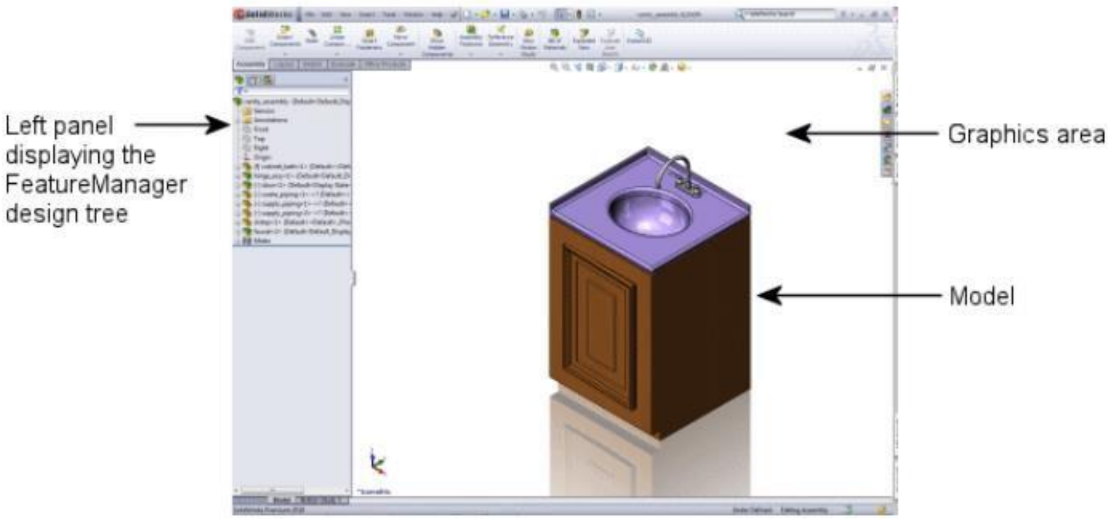


Figure 4.8:- User Interface

Design Process

The design process usually involves the following steps:

- Identify the model requirements.
- Conceptualize the model based on the identified needs.
- Develop the model based on the concepts.
- Analyze the model.
- Prototype the model.
- Construct the model.
- Edit the model, if needed.

Design Intent

Design intent determines how you want your model to react as a result of the changes you need to make to the model. For example, if you make a boss with a hole in it, the hole should move when the boss moves

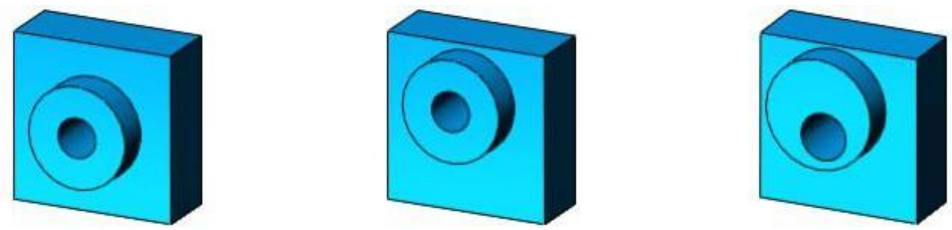


Figure 4.9:- Original part   Design intent maintained   Design intent not
maintained   when boss moves   when boss moves

Design intent is primarily about planning. How you create the model determines how changes affect it. The closer your design implementation is to your design intent, the greater the integrity of the mode.

Design method

Before you actually design the model, it is helpful to plan out a method of how to create the model.
After you identify needs and isolate the appropriate concepts, you can develop the model

Sketches

Create the sketches and decide how to dimension and where to apply relations.

Features

Select the appropriate features, such as extrudes and fillets, determine the best features to apply, and decide in what order to apply those features.
Assemblies

Assemblies select the components to mate and the types of mates to apply.

Sketches

The sketch is the basis for most 3D models.

Creating a model usually begins with a sketch. From the sketch, you can create features. You can combine one or more features to make a part. Then, you can combine and mate the appropriate parts to create an assembly. From the parts or assemblies, you can then create drawings .A sketch is a 2D profile or cross section. To create a 2D sketch, you use a plane or a planar face. In addition to 2D sketches, you can also create 3D sketches that include a Z axis, as well as the X and Y axes.

There are various ways of creating a sketch. All sketches include the following elements

Origin

Planes

Dimensions

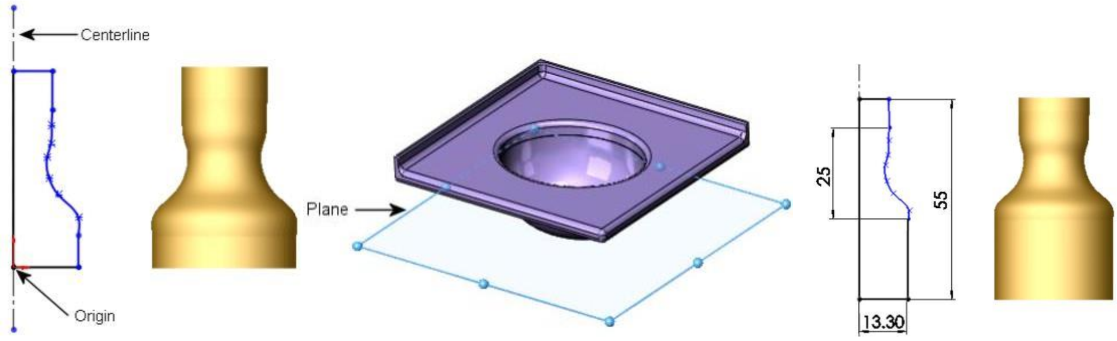


Figure 4.10:- Origin, Planes, and Dimensions(solidworks.com)

Features

Once you complete the sketch, you can create a 3D model using features such as an extrude (the base of the faucet) or a revolve (the faucet handle).

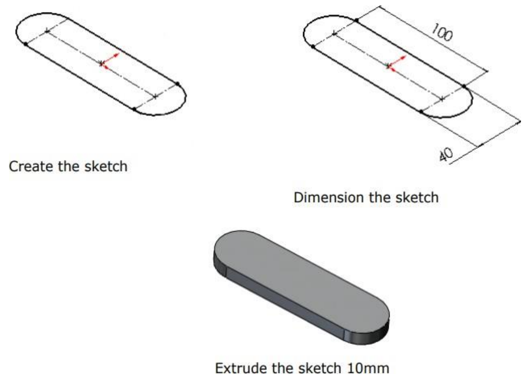


Figure 4.11:- Features

Some sketch-based features are shapes such as bosses, cuts, and holes. Other sketch-based features such as lofts and sweeps use a profile along a path. Another type of feature is called an applied feature, which does not require a sketch. Applied features include fillets, chamfers, or shells. They are called "applied" because they are applied to existing geometry using dimensions and other characteristics to create the feature. Typically, you create parts by including sketch-based features such as bosses and holes. Then you add applied features.

Assemblies

You can combine multiple parts that fit together to create assemblies. You integrate the parts in an assembly using Mates, such as Concentric and Coincident. Mates define the allowable direction of movement of the components. In the faucet assembly, the faucet base and handles have concentric and coincident mates. With tools such as Move Component or Rotate Component, you can see how the parts in an assembly function in a 3D context. To ensure that the assembly functions correctly, you can use assembly tools such as Collision Detection. Collision Detection lets you find collisions with other components when moving or rotating a component.

Figure 4.12:- Assembly

Drawings

You create drawings from part or assembly models. Drawings are available in multiple views such as standard 3 views and isometric views (3D). You can import the dimensions from the model document and add annotations such as datum target symbols.

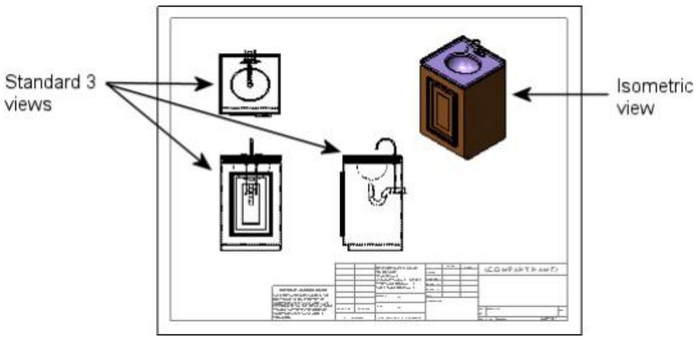


Figure 4.13:- Drawings

Model Editing

Use the SOLIDWORKS Feature Manager design tree and the Property Manager to edit sketches, drawings, parts, or assemblies. You can also edit features and sketches by selecting them directly from the graphics area. This visual approach eliminates the need to know the name of the feature.

Editing capabilities include

- Edit sketch
- Edit feature
- Hide and show
- Suppress and unsuppressed
- Rollback

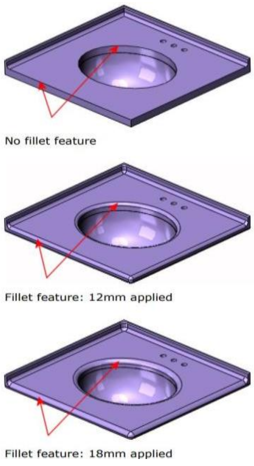


Figure 4.14:- Model Editing(solidworks.com)

4.2 METHODOLOGY

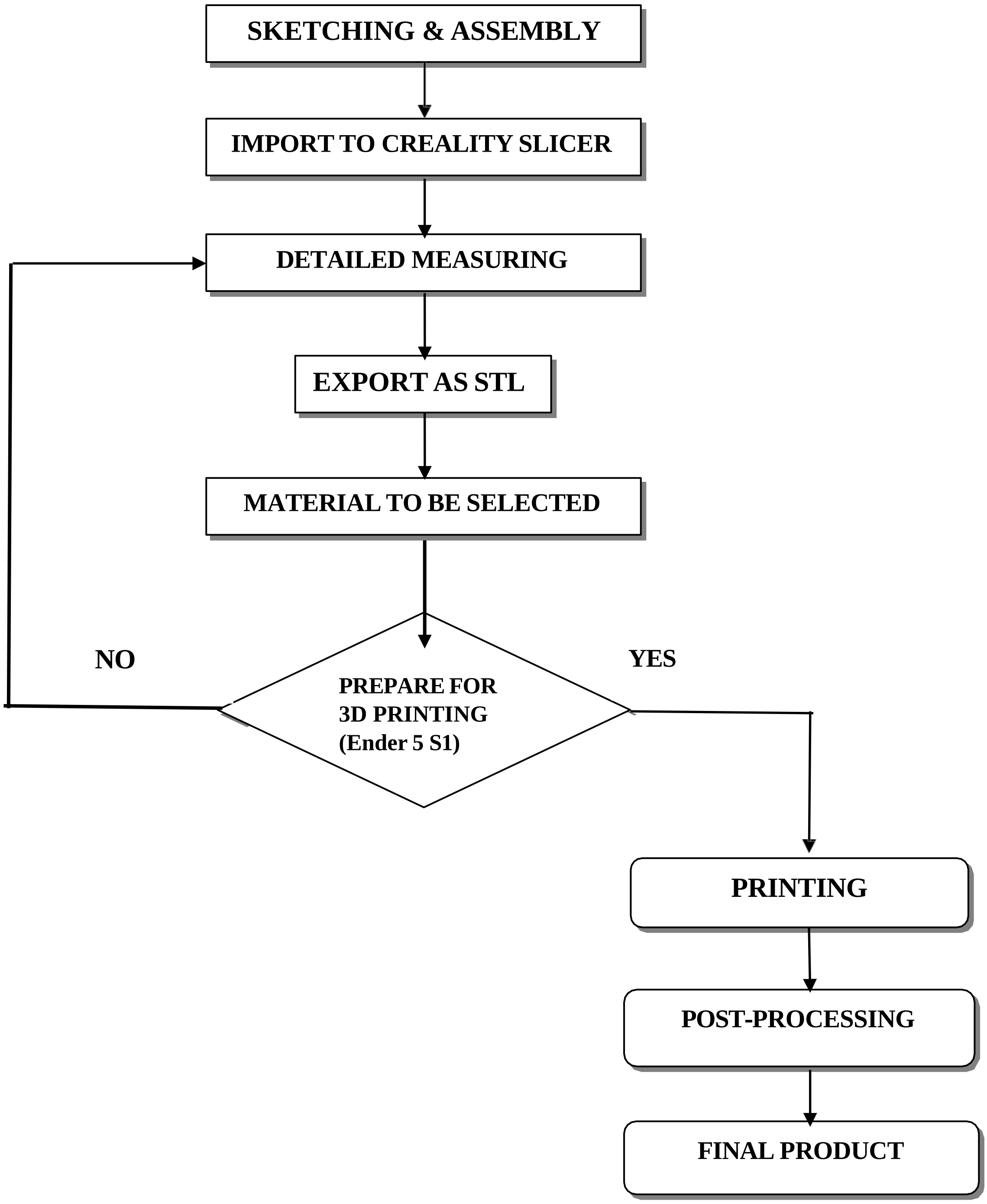


Figure: 4.15:- Flowchart of Methodology

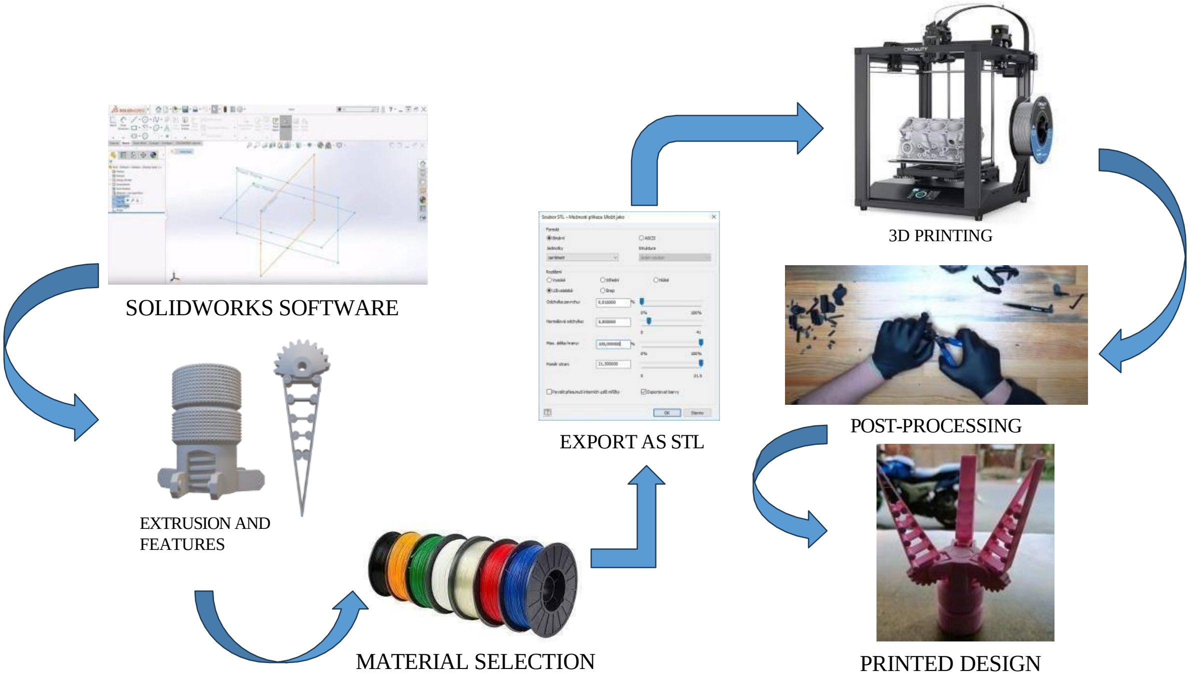


Figure 4.16 :- Methodology In Images

4.2.1 SKETCHING & ASSEMBLY

In SolidWorks, sketching serves as the foundational step in creating 3D models. To initiate a sketch, one selects a plane and uses tools like lines, circles, and arcs to craft the desired geometry. Dimensions and constraints are then applied to precisely define the sketch. The subsequent exit from the sketching environment leads to the assembly phase. In the assembly workspace, existing parts are inserted, and relationships between components are established through mates. This ensures the correct positioning and alignment of parts within the assembly. Additional features, such as cuts or fillets, can be applied globally to influence multiple components simultaneously. Users may further refine their design through motion studies for dynamic simulations and employ interference detection tools to ensure components do not intersect improperly. Saving the assembly, creating a Bill of Materials, and potentially exporting the model complete the process, showcasing SolidWorks versatility in facilitating both sketching and assembly tasks.

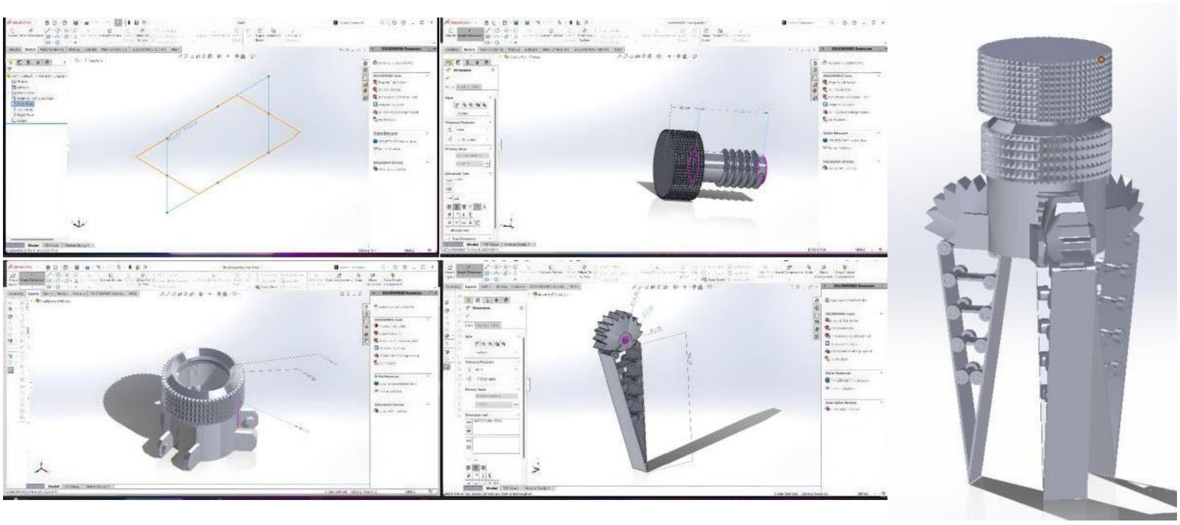


Figure 4.17 :- Sketching and Assembly

4.2.2 IMPORT TO CREALITY SLICER

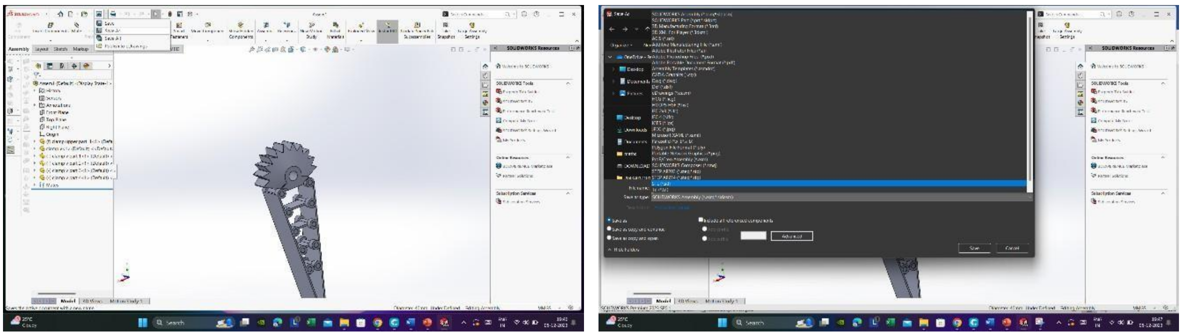


Figure 4.18 :- Import To Creality Slicer(SolidWorks, File explorer)

Save as STL in SolidWorks

- In SolidWorks, open the part or assembly you want to export.
- Click on "File" in the menu and select "Save As."
- Choose "STL (*.STL)" as the file type.
- Specify a location to save the file and click "Save."
- In the "Save As" STL options, set the resolution and other parameters as needed and click "OK."

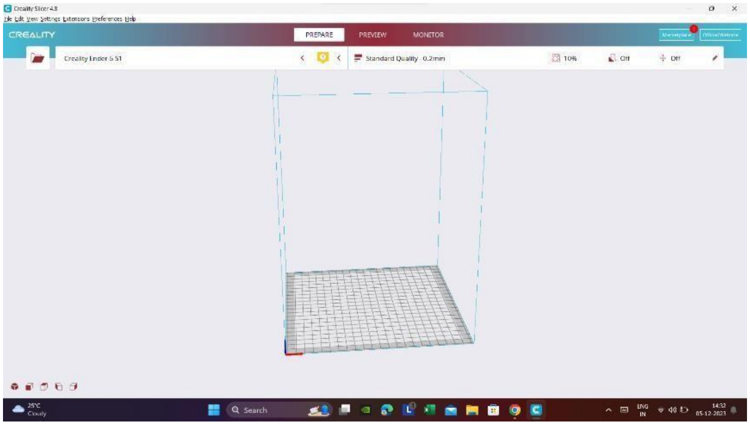


Figure 4.19 :- Creality slicer

Open Creality Slicer:

- Launch the Creality Slicer software on your computer. import STL file:
- In Creality Slicer, look for an option like "Open" or "Import."
- Navigate to the location where you saved the STL file from SolidWorks.
- Select the file and click "Open" to import it into the slicer software.

Adjust Interface

Once the file is loaded into Creality Slicer, you can adjust various settings for your 3D print. Configure layer height, infill density, support structures, and other print parameters based on your project requirements.

4.2.3 DETAILED MEASURING

Creality Slicer is not just software; it's a gateway to seamless 3D printing. Crafted by Creality3D, it effortlessly translates 3D models into printable G-code instructions, setting the stage for flawless fabrication. Its user-friendly interface caters to beginners and advanced users alike, providing easy access to a plethora of features.

For the tech-savvy, Creality Slicer unfolds a canvas of customization options tweak layer height, infill density, and print speed with finesse. The software's reliability and efficiency

Shine through regular updates, ensuring a cutting-edge experience for both novices and seasoned professionals.

What sets Creality Slicer apart is its compatibility with a multitude of 3D printers, offering a versatile solution for users with diverse printing needs.

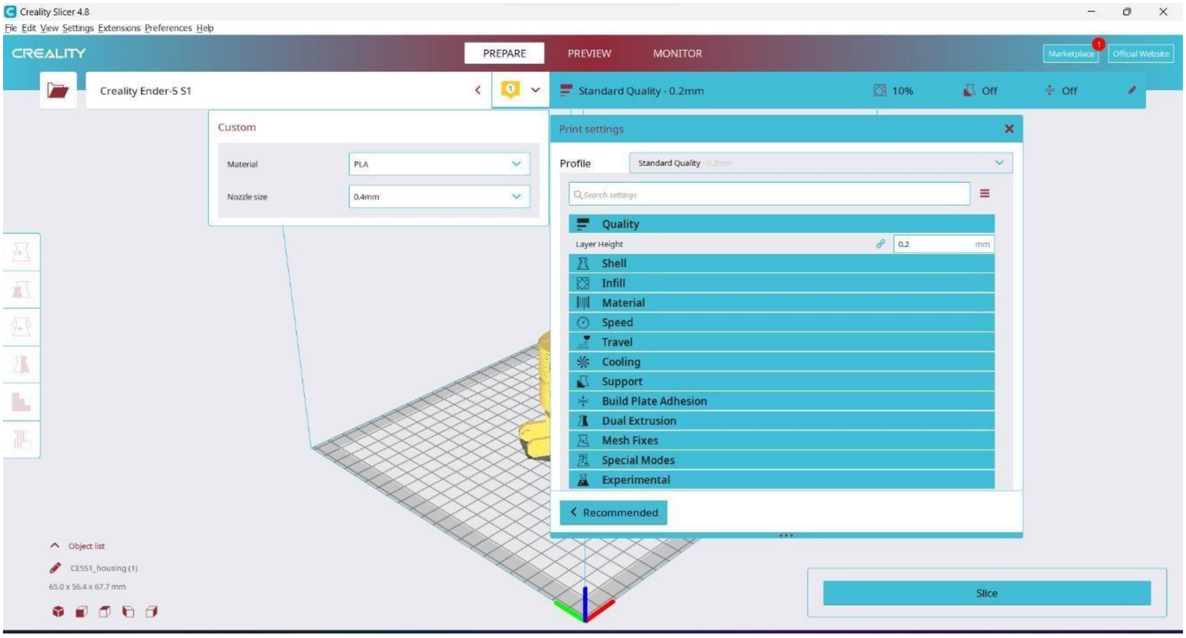


Figure 4.20 :- Detailed Measuring(Creality slicer)

- Printer: The printer that you want to use. In this case, the printer is a Creality Ender- 5 S1.
- Profile: The slicing profile that you want to use. In this case, the profile is Standard Quality-0,2mm 10% or Off. This means that the model will be sliced with a layer height of 0.2 mm and an infill density of 10%.
- Custom Print Settings: This section contains all of the slicing settings that you can customize. You can change the layer height, infill density, support settings, and much more.
- Slice: This button slices your model into G-code, which is the language that your 3D printer understands. Once you have sliced your model, you can save the G-code file to an SD card and print it on your 3D printer.

Here is a more detailed explanation of some of the most important slicing settings:

- Layer height: The layer height is the thickness of each layer that the 3D printer prints. A lower layer height will produce a smoother print, but it will also take longer to print.
- Infill density: The infill density is the percentage of the inside of the model that is filled with solid material. A higher infill density will make the model stronger, but it will also use more material.
- Supports: Supports are temporary structures that are printed to support overhanging parts of the model. Supports are not necessary for all models, but they can be helpful for complex models with overhangs.

4.2.4 EXPORT AS STL

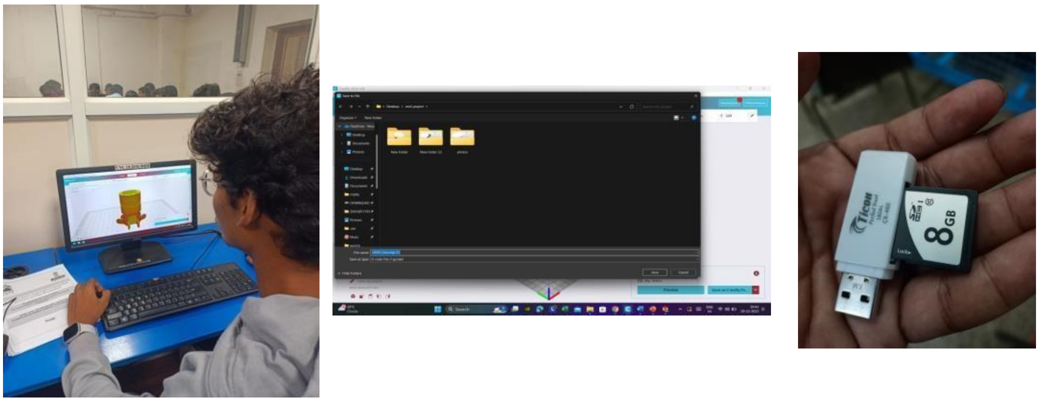


Figure 4.21 :- Export as STL

1. Export STL in Your 3D Modeling Software:
   - Open your 3D model in your preferred modeling software.
   - Export the model in STL format.
2. Open Creality Slicer:
   - Launch Creality Slicer on your computer.
3. Import STL into Creality Slicer:
   - Use Creality Slicer to import the STL file by selecting "Open" or "Import."
4. Configure Slicing Settings:

- Adjust slicing settings as needed, specifying layer height, infill density, and other parameters.

5. Generate G-code:
   - Creality Slicer will generate G-code based on your slicing settings. Save the G-code file to your computer.
6. Prepare SD Card:
   - Insert an SD card into your computer.
7. Copy G-code to SD Card:
   - Copy the saved G-code file from your computer and paste it onto the root directory of the SD card.
8. Eject SD Card:
   - Safely eject the SD card from your computer

4.3 SELECTED OF MATERIAL

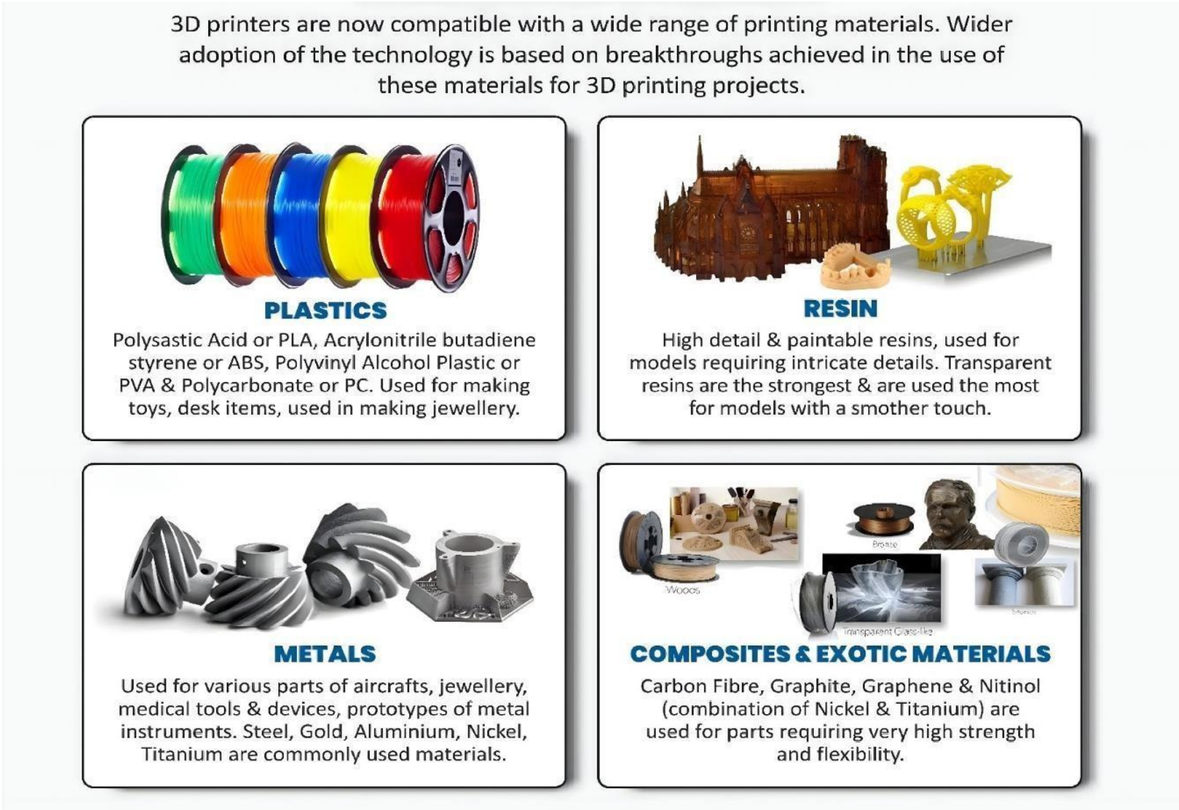


Figure 4.22:- Selected of material(3idea.in)

Material Types:

Photopolymers: Used in SLA, DLP, and MSLA printers. Offer high resolution and smooth surface finish. Examples: resins, biocompatible materials.

Thermoplastics: Used in FDM and SLS printers. Wide variety of options with varying strength, flexibility, and temperature resistance. Examples: ABS, PLA, nylon, PEEK.

Elastomers: Used in specific technologies like PolyJet. Offer flexibility and rubber- like properties. Examples: TPU, TPE.

Material Properties:

- Mechanical properties: Strength, stiffness, elasticity, fatigue resistance, impact resistance, etc.

- Thermal properties: Melting point, glass transition temperature, thermal expansion coefficient, etc.
- Chemical properties: Chemical resistance, biocompatibility, UV resistance, etc.
- Aesthetics: Color, transparency, surface finish, etc.
- Cost: Material price, support material needs, post-processing requirements, etc.

3D Printing Technology:

Different technologies require specific types of materials. For example, FDM printers use filament-based thermoplastics, while SLA printers use liquid photopolymers.

Application:

The intended use of your 3D printed object significantly impacts material selection. Consider the object's function, operating environment, required strength, durability, and aesthetic qualities.

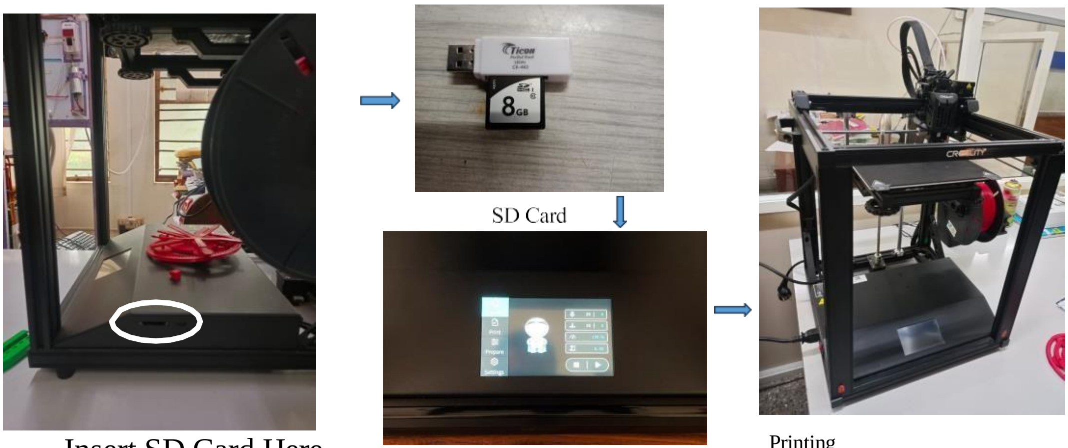
Additional Factors:

- Environmental impact: Biodegradable or recyclable materials may be preferred.

- Safety: Toxicity and fumes during printing should be considered.

- Post-processing: Some materials require additional processing like sanding, painting, or polishing.

4.4 PREPARE FOR 3D PRINTING



Insert SD Card Here

SD Card

Digital Interface With Start Option

Printing

Figure 4.23:- Prepare For 3d Printing

Insert SD Card into 3D Printer:

- Insert the SD card into the SD card slot on your Creality 3D printer.

Select and Print:

- Navigate through the printer's menu to locate and select the G-code file on the SD card.
- Initiate the printing process, and the 3D printer will follow the instructions in the G-code file to produce your model.

These steps should guide you through the process of exporting an STL file, converting it to G-code using Creality Slicer, and transferring the G-code to an SD card for 3D printing on a Creality 3D printer. Keep in mind that specific details may vary depending on the versions of software and hardware you are using, so consult the user manuals or documentation for your specific equipment if needed.

4.5 PRINTING

Printing Housing

Printing Clamps

Figure 4.24:- Printing

3D printing, also known as additive manufacturing, is a process of creating three-dimensional objects by layering materials based on a digital model. This technology has a wide range of applications across various industries and has gained popularity for its versatility and capability to produce complex and customized designs. Here are some key aspects of 3D printing.

Layer-by-Layer Construction: 3D printing builds objects layer by layer, adding material incrementally based on a digital 3D model.

Materials: Various materials can be used, including plastics, metals, ceramics, and even biological materials.

4.6 POST-PROCESSING

Removing Printed Material

Post Process Tools

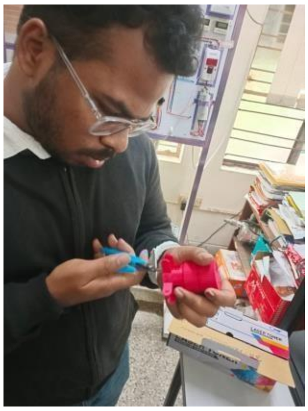


Figure 4.25:- Post-Processing

Post-processing is an essential step after 3D printing to enhance the appearance, functionality, and properties of the printed objects. The extent of post-processing required often depends on the 3D printing technology used and the specific requirements of the project. Here are common post-processing techniques:

Removal of Support Structures:

Many 3D prints require support structures during printing to prevent overhangs. These supports need to be removed after printing. This can be done manually, with tools like pliers or tweezers, or through automated processes.

Surface Smoothing:

Depending on the printing technology, the surface of 3D-printed objects may have a layered appearance. Smoothing techniques, such as sanding, filing, or chemical smoothing, can be applied to achieve a more polished and aesthetically pleasing finish.

The specific post-processing steps depend on the material, the intended use of the printed object, and the desired finish. As technology advances, there are continuous developments in post-processing techniques to improve the efficiency and quality of 3D-printed parts.

4.7 FINAL PRODUCT

The gripper operates by transforming rotary motion into linear motion through the utilization of a rack and pinion gear mechanism.

Technical features	
Weight (including clamps)	77g
Operating degree's	360 °
Maximum operating diameter	60mm

Material type	Housing	clamps
Material	PLA (Poly lactic acid)	PLA
Geometric parameters		
Width	55mm	15mm
Length	68mm	105mm

Figure 4.26:- Final Product

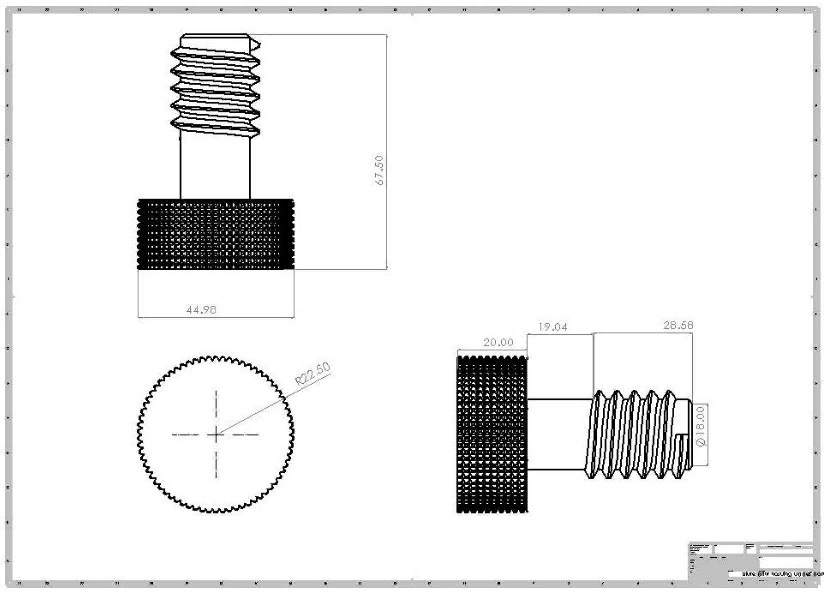
CHAPTER 5

MODELLING OF FLEXIBLE GRIPPER

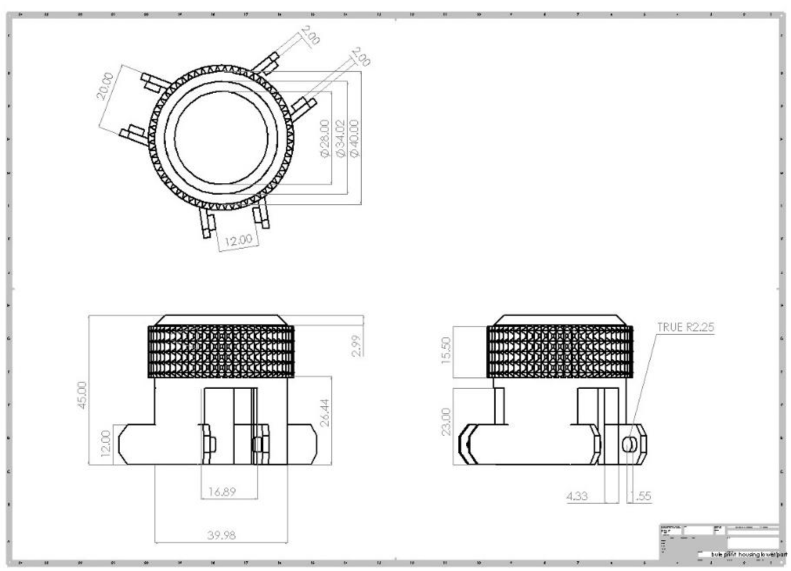
5.1 BLUE PRINT OF FLEXIBLE GRIPPER

Modelling of flexible gripper in solid works of different parts are:

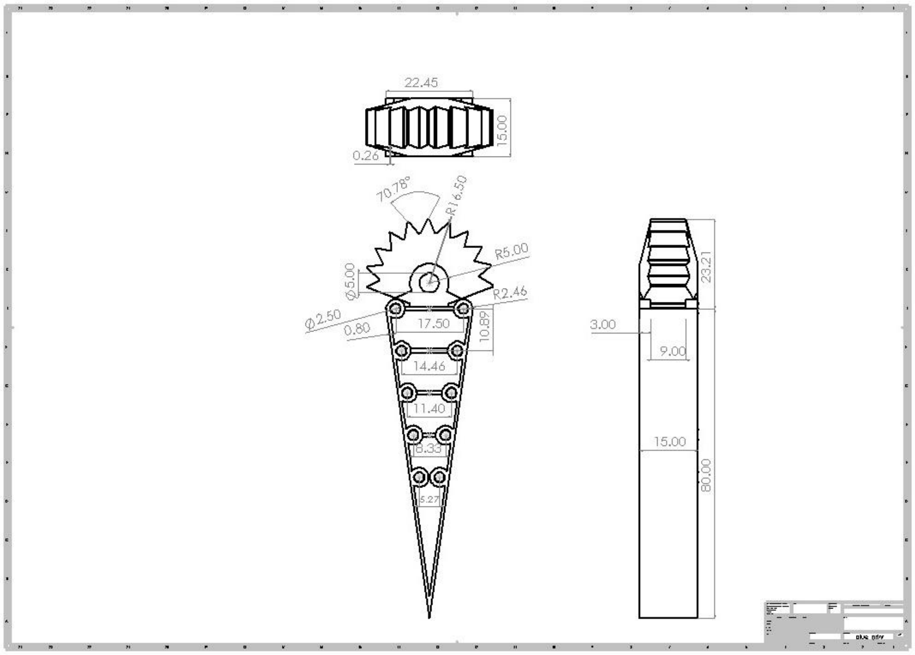
- Housing upper part
- Housing lower part
- Clamp



Housing upper part



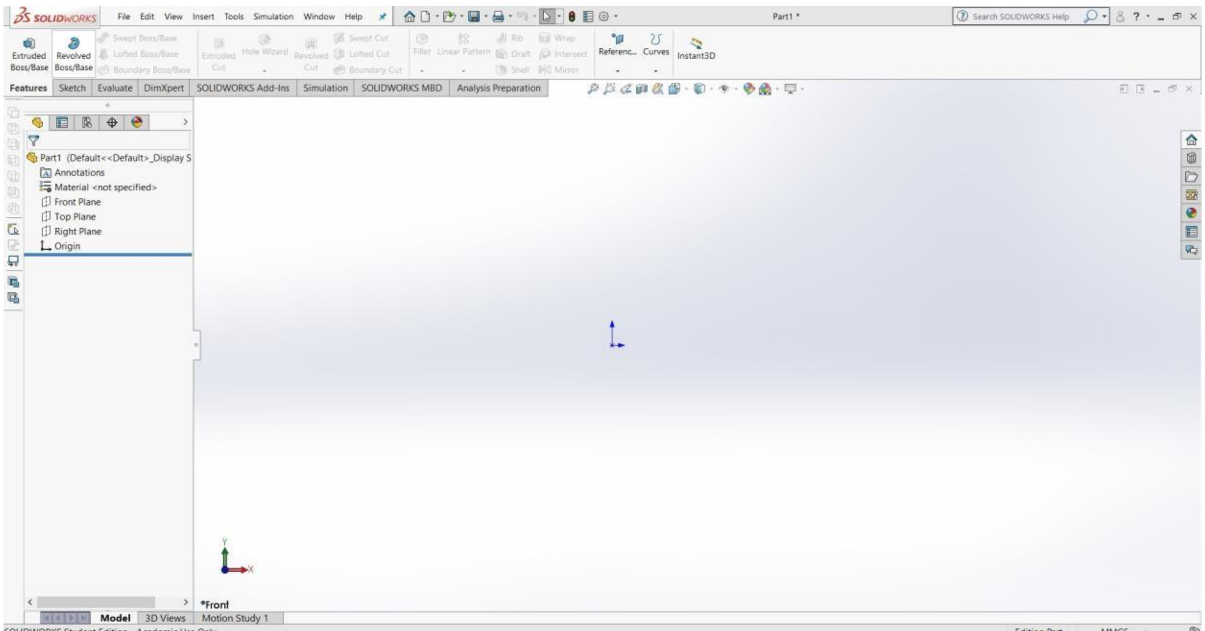
Housing Lower Part


22.45
15.00
0.26
70.78°
R16.50
R5.00
Ø5.00
R2.46
Ø2.50
0.80
17.50
10.89
14.46
11.40
8.33
5.27
3.00
9.00
23.21
15.00
80.00

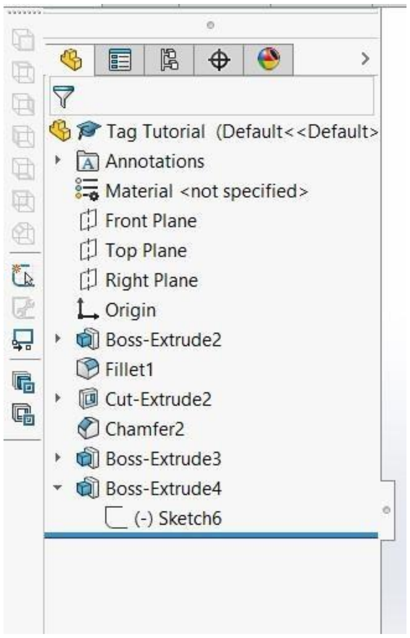
Clamp

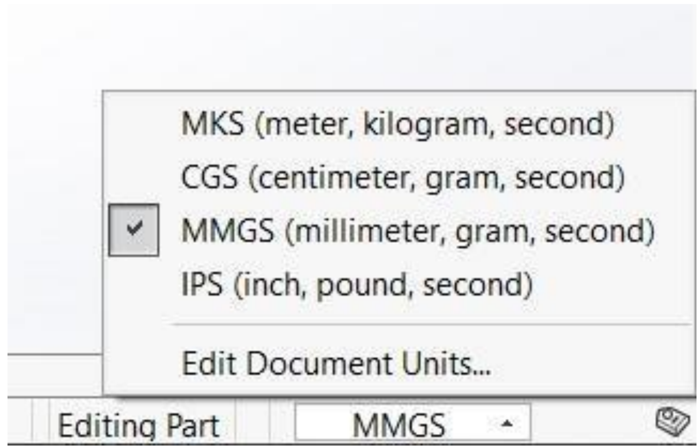
5.2 VIRTUAL MODELLING

A basic model design is required to use 3D printing to turn an idea into a working prototype. After acquiring the appropriate design, optimization is carried out, and several iterations are taken into consideration to enhance the model's ergonomics. In contrast to traditional manufacturing, which requires testing finished products, 3D printing enables component analysis in the software, reducing material waste and costs while also producing the required results.

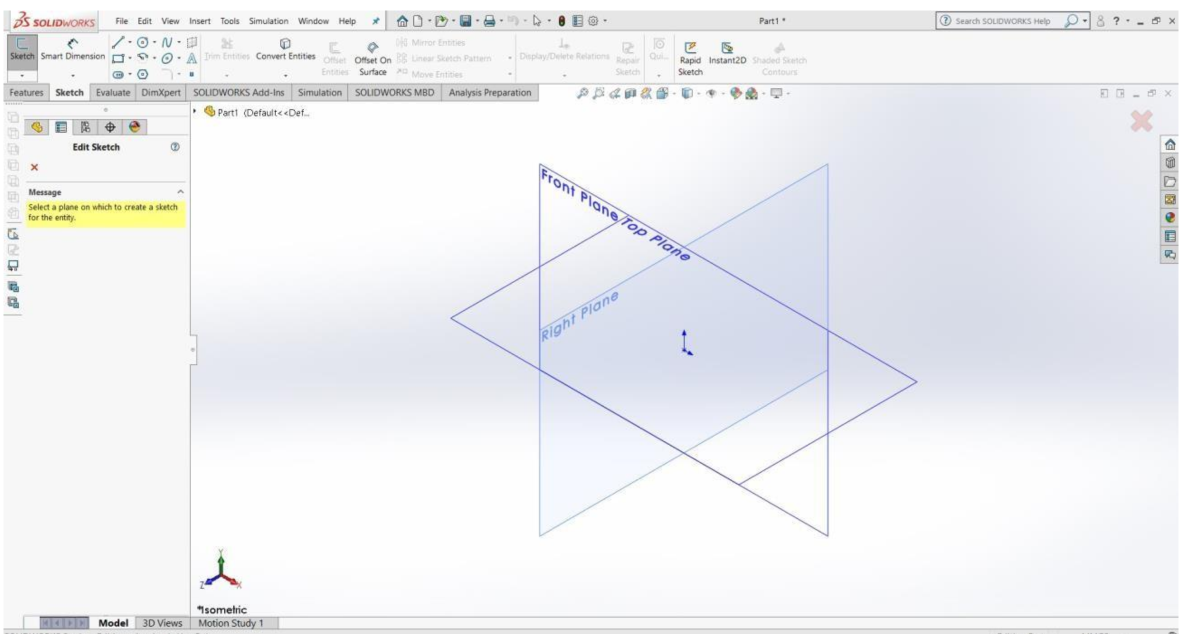


This is the screen when we start a new part.

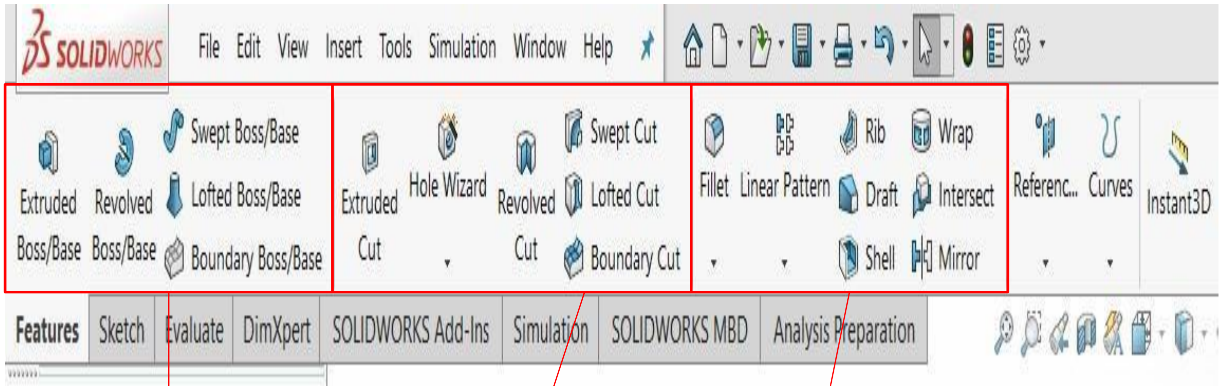




The design lets select and modify sketches and features and units can be changed in bottom right corner.



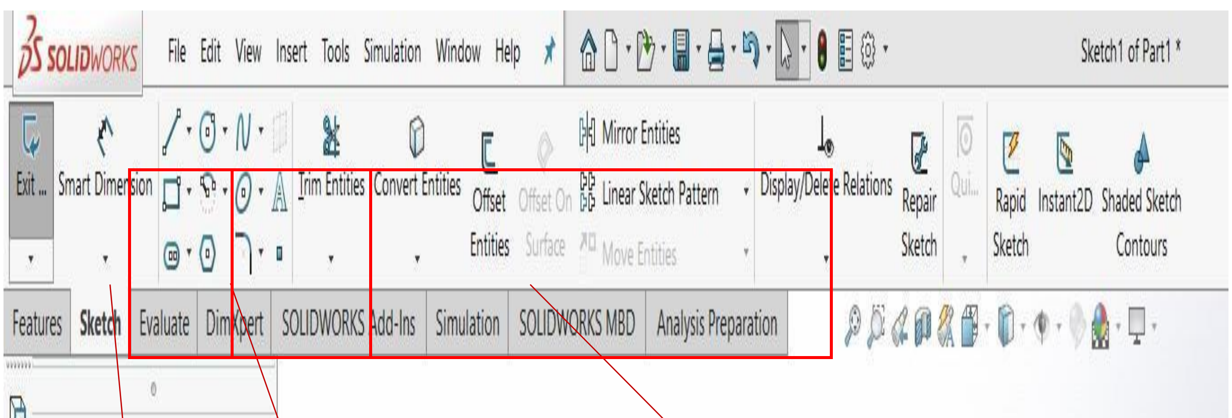
Select a plane using sketch tool.



Extrusion Tools used to
add volume from sketches

Specialty Tools

Cutting tools used to remove volume

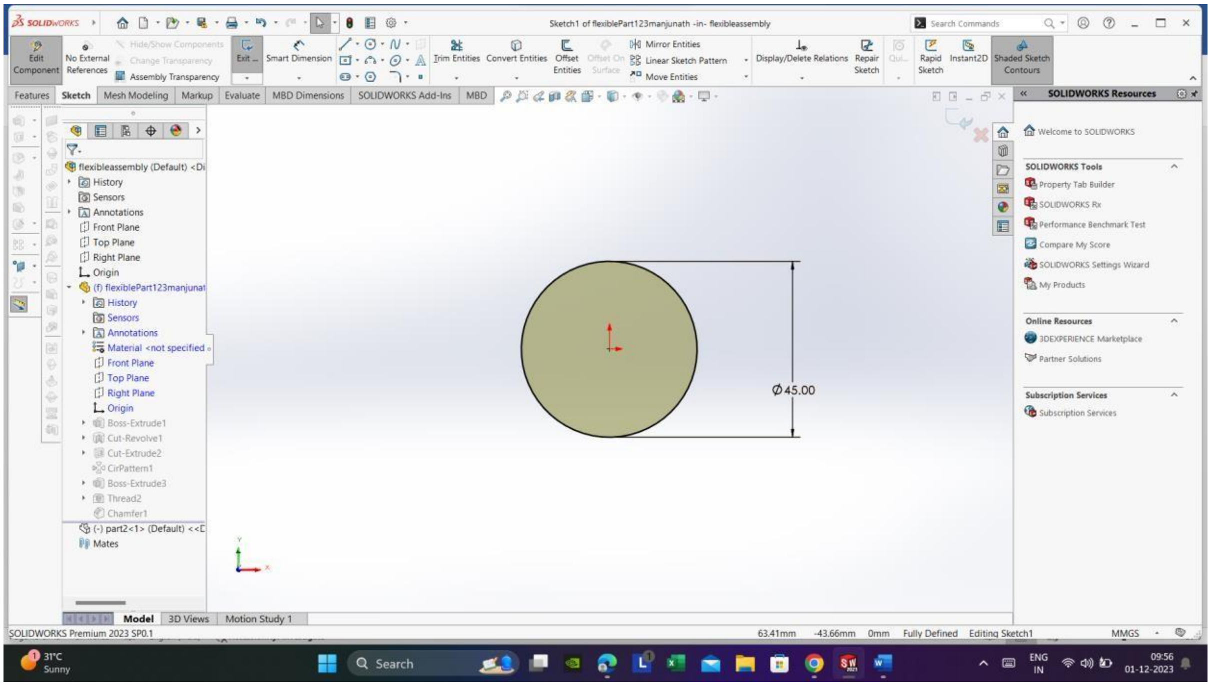


Modify Lines

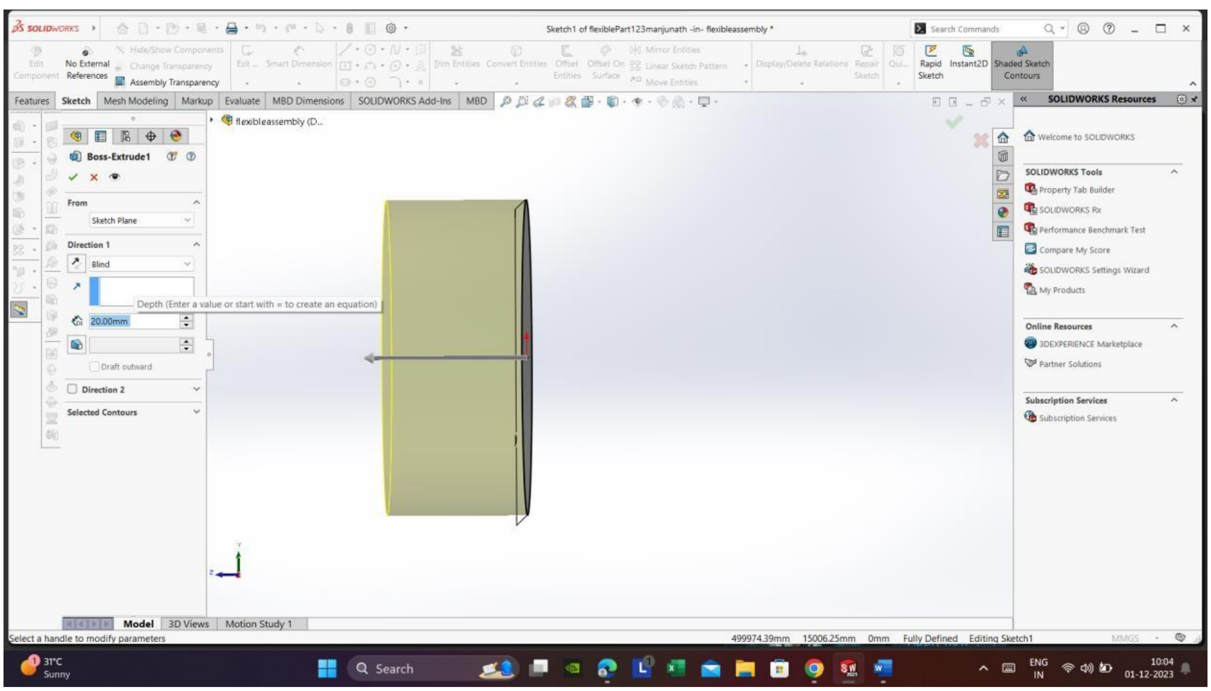
Tools within the feature tab.

Create Patterns Lines, Curves, and Shape

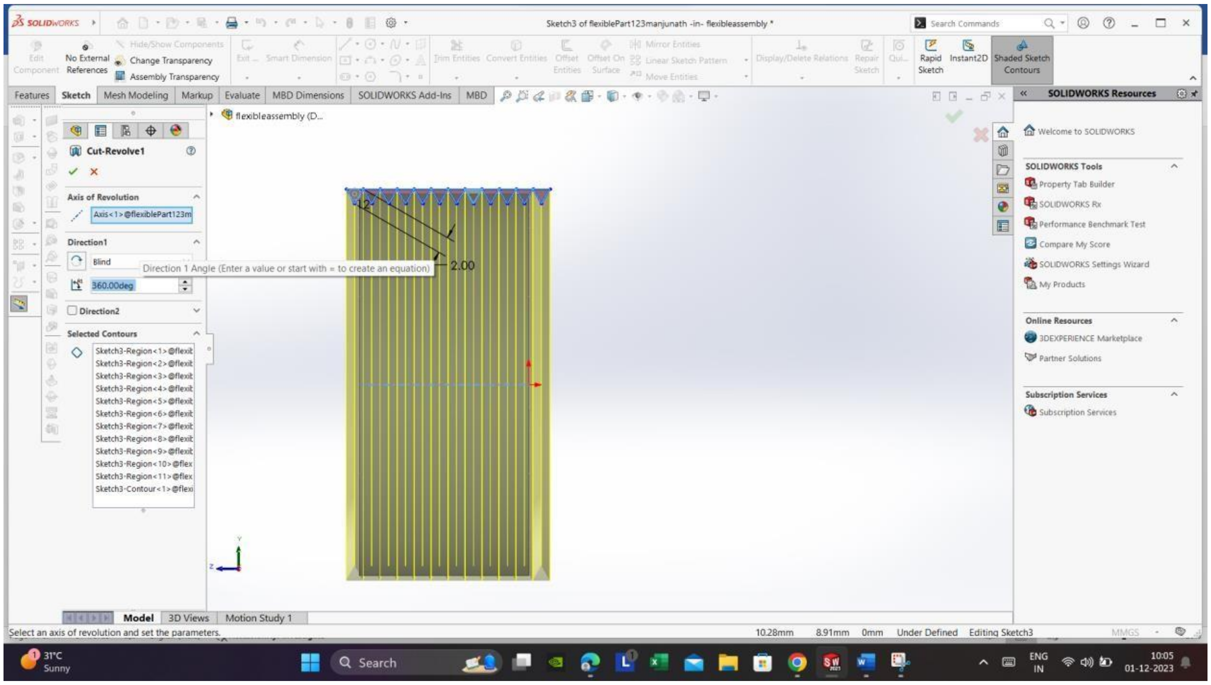
5.2.1 HOUSING UPPER PART



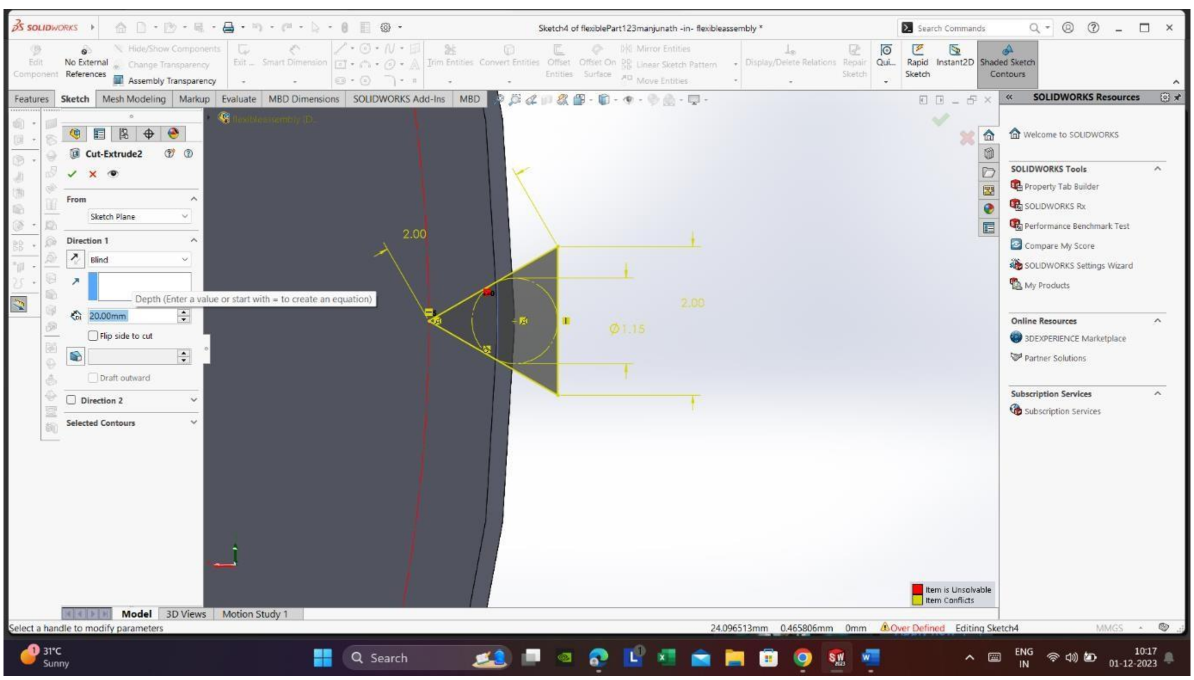
Draw the circle of diameter Ø45mm using smart dimensions



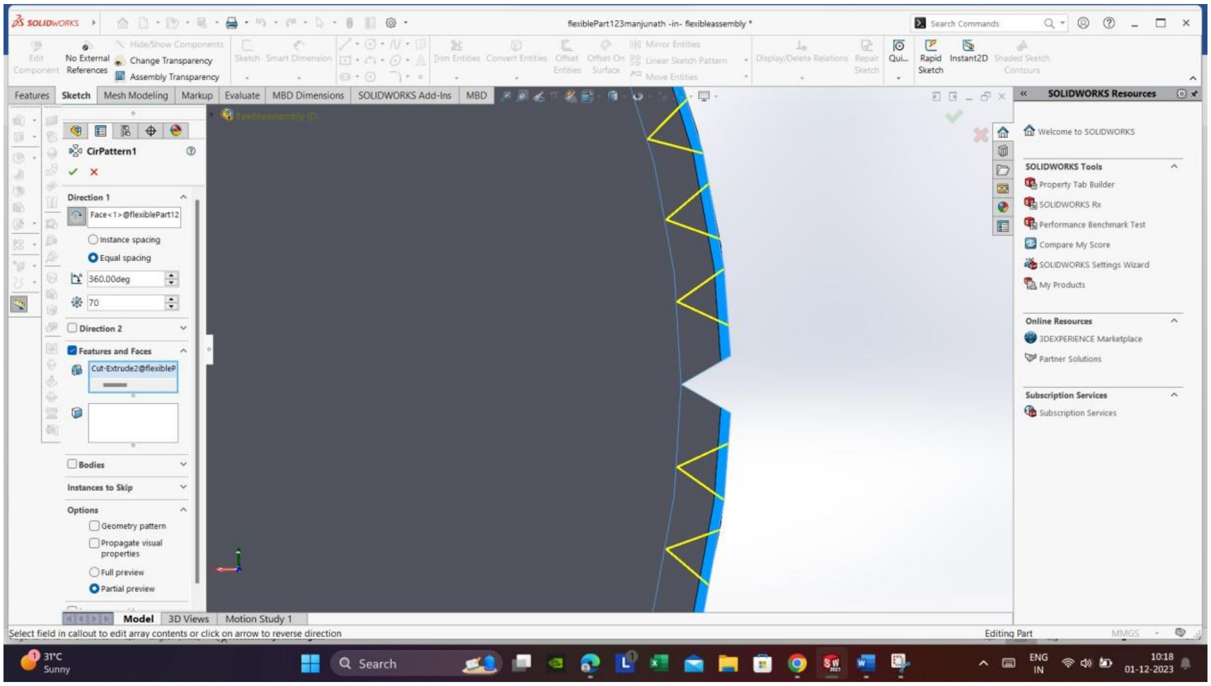
Select Extrude boss/base to add depth to circle up to 20mm.



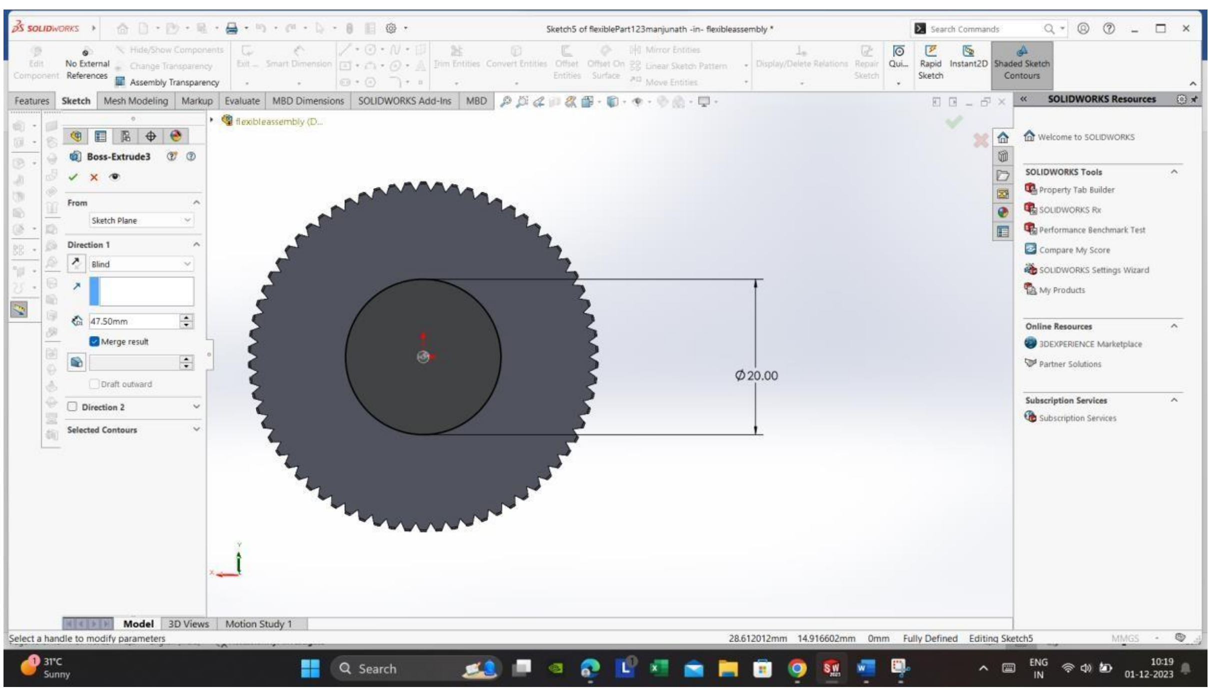
Draw the triangle of 2mm length on the extruded circle and cut it horizontally using revolve-cut command.



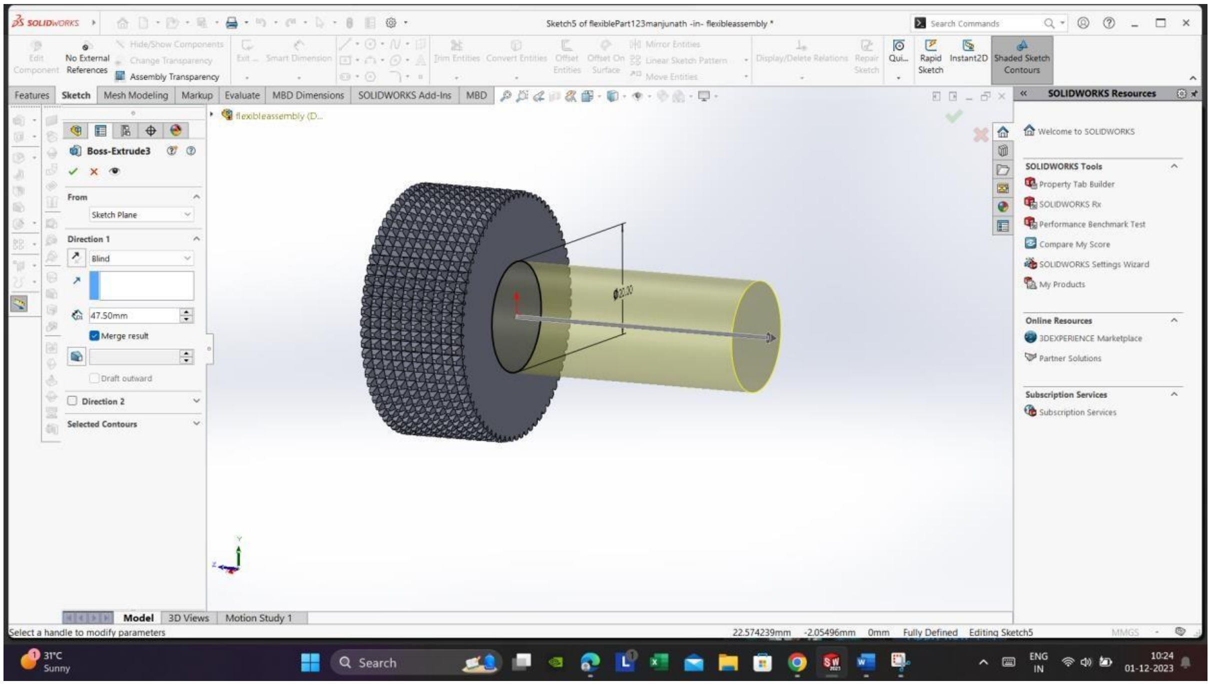
Draw the triangle of 2mm perpendicular to the revolve-cut triangle.



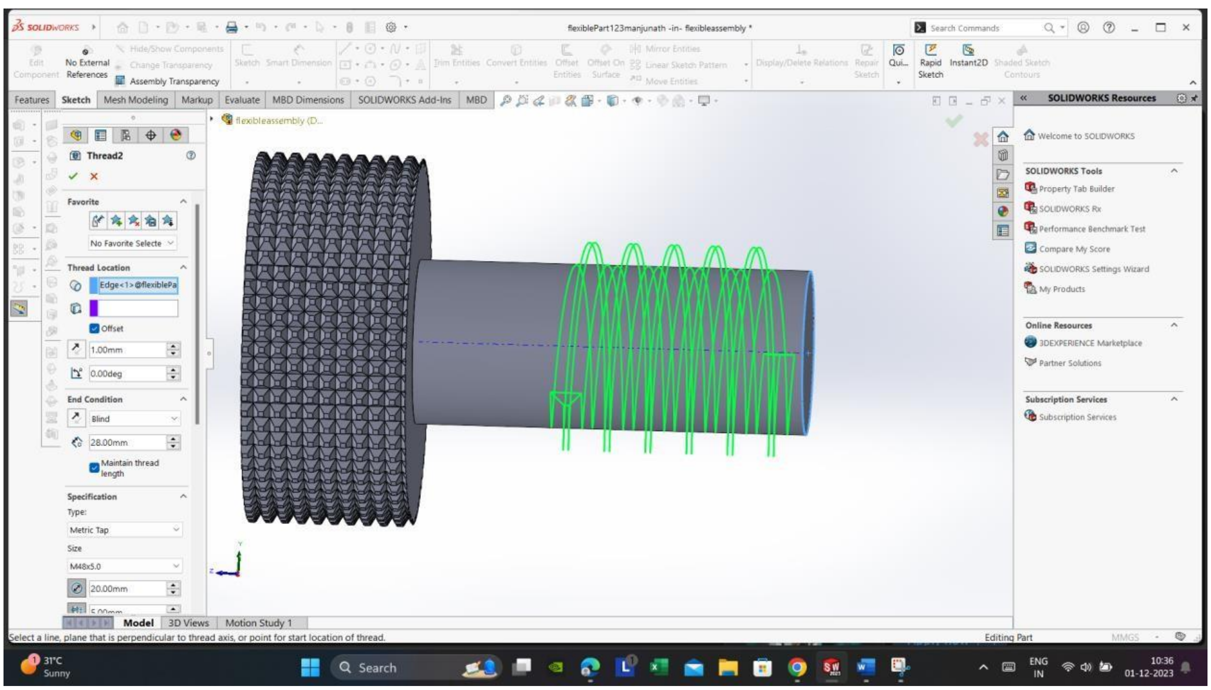
Select the revolve-cut the triangle for knurling grip on sketch.

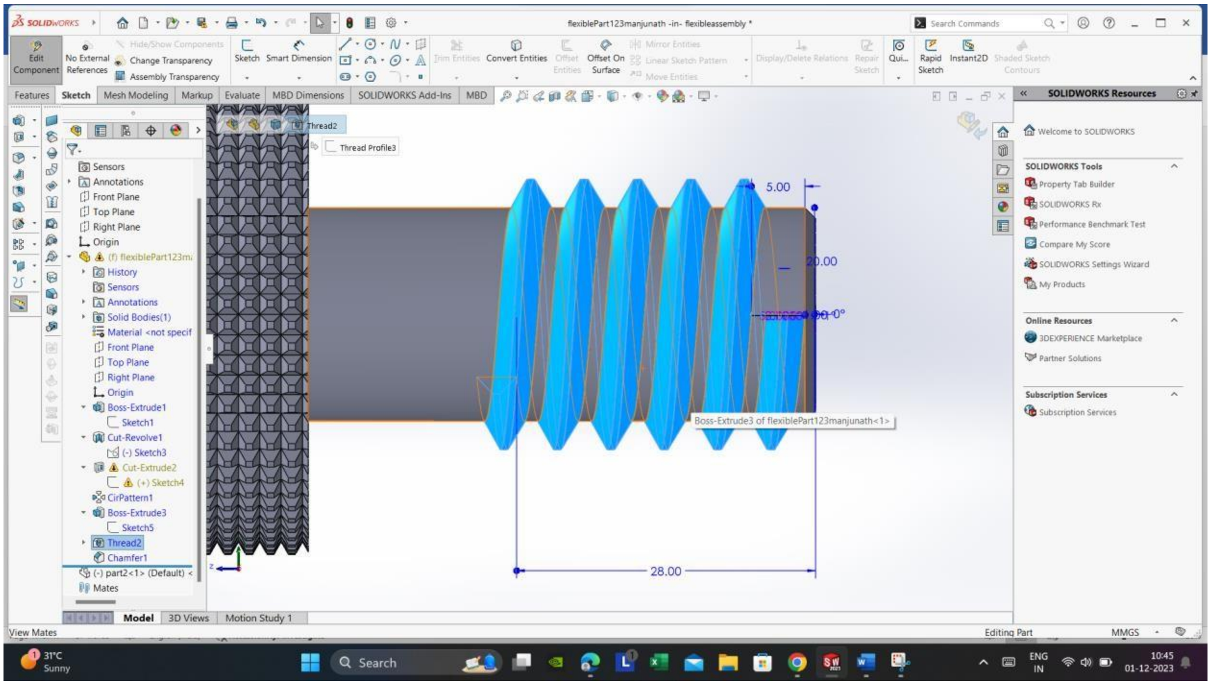


Now draw the circle of Ø20mm diameter on sketch.

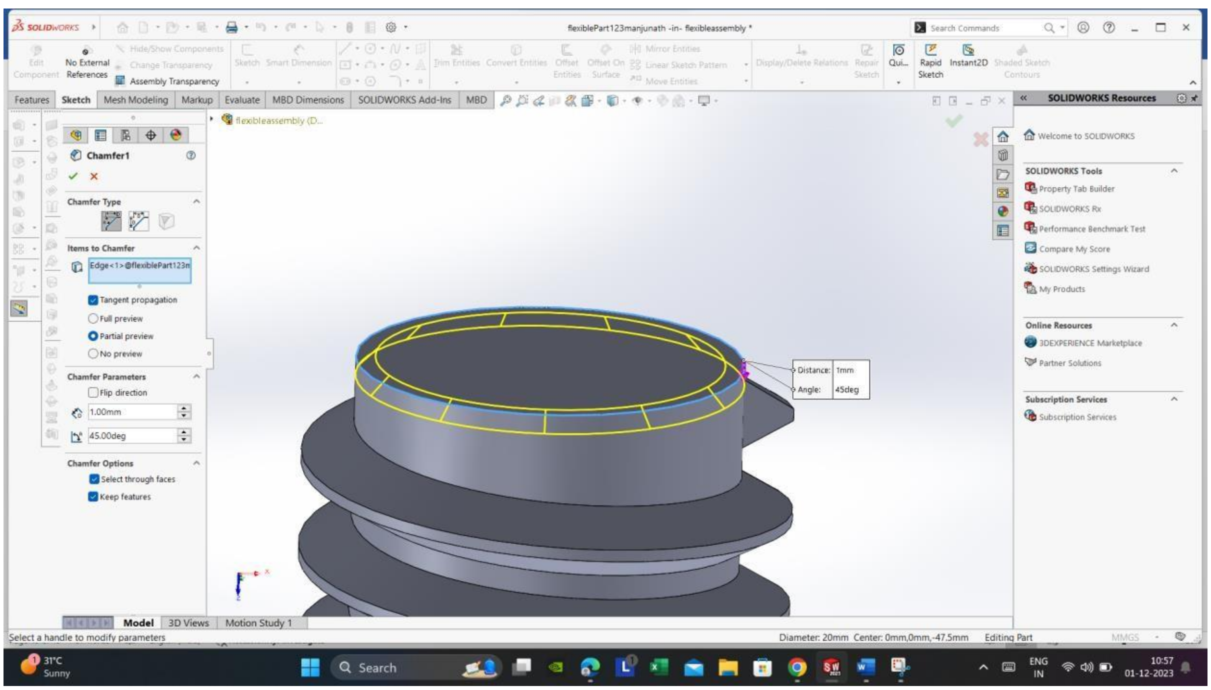


Select Extrude boss/base to add depth to circle2 up to 47.5mm.

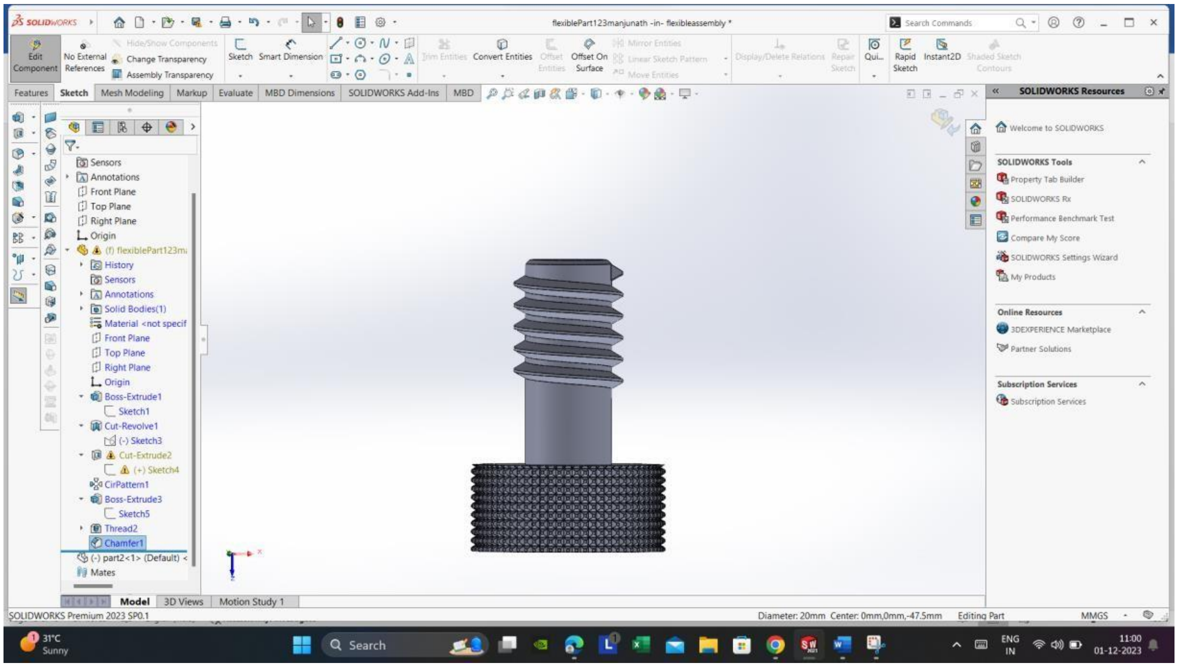




Select the thread command for metric tap on extrude circle2(sketch2) of length28mm.

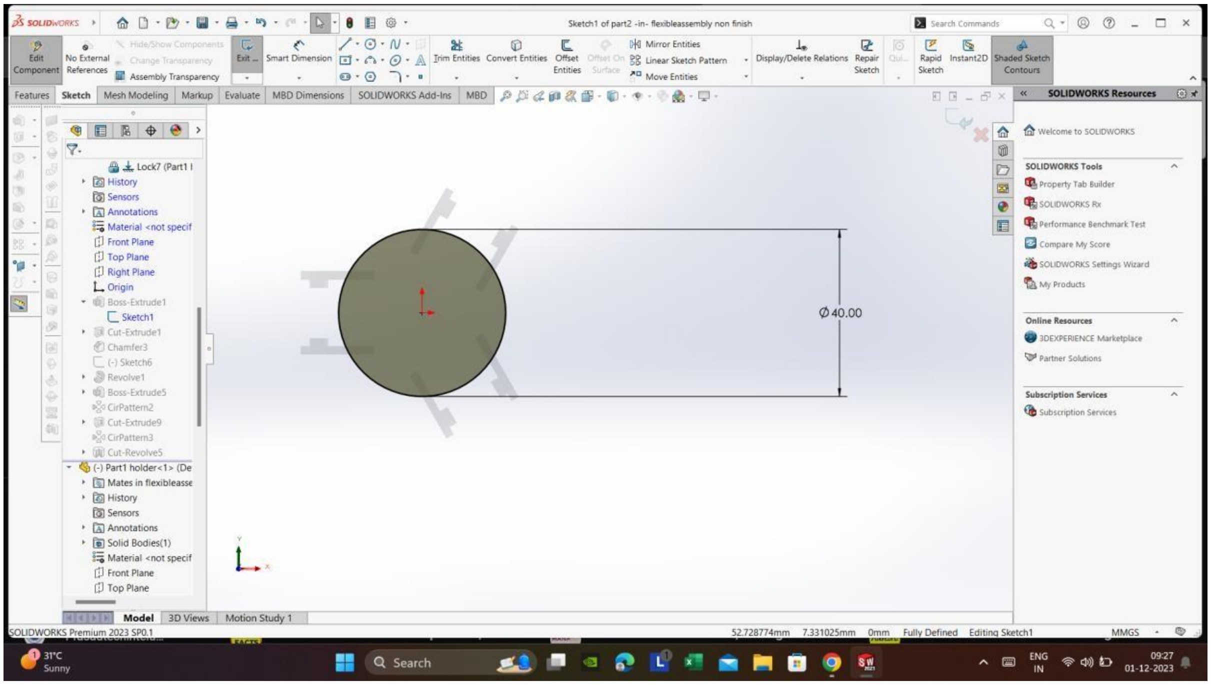


Select the chamfer on bottom of sketch2 of 1mm.

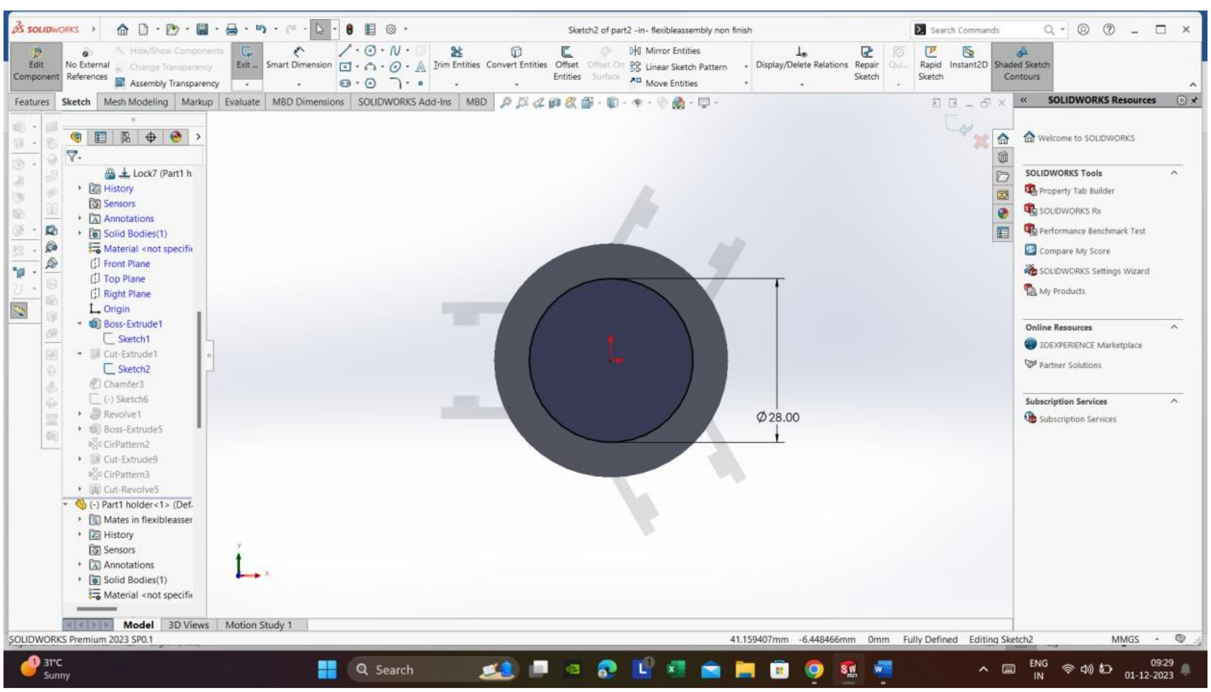


Use the trim command to remove the unwanted lines and Finished upper part of the housing.

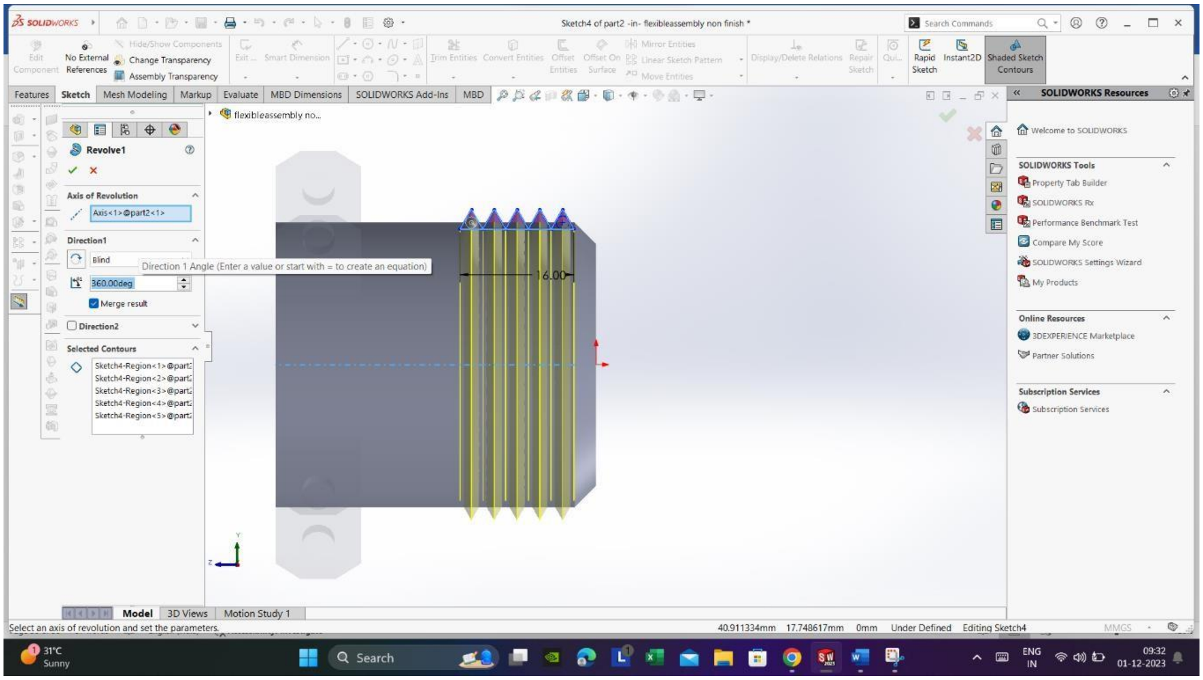
5.2.2 HOUSING LOWER PART



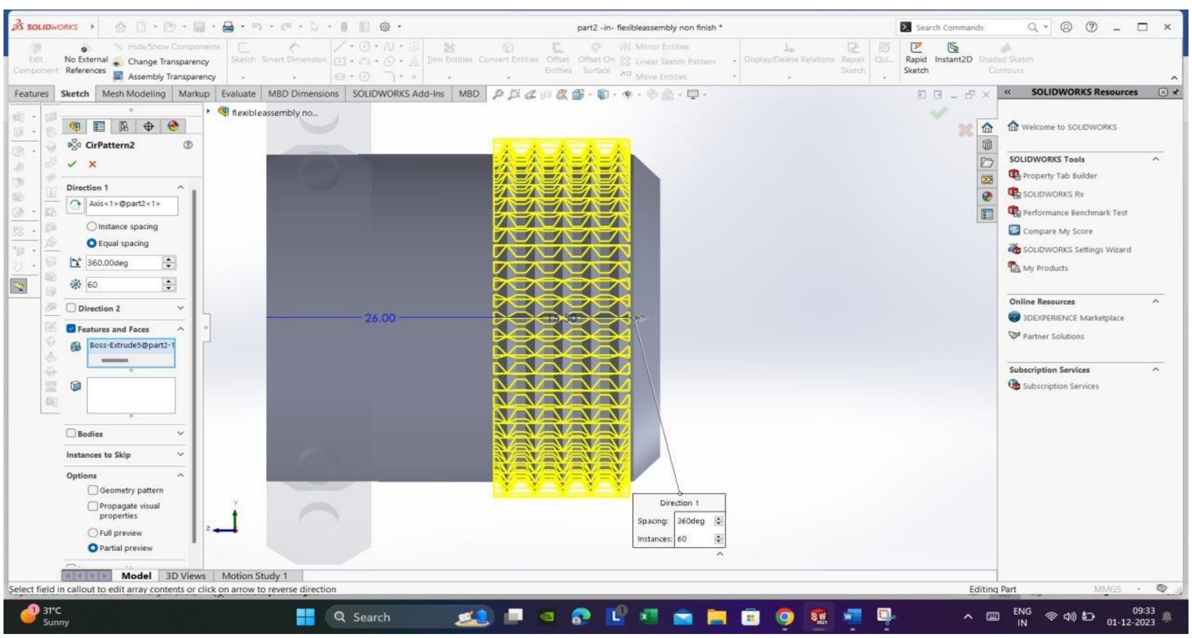
Draw the circle of diameter Ø40mm.



Draw another circle of diameter Ø28mm and select the extrude-cut to remove Ø28mm from the sketch.

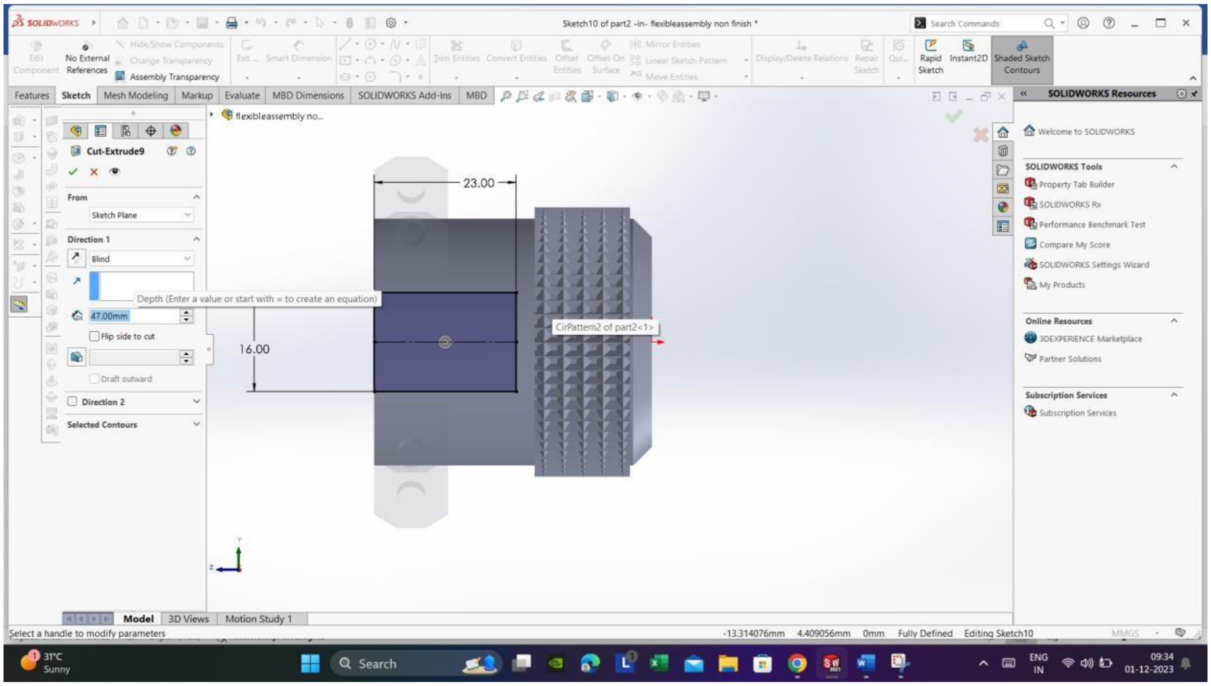


Draw the triangles of length up to 16mm and select the revolve1 in 360degrees to the triangles.

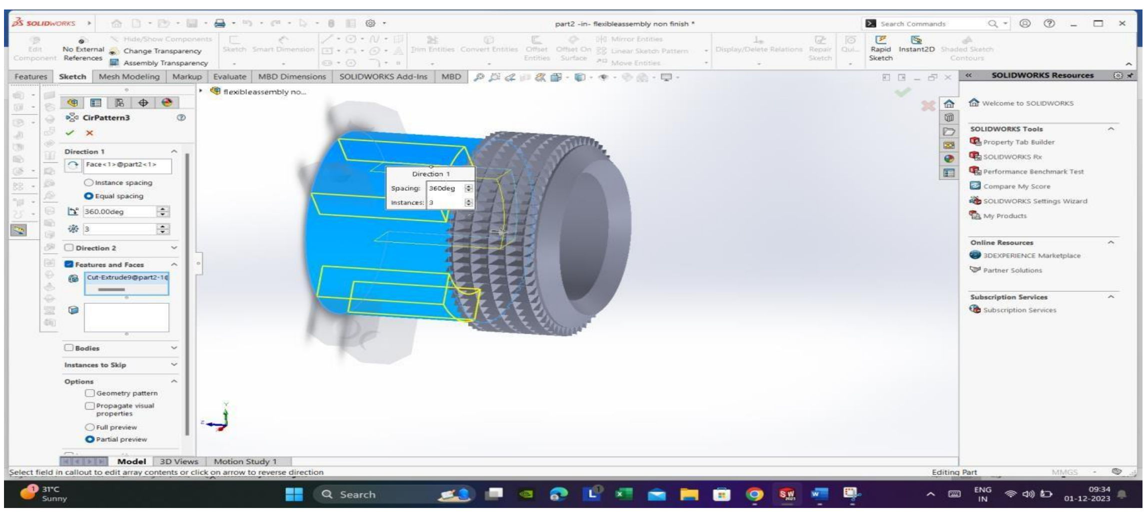


Again, draw the triangles perpendicular to the revovle1 through the cirpattern in 360degrees.

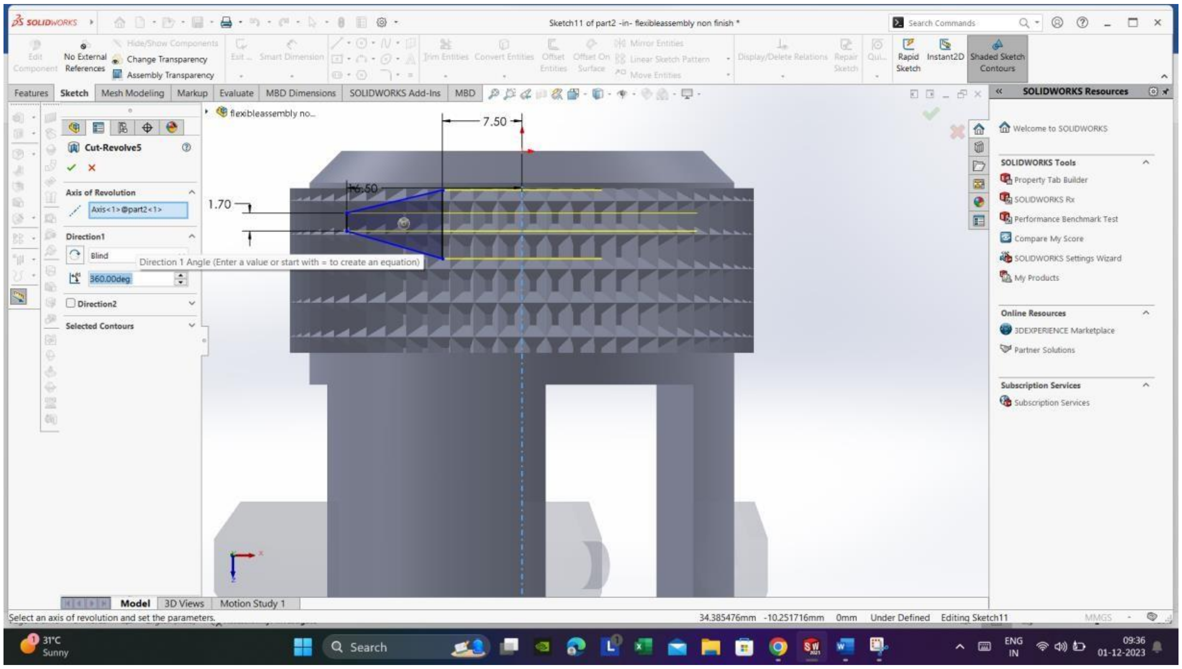
Now select the extrude boss/base to cirpattern up to 16mm.



Select the rectangle of width 16mm and length 23mm and select the extrude-cut to cut depth up to 12mm.

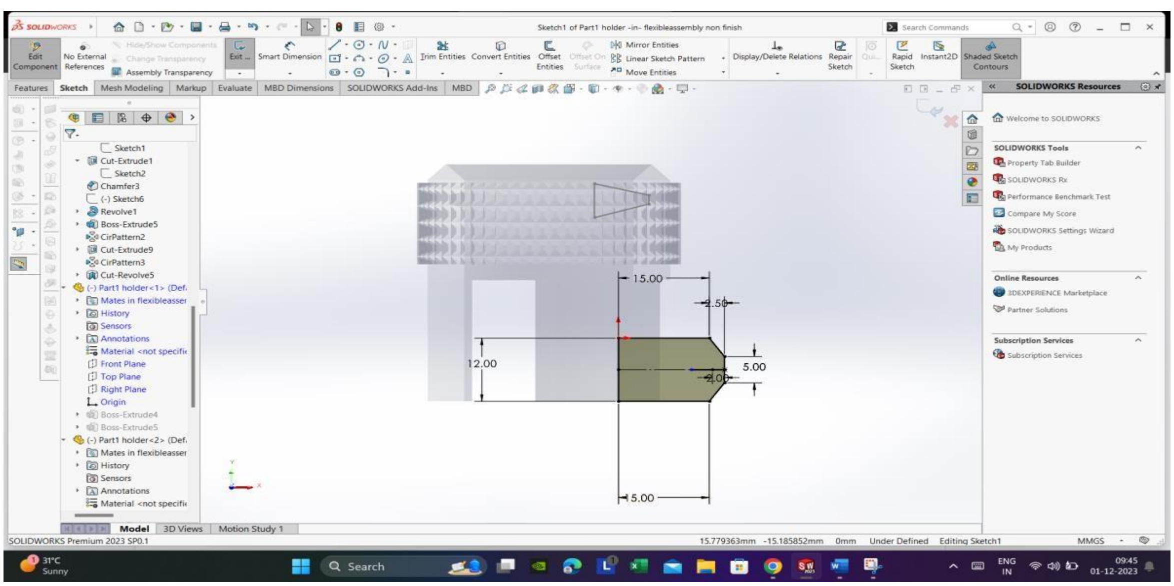


Select the cirpattern to the extrude-cut rectangle in the 360degrees of 3patterns.



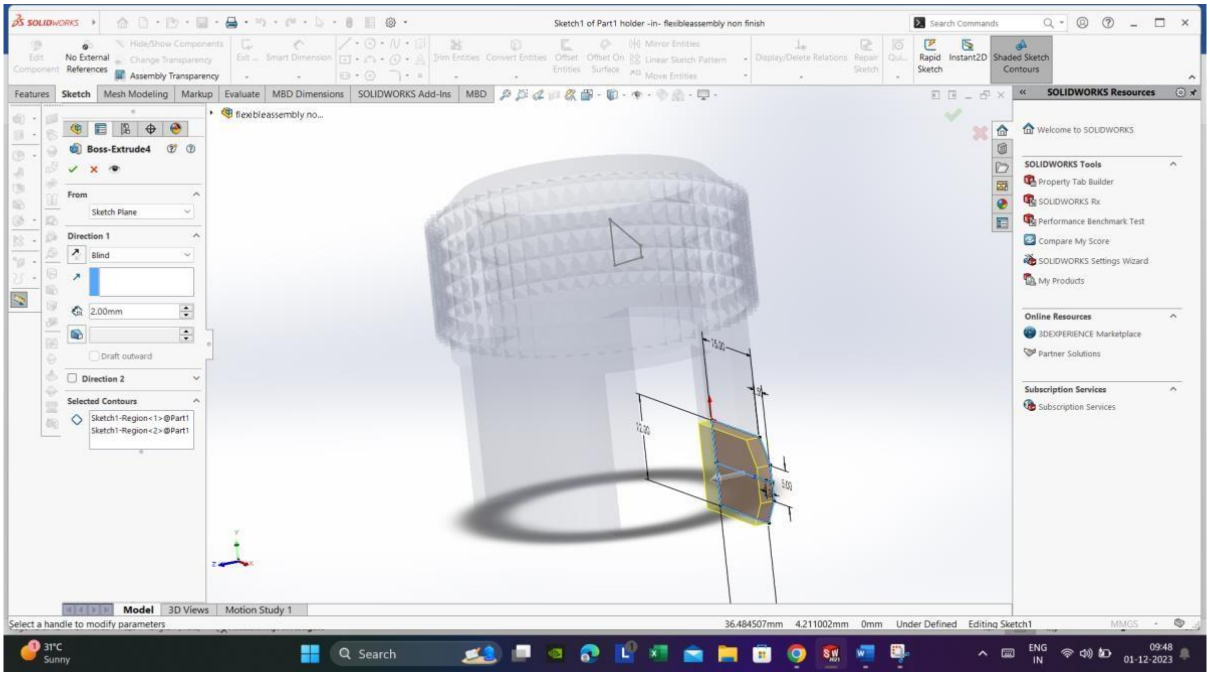
Select the required plane to draw the triangle 7.5mm from the axis.

Select the revolve-cut to the triangle from inside part of sketch in 360degrees.

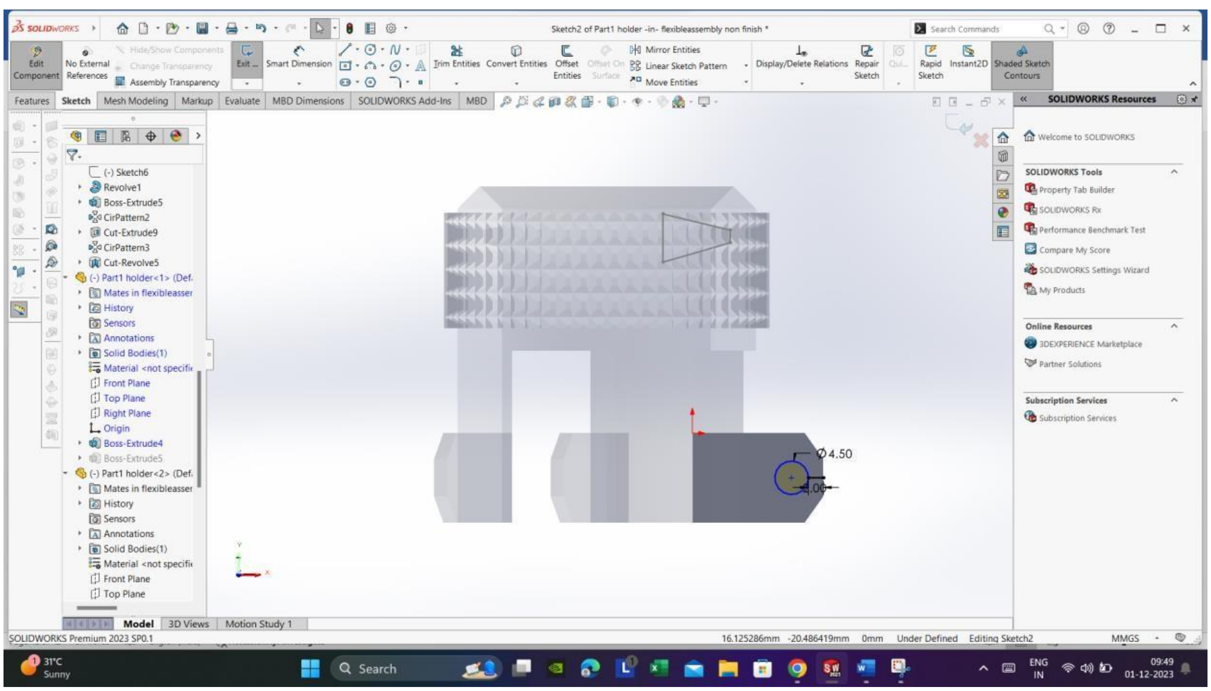


Select the required plane.

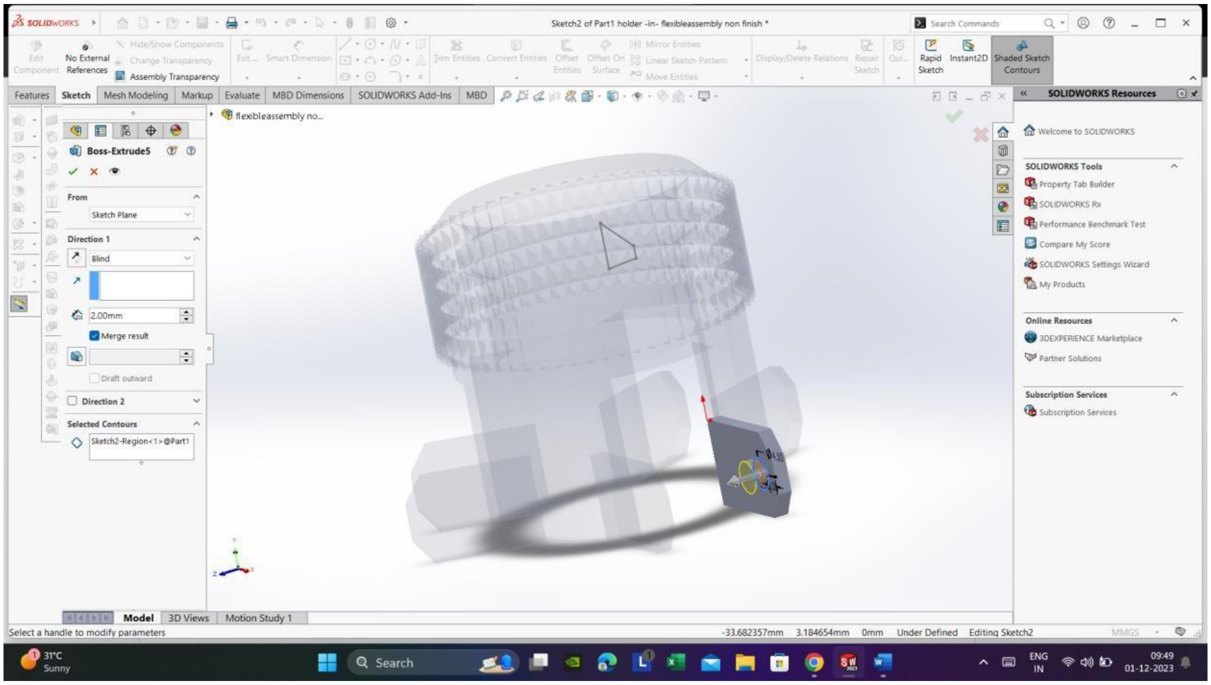
Now select the line command, draw a rectangle shaped support on bottom rectangular opening of the housing.



Select the extrude boss/base to the sketch up to 2mm.

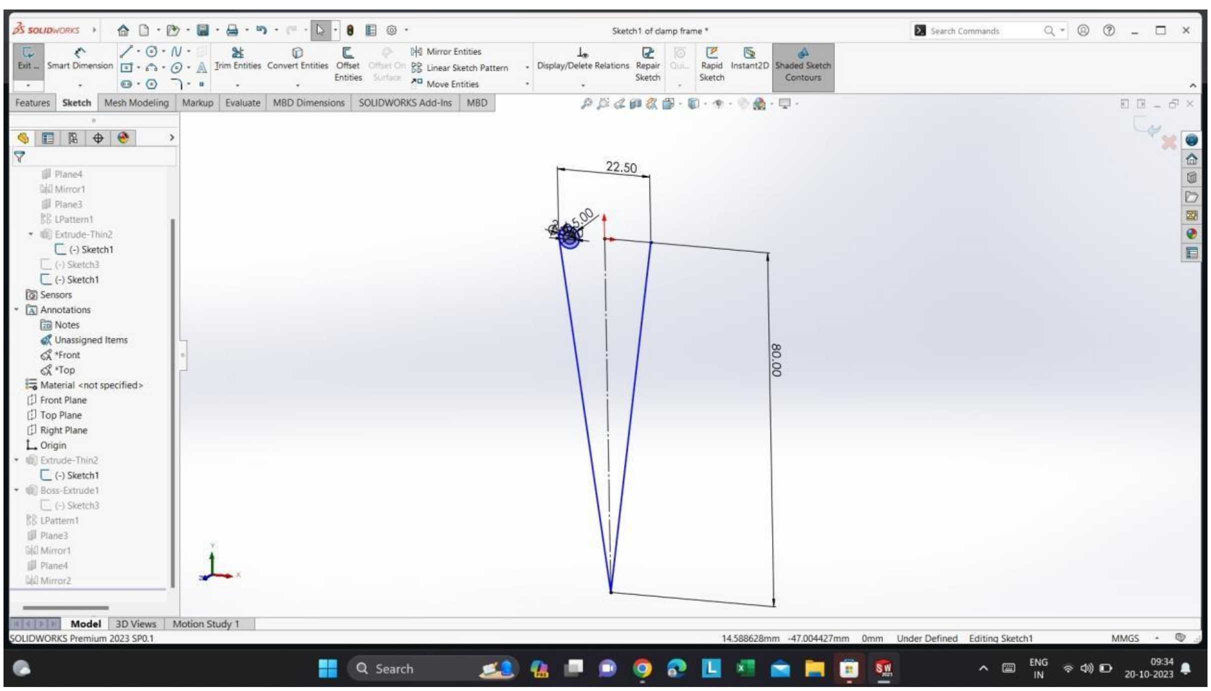


Select the circle of diameter of Ø4.5mm and circle is drawn from right side of sketch distance of 4mm.



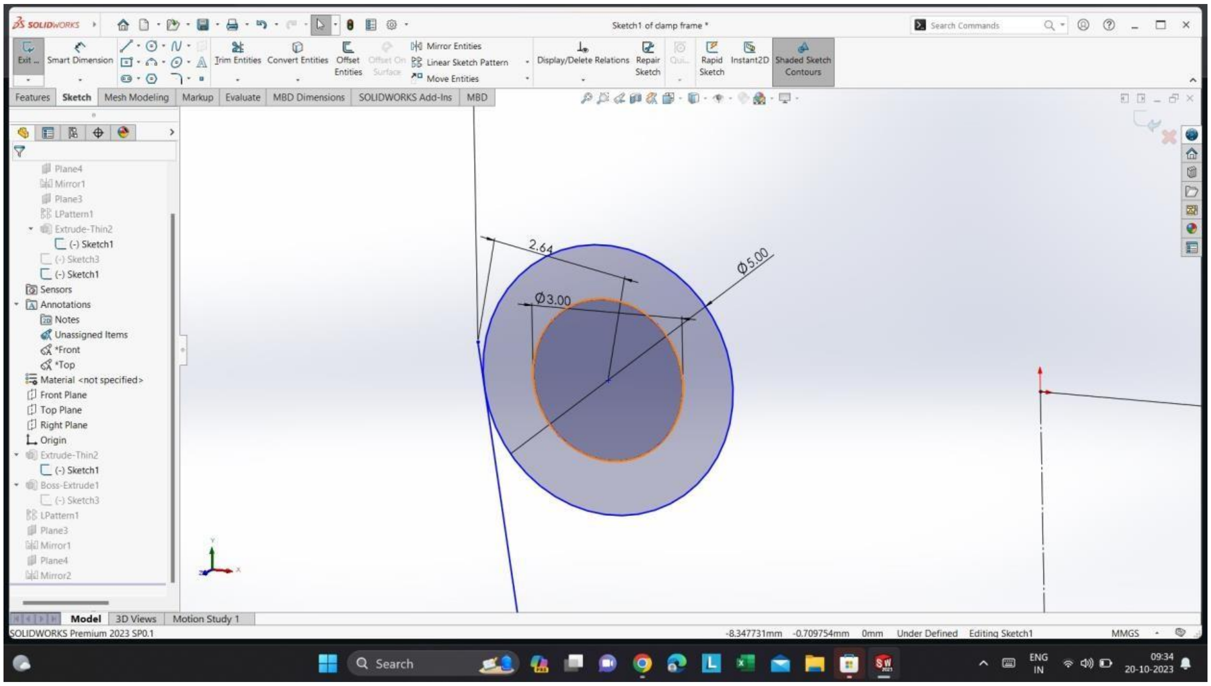
Extrude the circle upto 2mm.

5.2.3 CLAMP

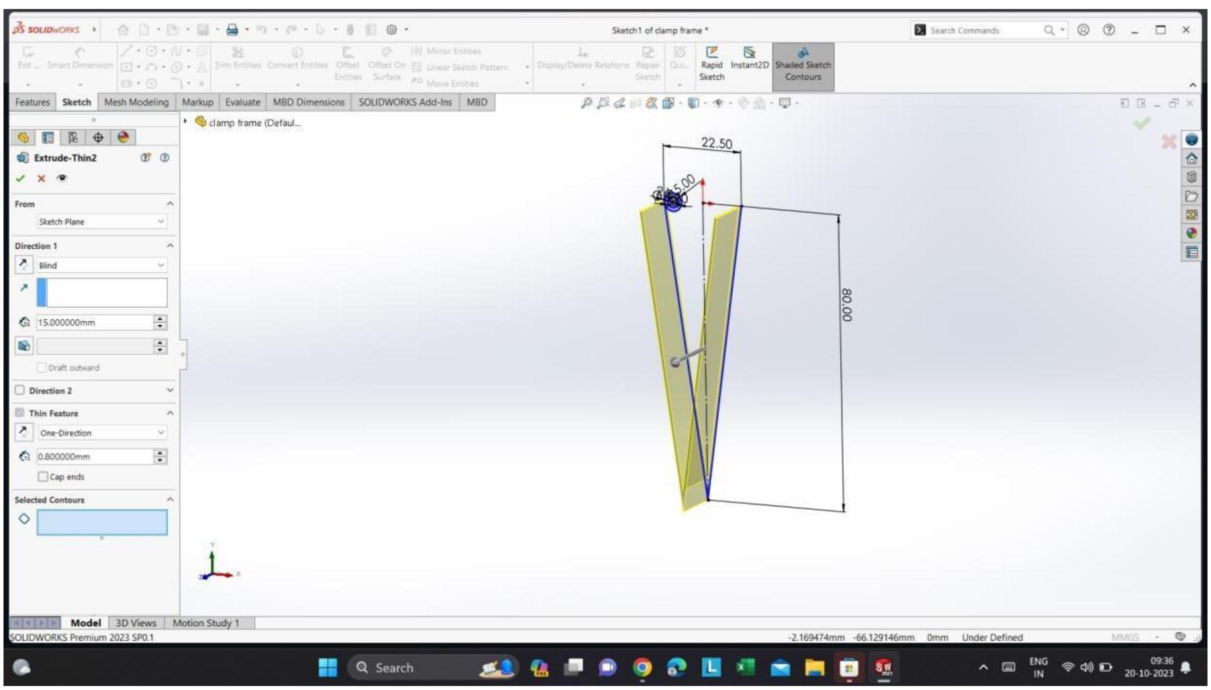


Select the part and also select the plane to start the sketch.

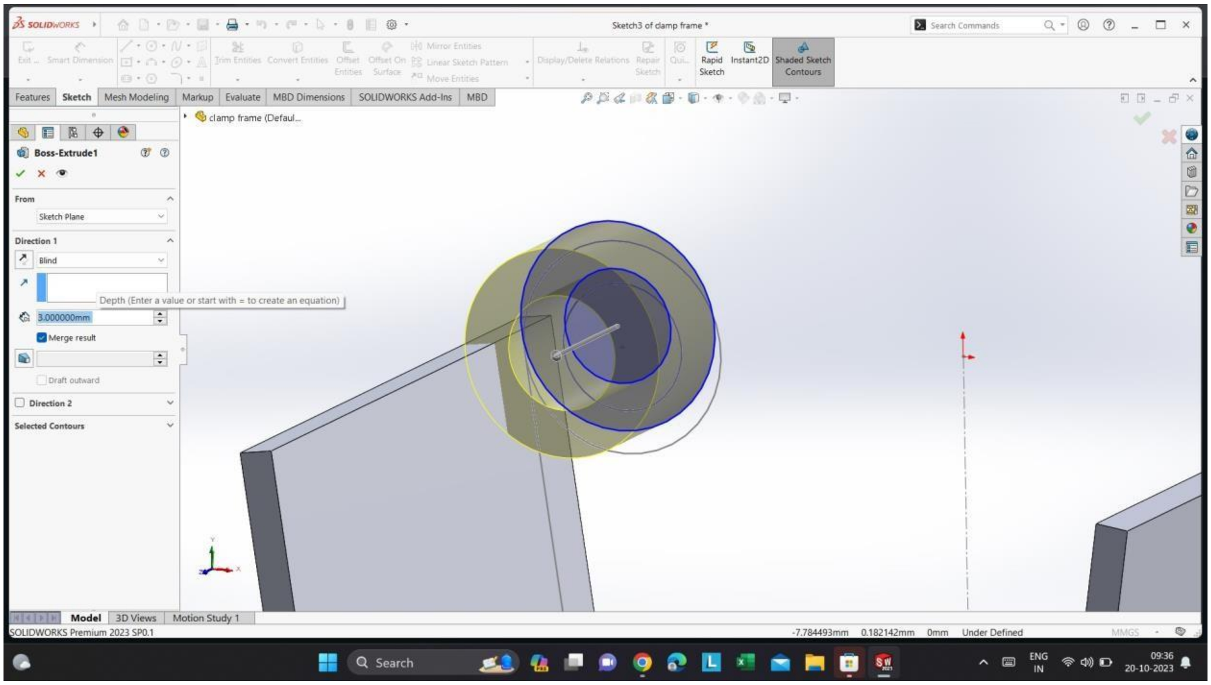
Using the line command draw the triangle face of height 80mm and width 22.5mm without base.



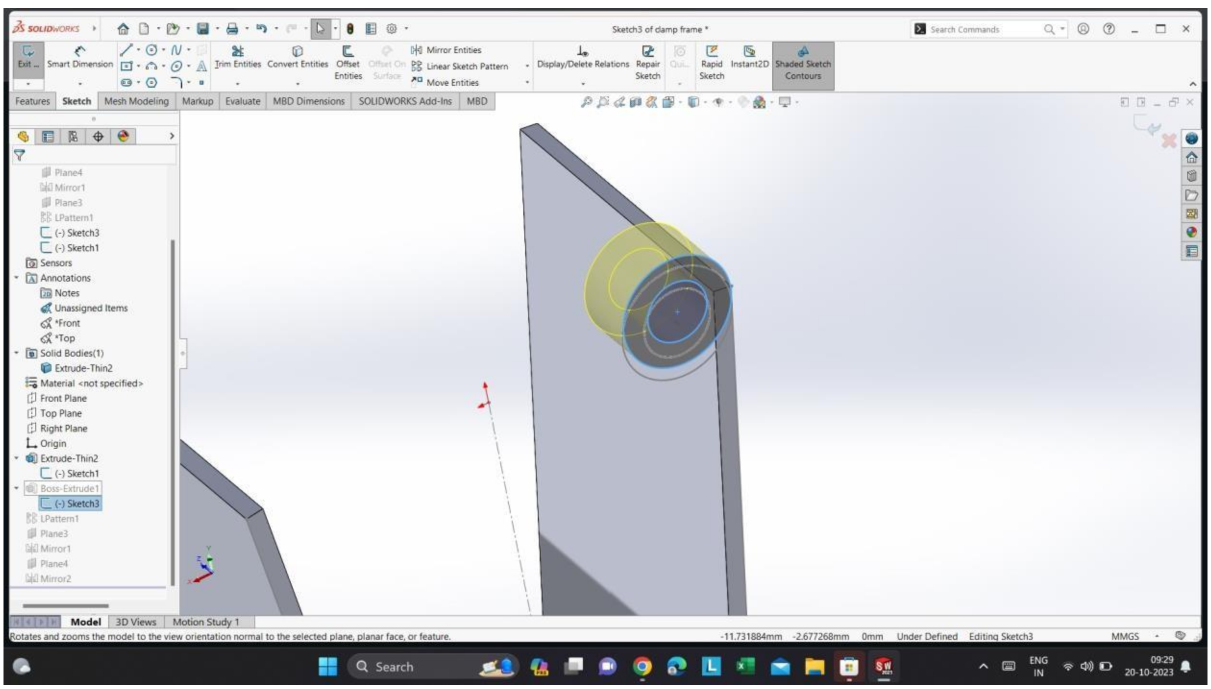
And also select the circle command of diameters Ø5mm and Ø3mm.

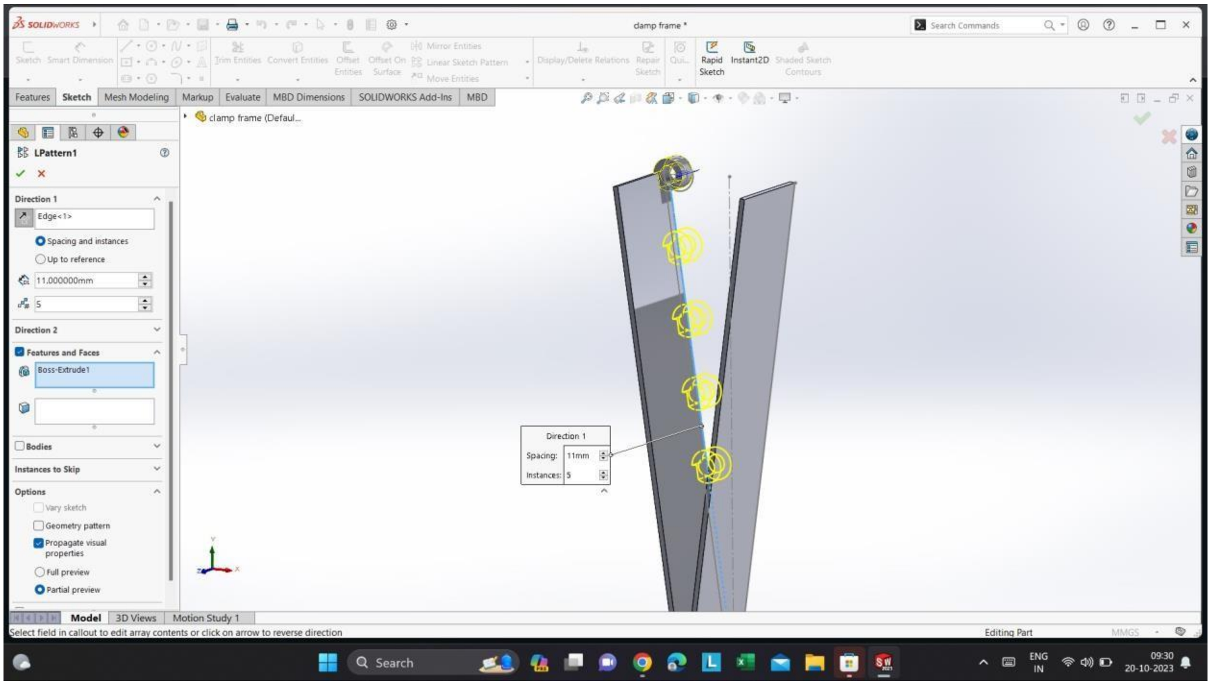


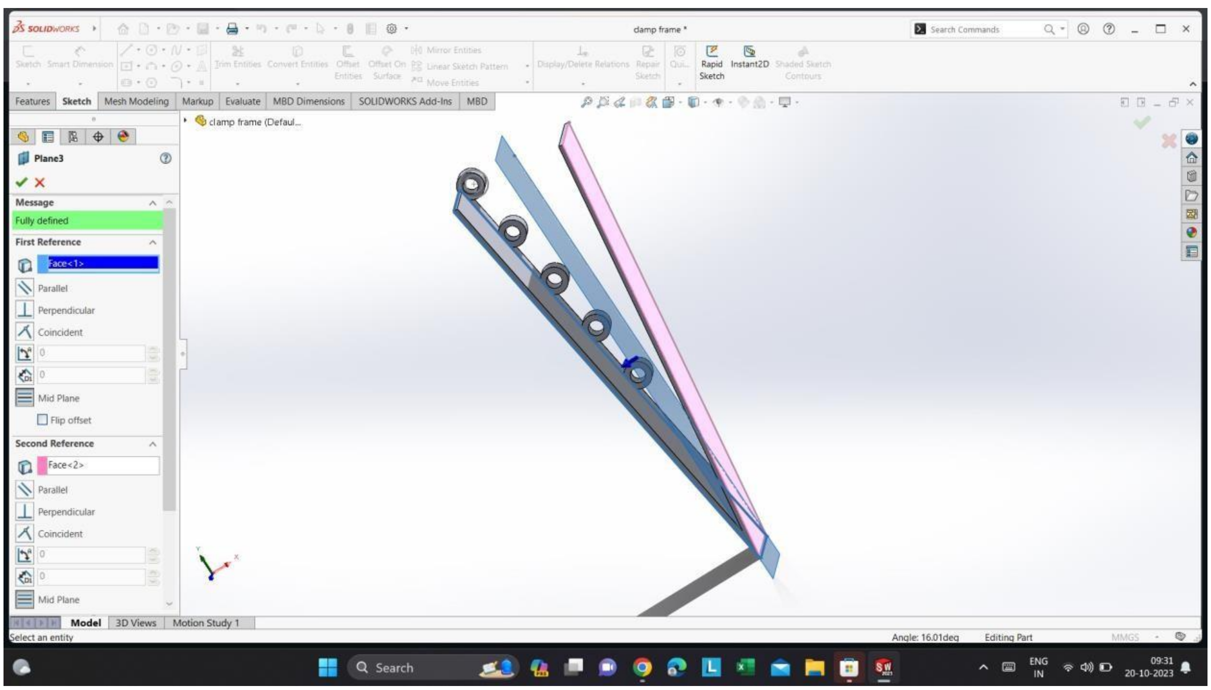
Extrude the triangle face up to 15mm.



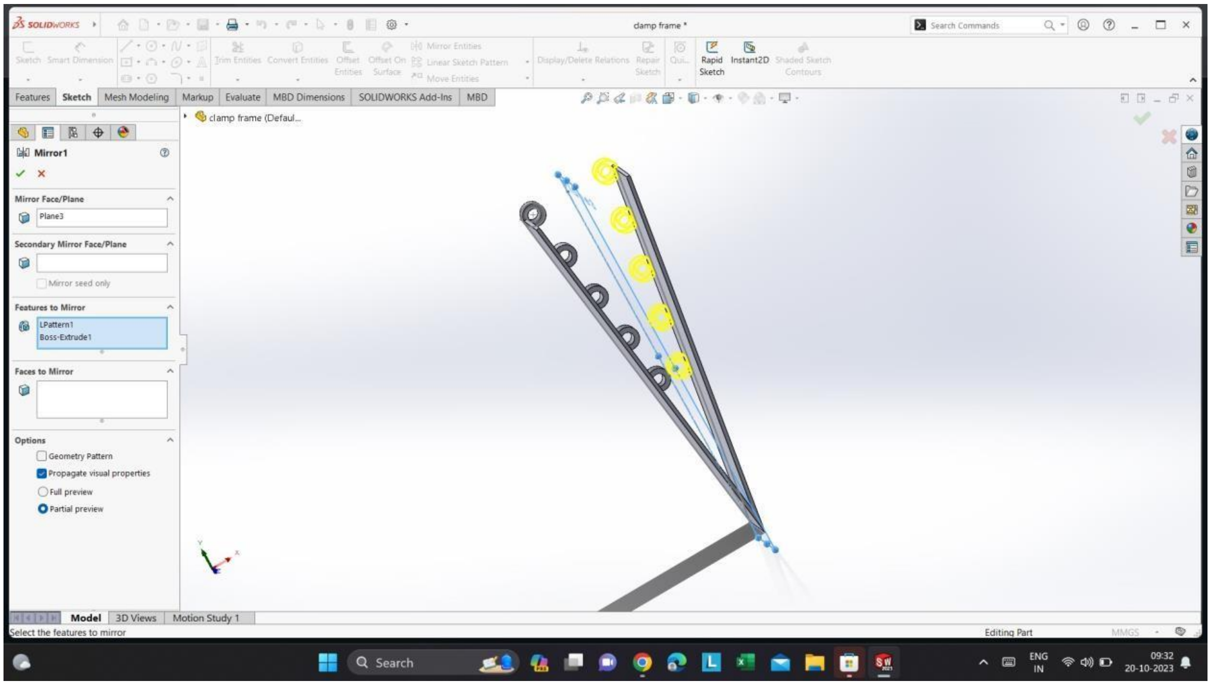
Select the extrude boss/base to the circle of 5mm upto 3mm inside to form a hollow surface.



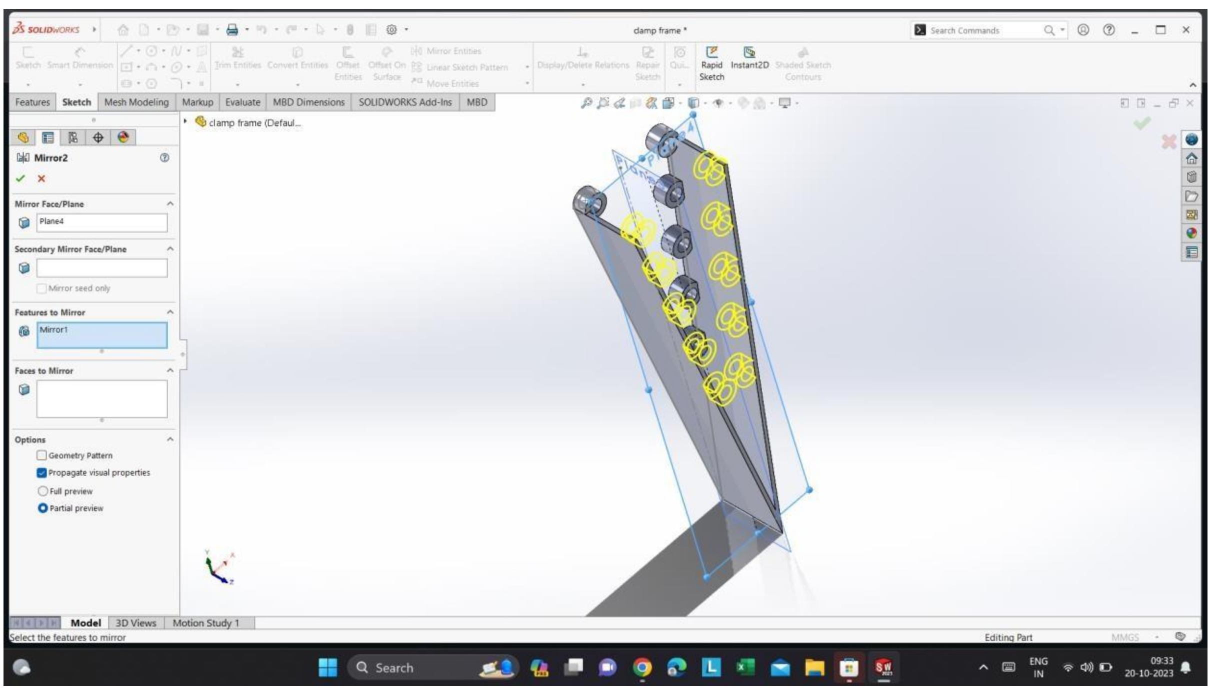




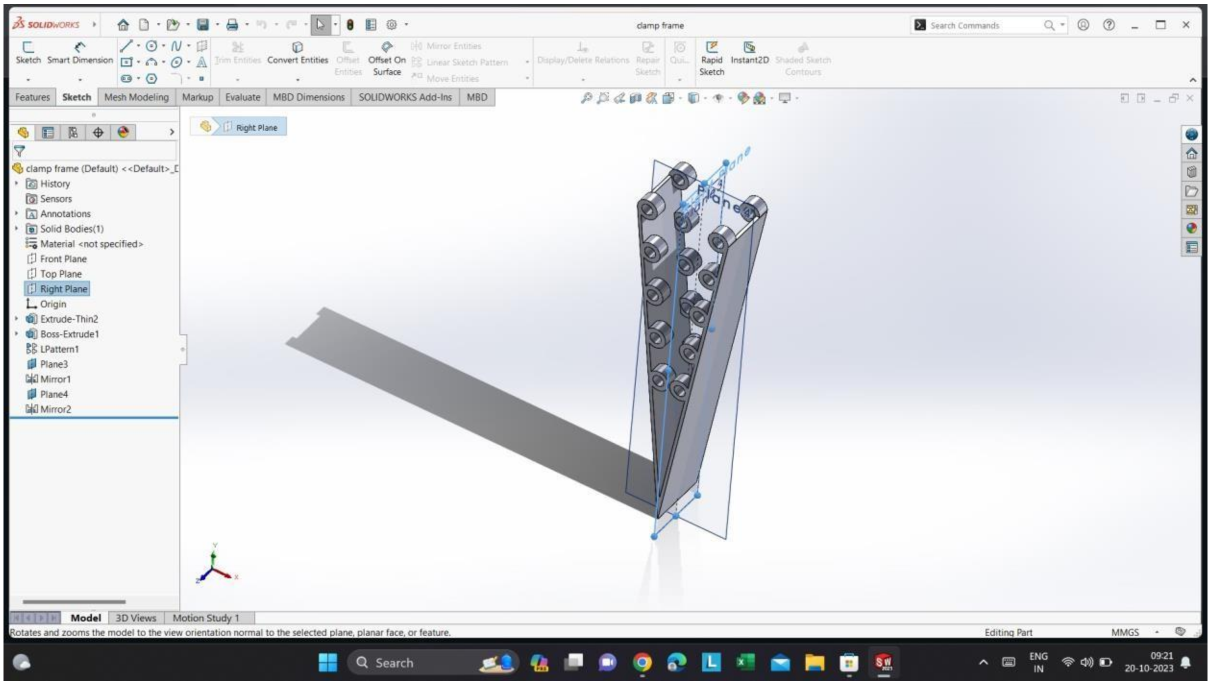
Select the plane and also select the references faces to form a plane in between them.



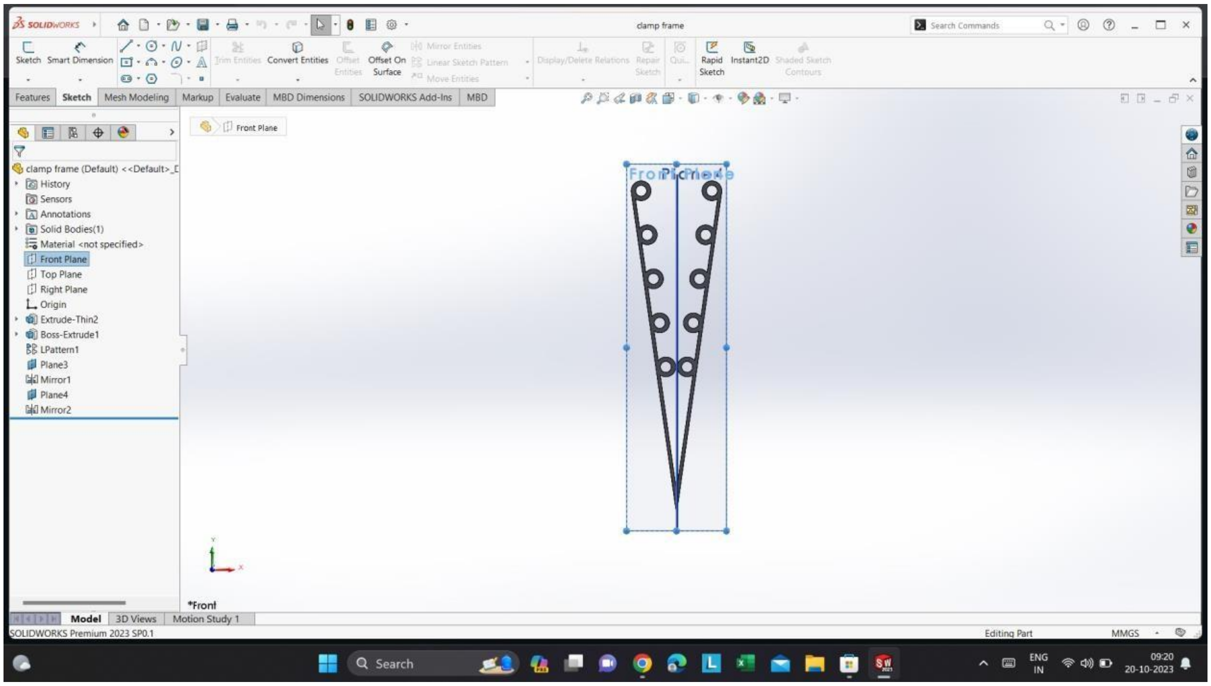
Select the mirror command to mirror the hollow circles through the plane to another side.

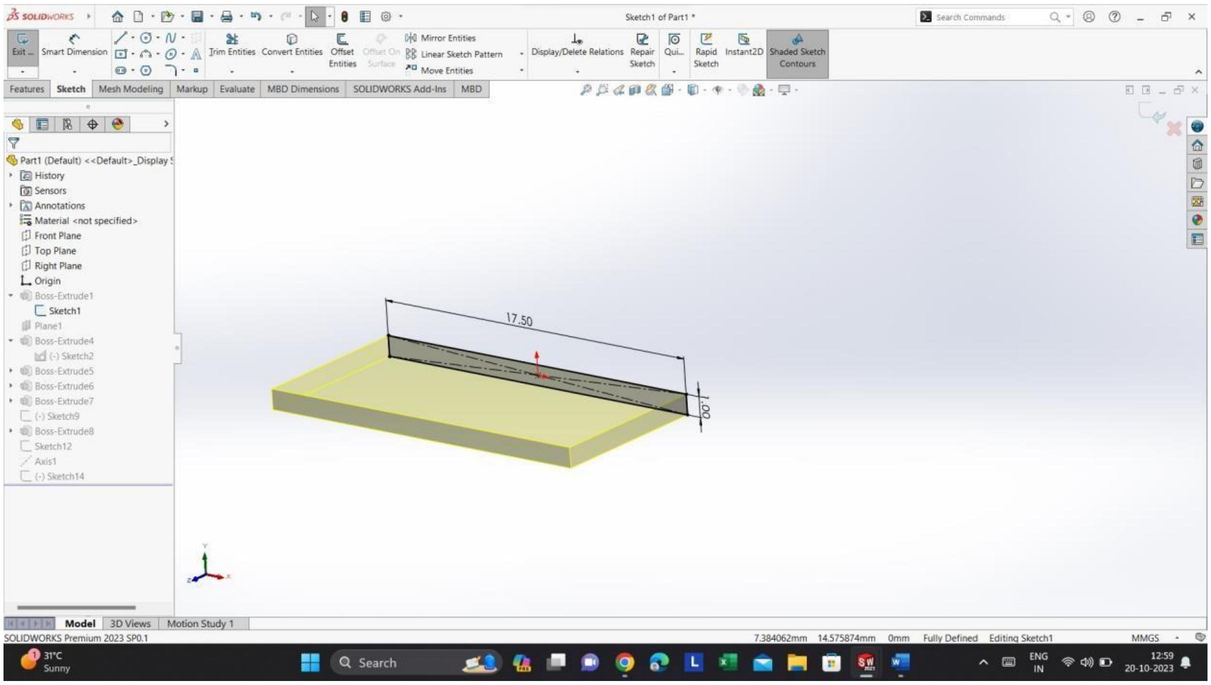


Again select the required plane4 perpendicular to plane3 and again to mirror the hollow circles to opposite side of plane4.

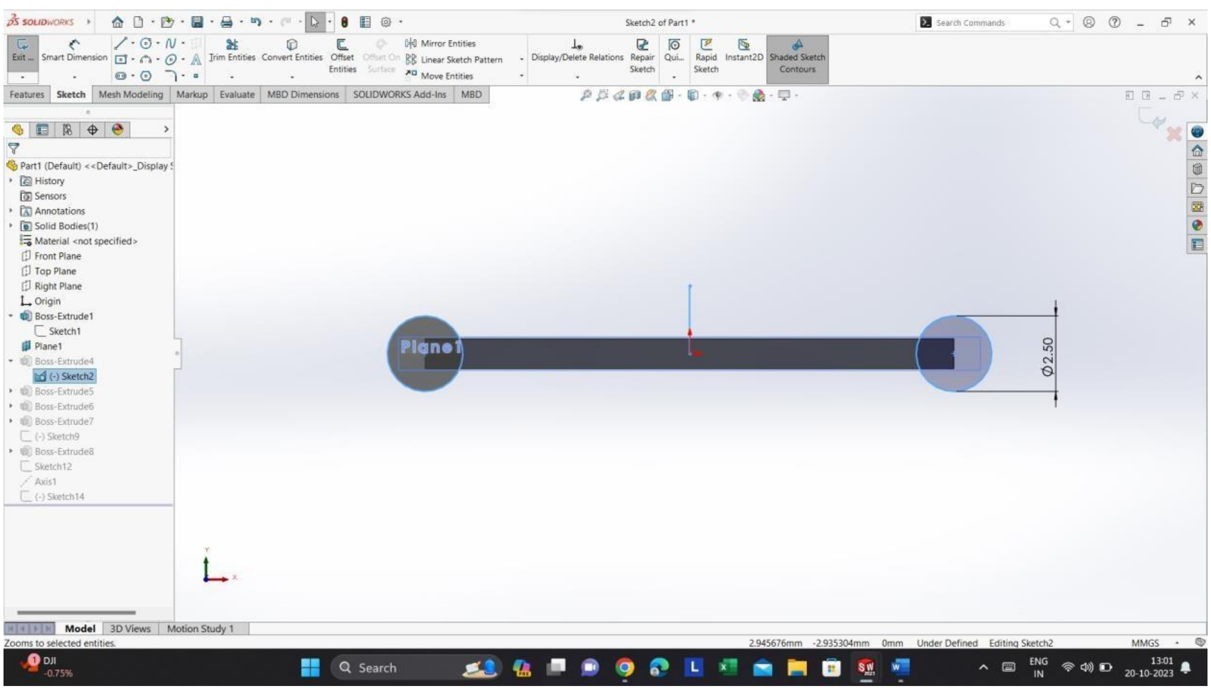


The extruded the hollow circles and triangular face.

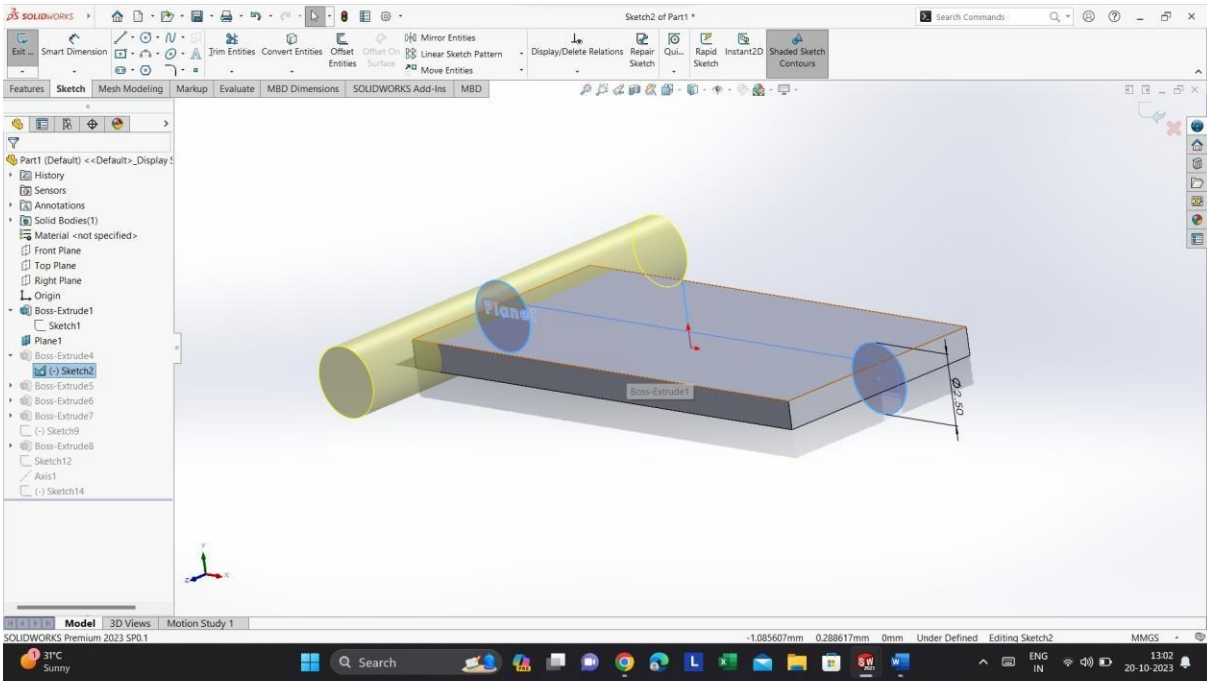




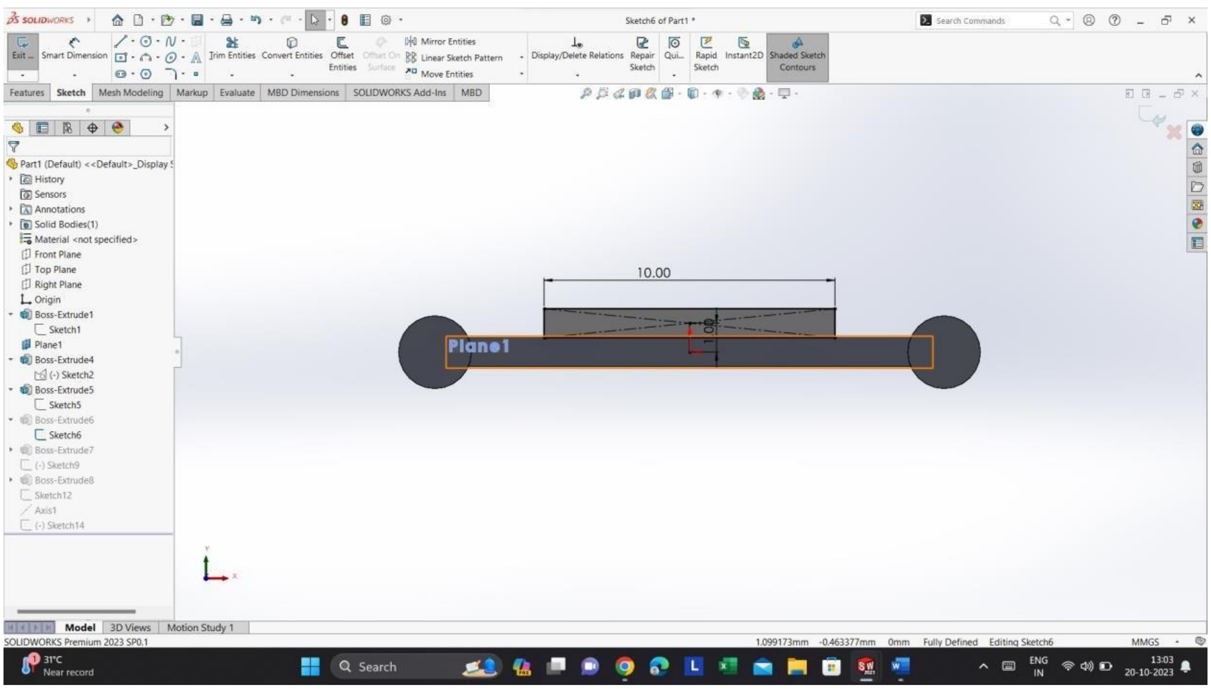
Select the rectangle face of length 17.5mm and width 1mm and extrude upto 10mm.



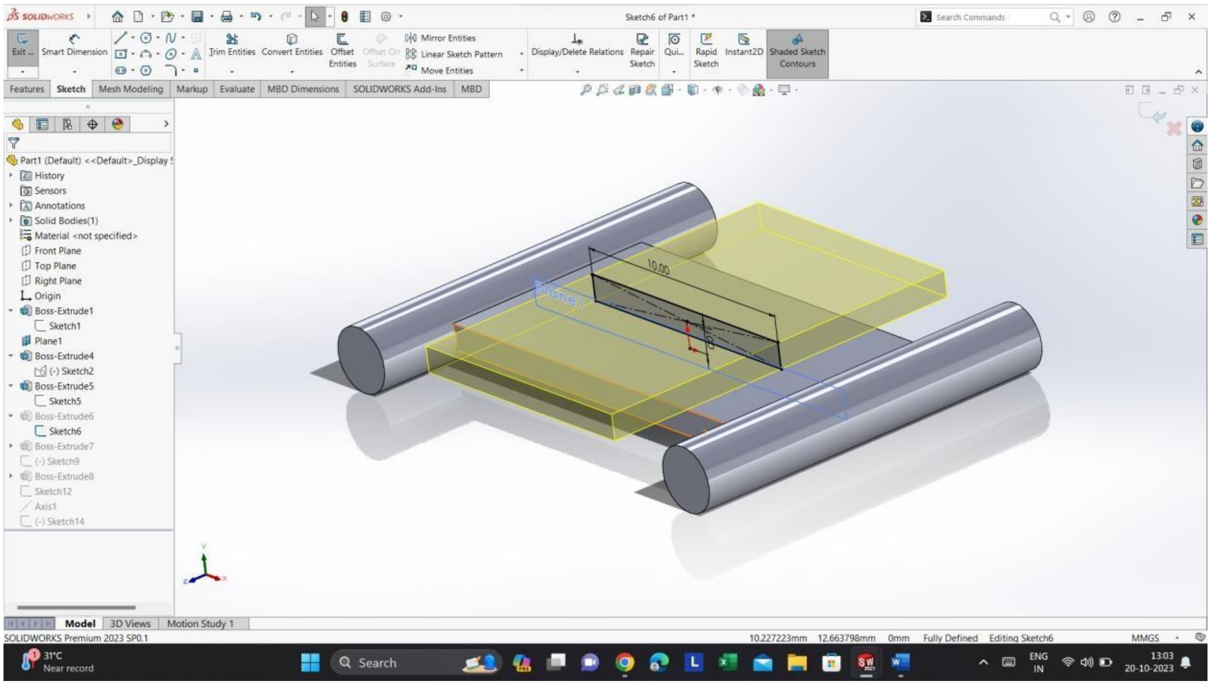
Select the circle of diameter Ø2.5mm on both sides of rectangle.



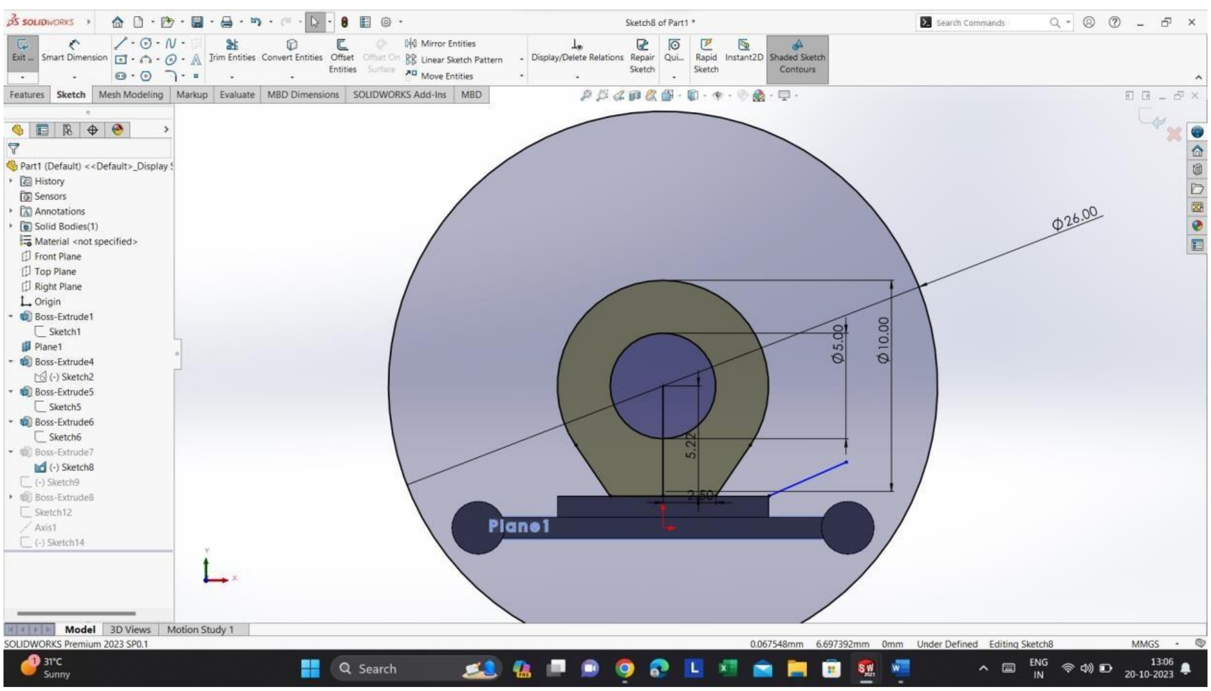
Select the extrude boss/base to the both circles upto 15mm.



Again draw the rectangle on top the rectangle sketch of length10mm and width 1mm.

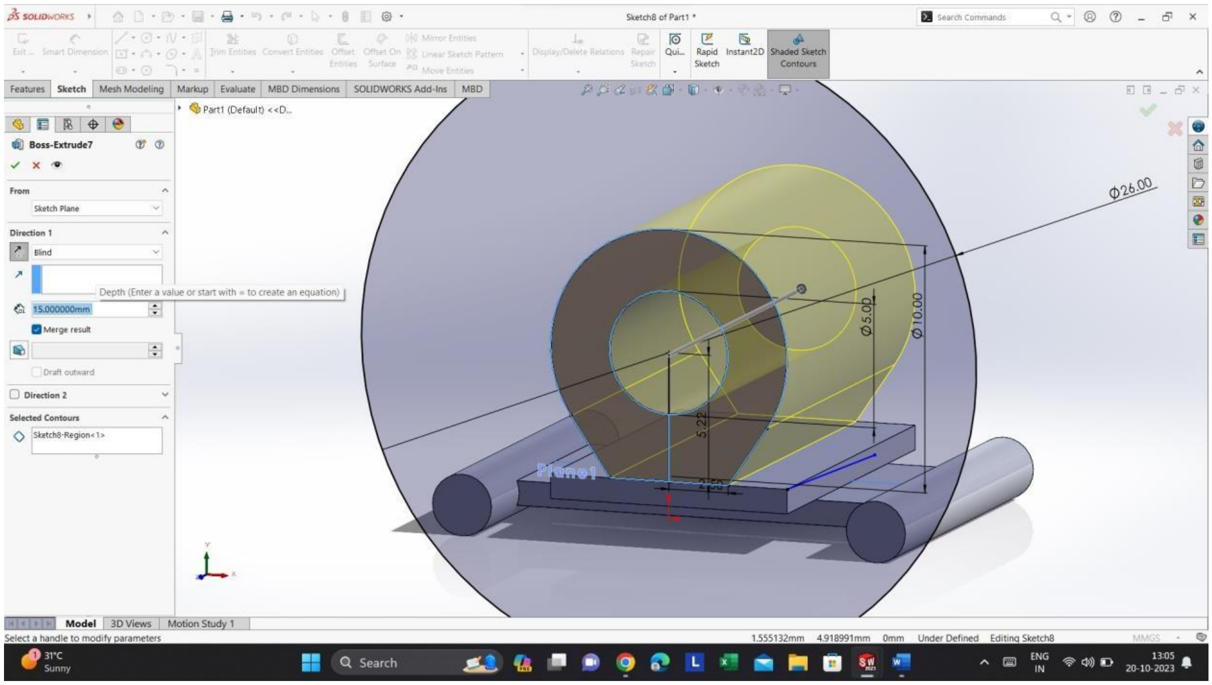


Extrude the rectangle upto 15mm.

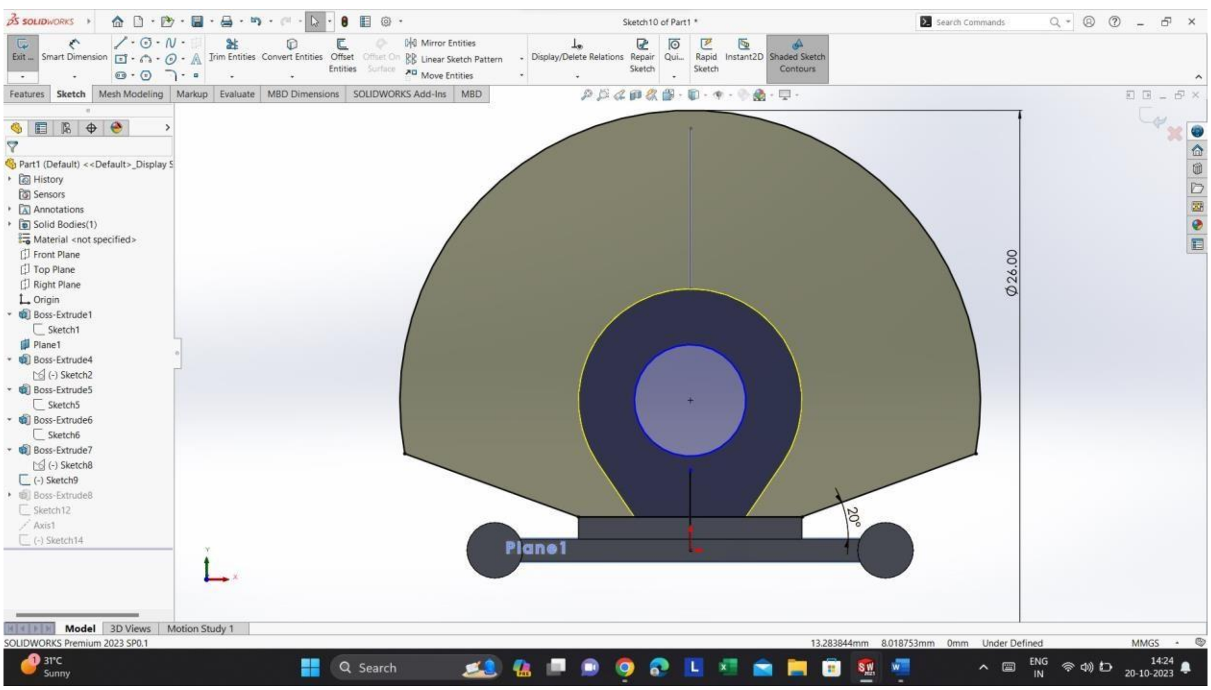


Select the circle of diameters Ø5mm, Ø10mm and Ø26mm.

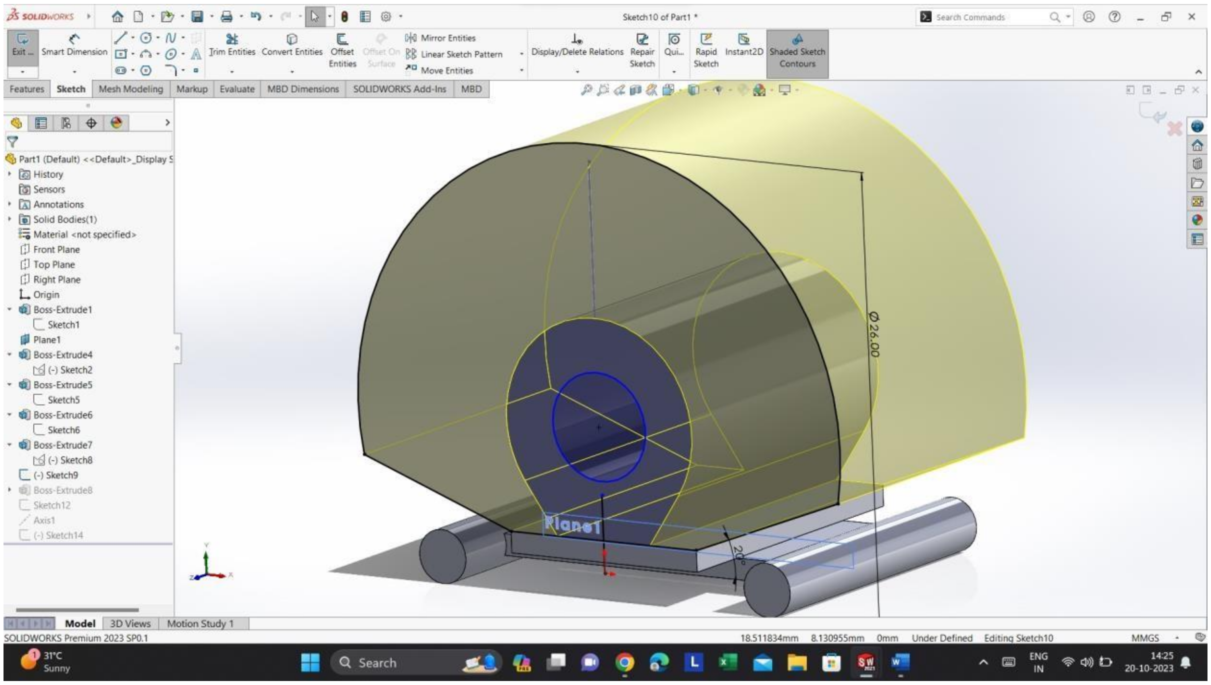
Join the circle of Ø10mm to the rectangle through lines and trim the unwanted lines from sketch.



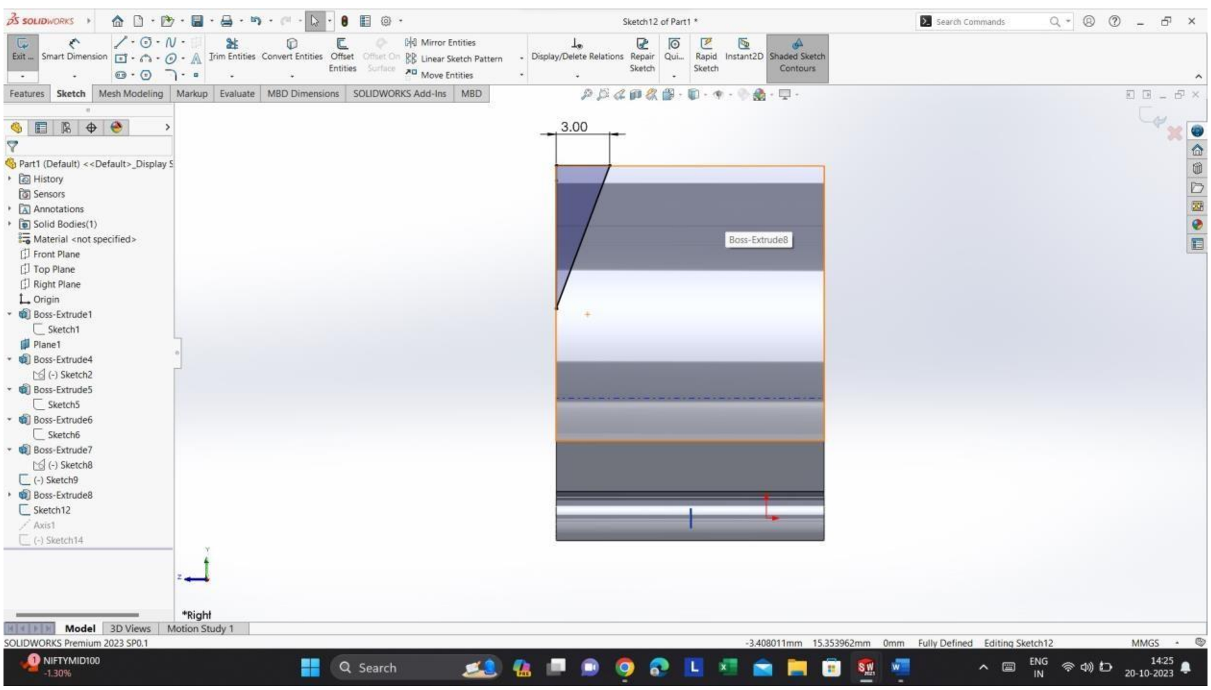
Select the extrude boss/base to Ø10mm circle to form hollow sketch from Ø5mm upto 15mm.



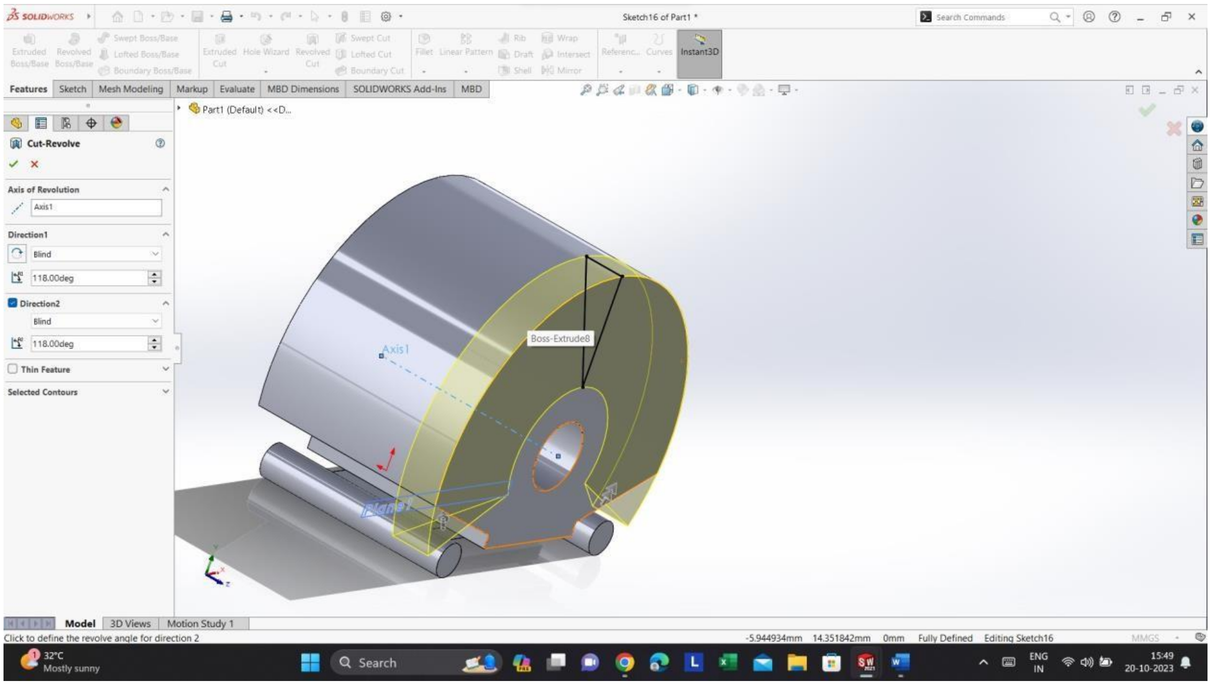
Select the trim command to remove unwanted lines from the Ø26mm circle and join the trim circle to the rectangle through line command.



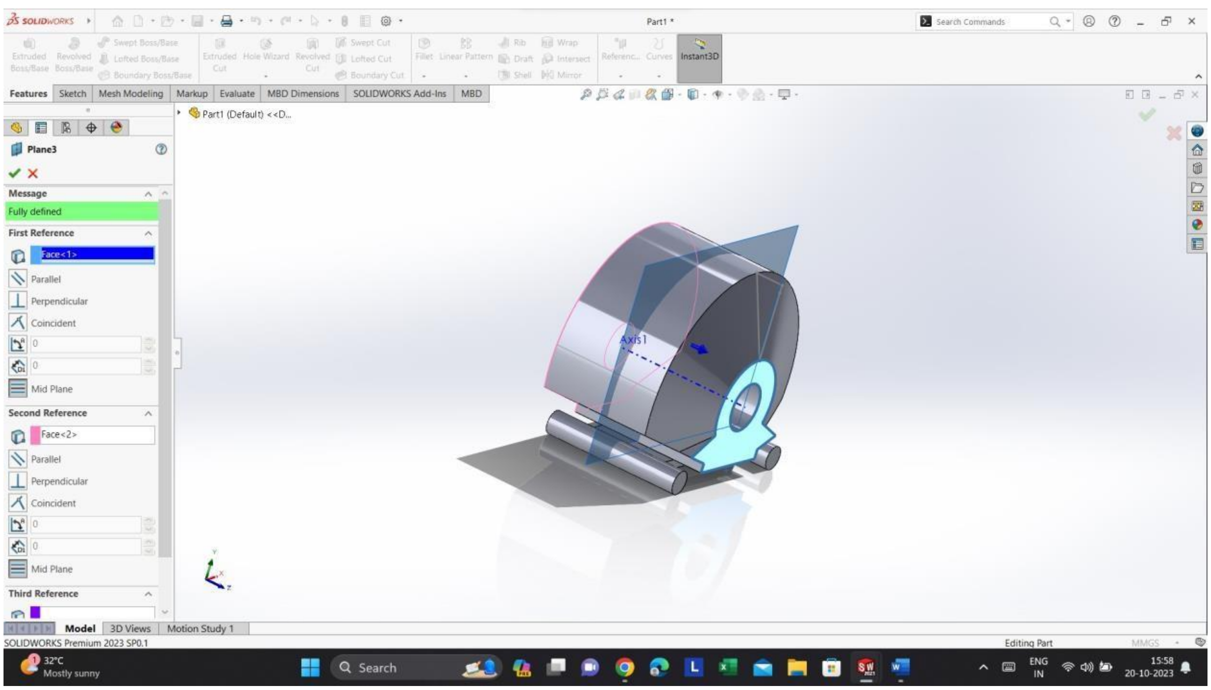
Extrude the circle of diameter Ø26mm upto 15mm.



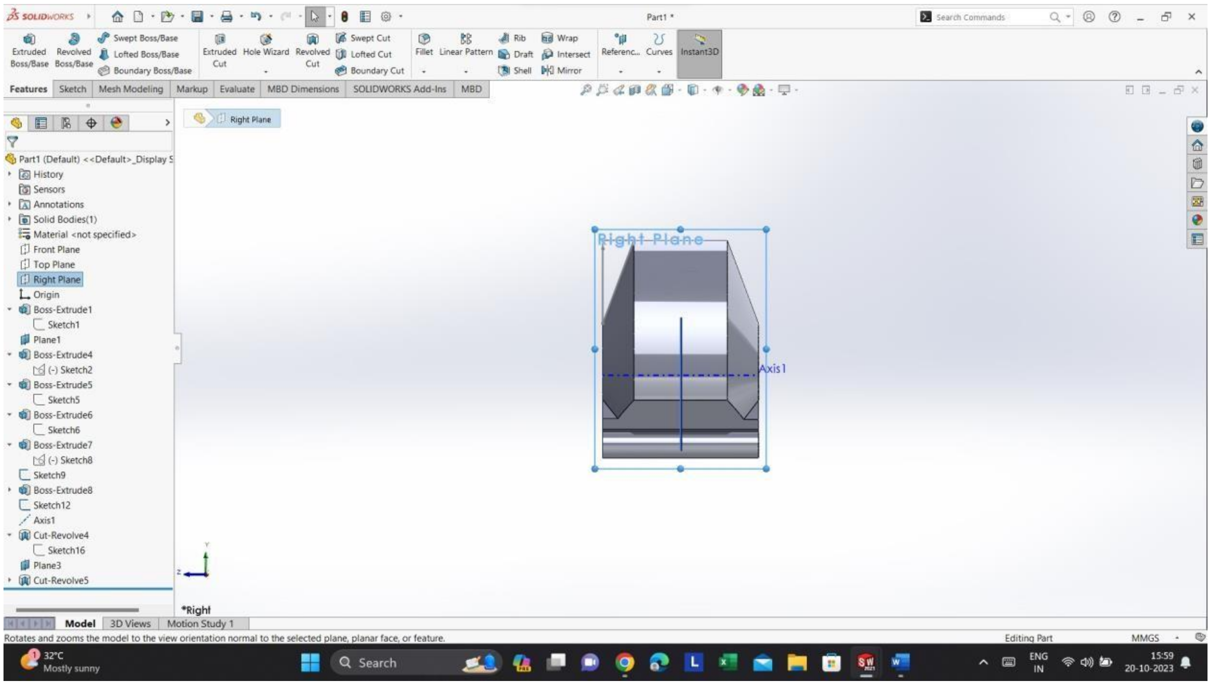
Select the right plane of sketch to form triangle sketch to required dimension.

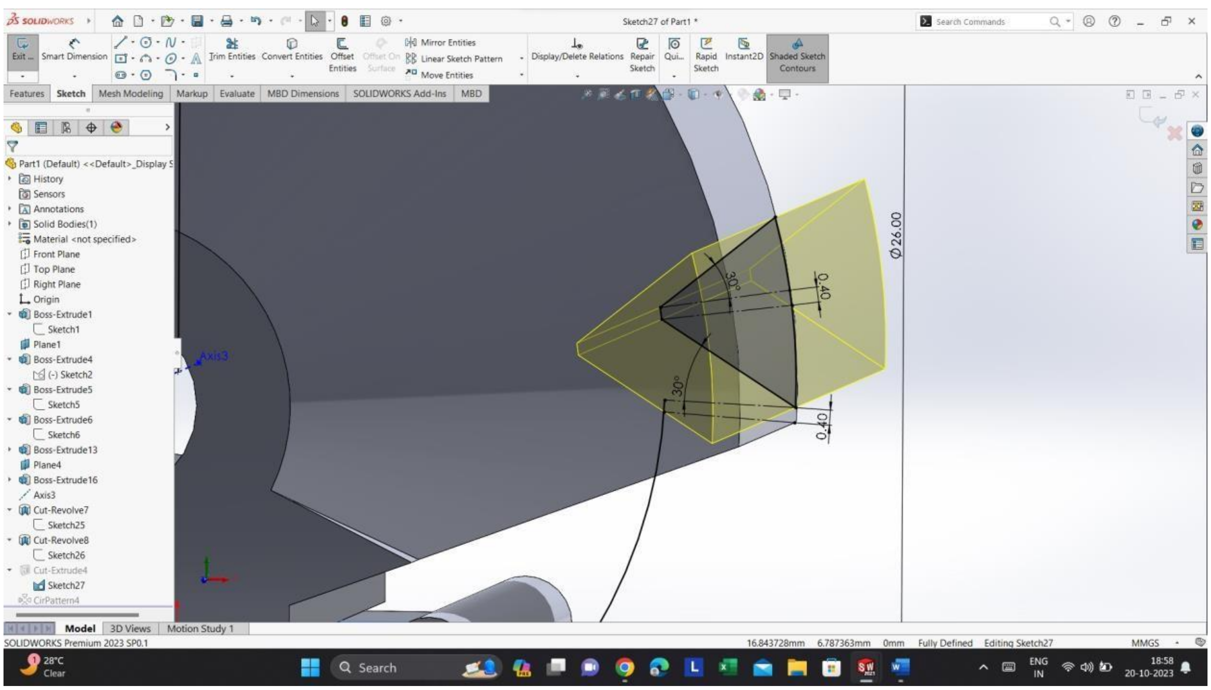


Select the revolve-cut to triangle sketch to the axis of circle in 118degrees direction.

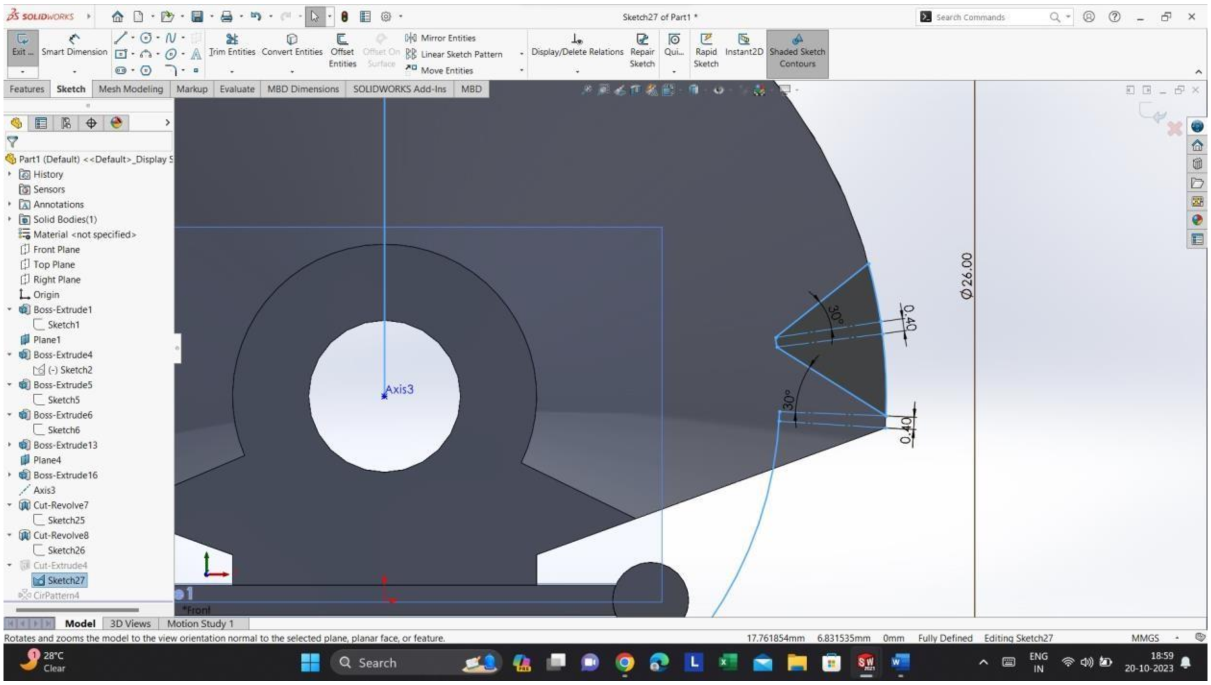


Select the plane references to the both faces of extruded circle and mirror the triangle sketch.

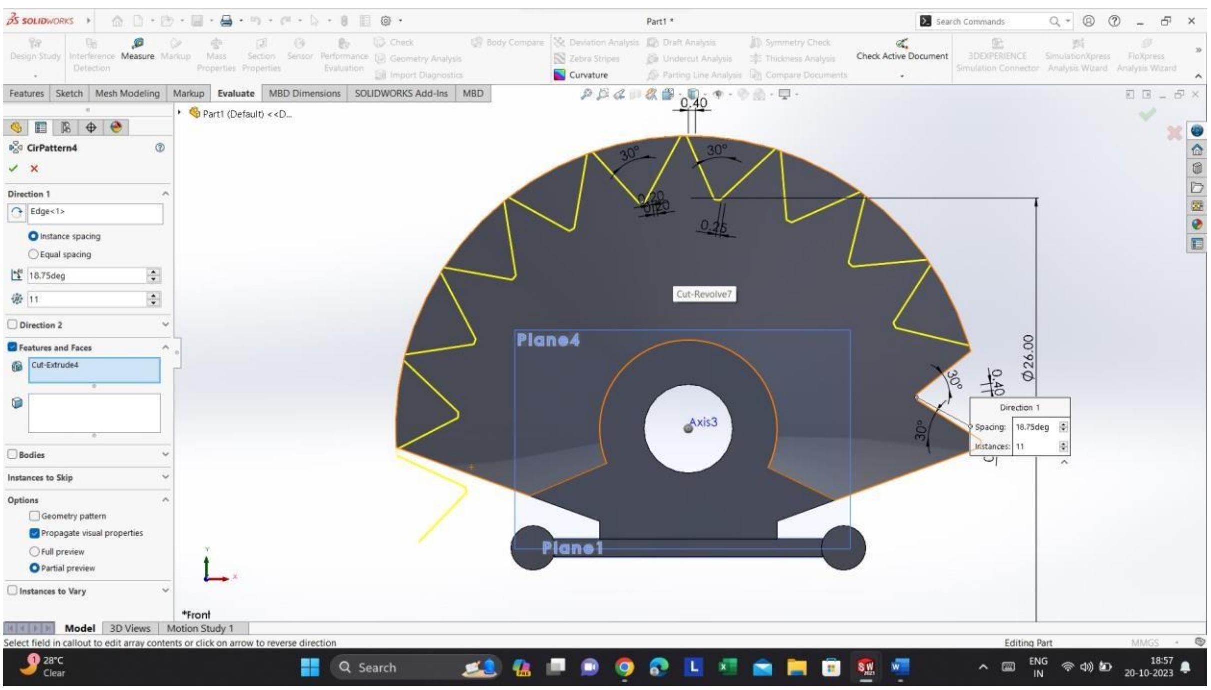




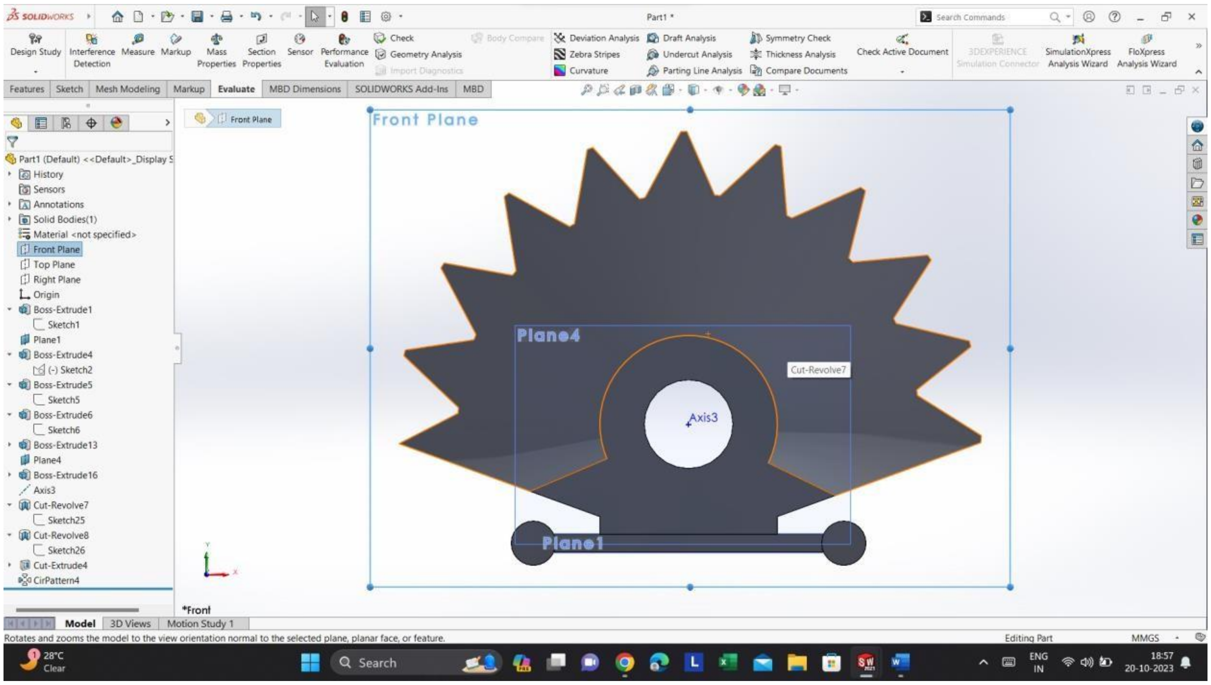
Select the line command in shape of triangle on the sketch to required dimension.



Select the extrude-cut to the sketch.



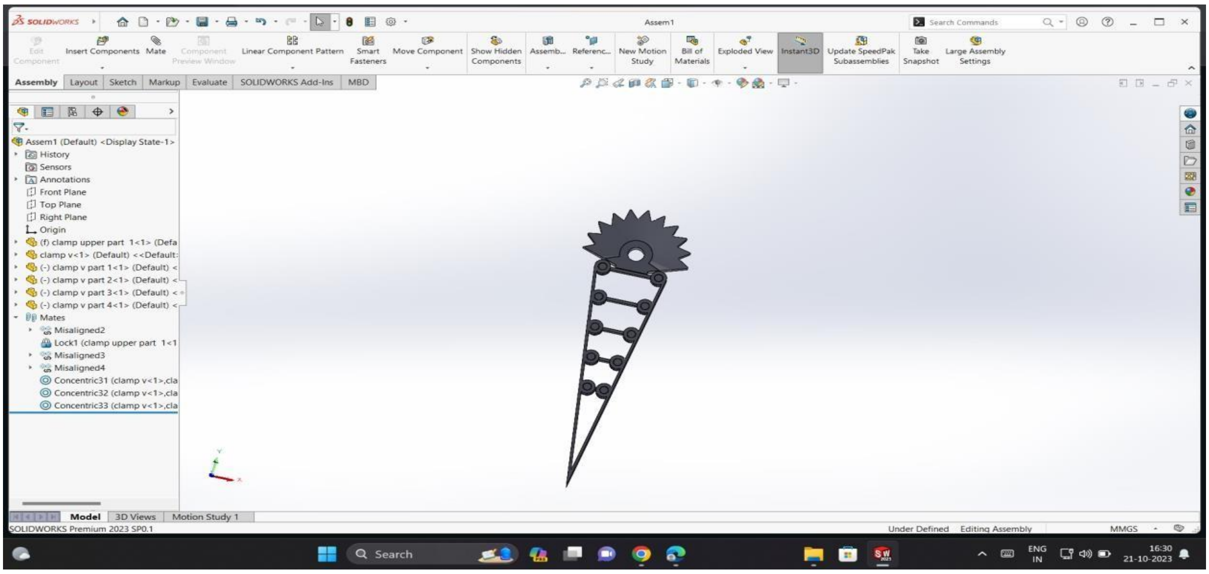
Select the circlepattern to the sketch upto required distance.



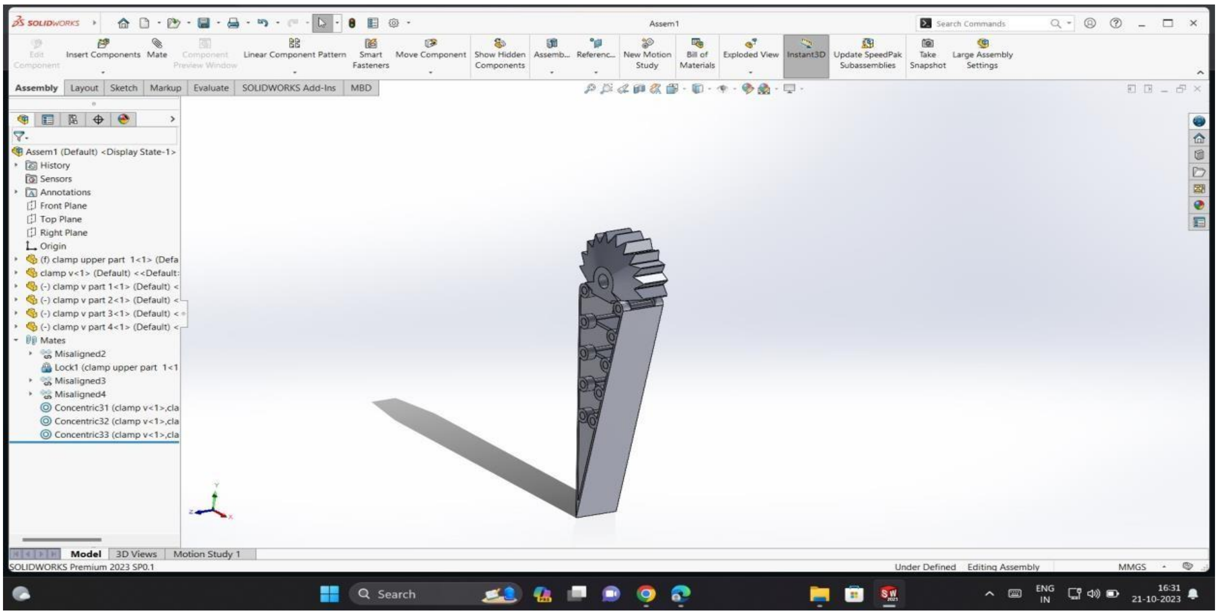
The required sketch is formed.

5.3 ASSEMBLY

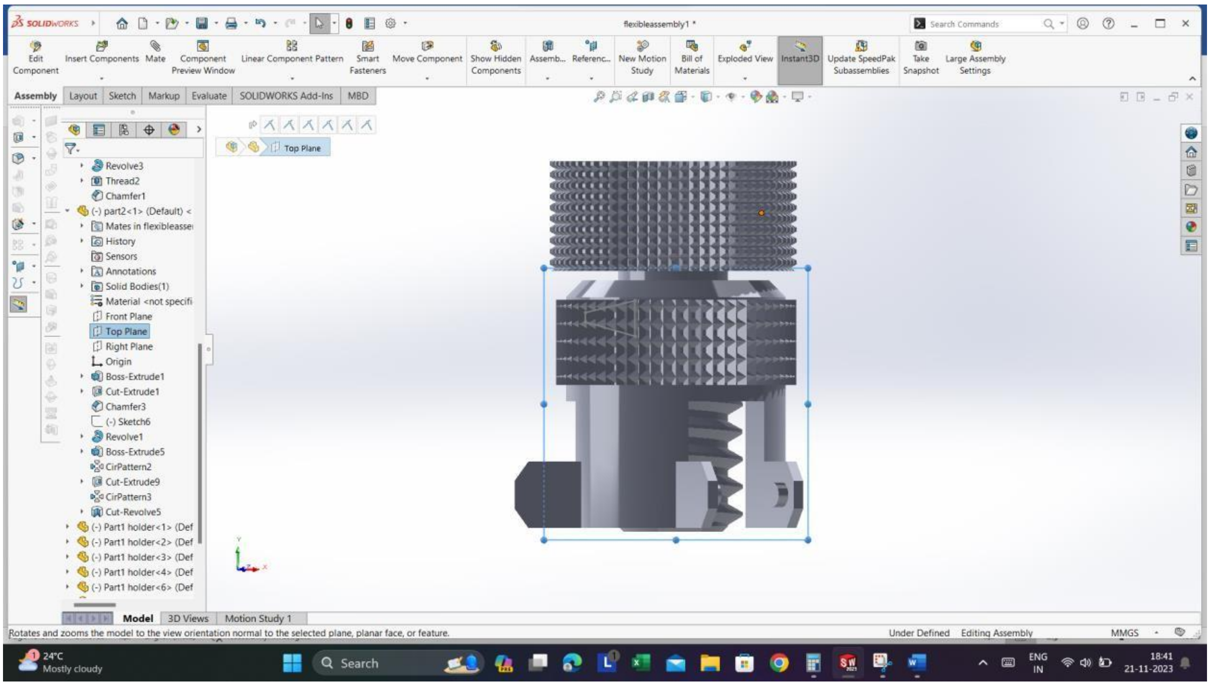
Before assembling the parts together use insert components in assembly part for different sketches.



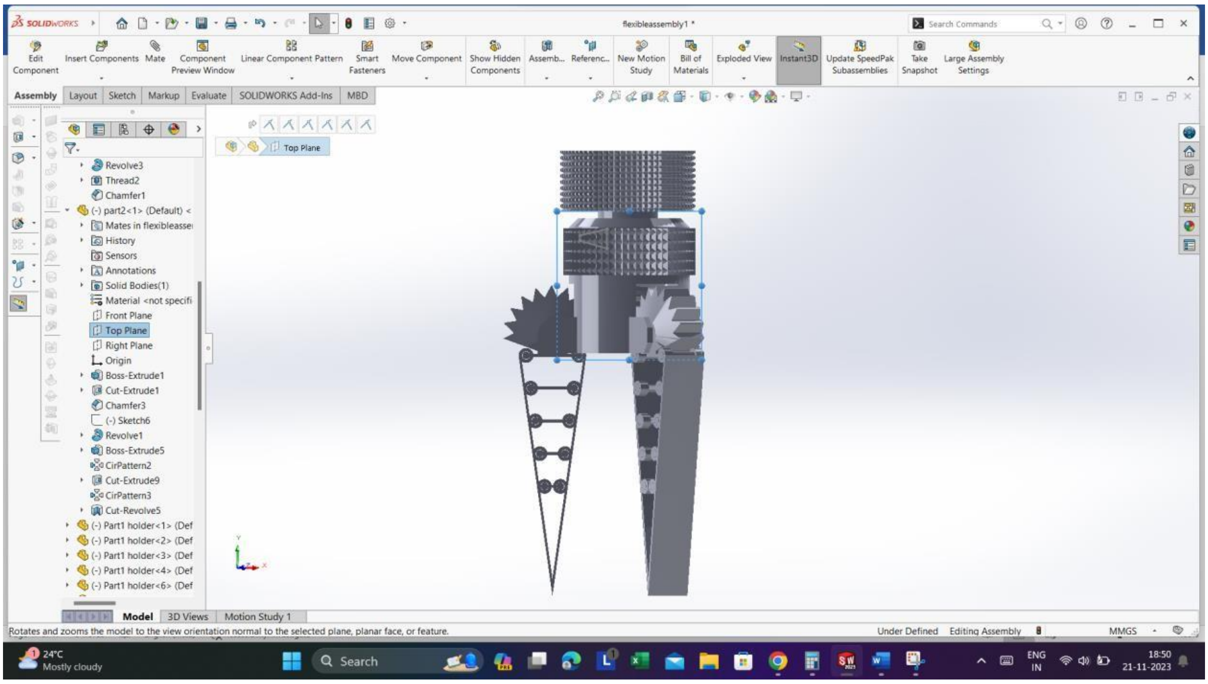
Assemble the upper part and bottom part of clamp using mate command through concentric point.



Isometric view of the clamp.



Assemble the upper and lower part of housing by using mate command through concentric point.Insert the components in assembly of housing and 3clamps together.



Assemble the 3calamps to housing on 3space opening of housing to required shape of flexible gripper.

Select the mate command to clamps and housing through concentric point and adjust them specified shape of flexible gripper.

5.4 CUSTOMIZATION AND ADAPTABILITY OF A MANUAL FLEXIBLE GRIPPER

The customization and adaptability of a flexible gripper play pivotal roles in its versatility across a spectrum of applications. These characteristics are crucial for addressing the varied shapes, sizes, and materials encountered in different tasks. One key feature is the ability to customize the gripper's configuration, allowing users to adjust its shape and grasping modes according to the specific needs of a task. This adaptability ensures that the gripper can efficiently handle objects with diverse geometries, offering a tailored approach for different applications.

Adjustable compliance is another noteworthy aspect of customization in flexible grippers. The compliance, or softness, of the gripper's materials can often be fine-tuned. This customization empowers users to modify the gripper's stiffness, making it suitable for handling delicate items with precision or providing a firmer grip for robust objects. The ability to adapt the compliance of the gripper enhances its versatility across a wide range of materials and applications.

Interchangeable fingers or attachments further contribute to the customization of flexible grippers. Users can easily swap out fingers or add specialized attachments based on the unique requirements of the task. This feature allows the gripper to adapt to various shapes and sizes of objects, facilitating efficient manipulation in scenarios where versatility is paramount.

The user-defined control inherent in manual flexible grippers is a key factor in their adaptability. Being operated directly by human users provides an intuitive and hands-on approach to control. This real-time control allows for immediate adjustments, ensuring precise manipulation based on the user's judgment and experience. The adaptability of manual control is particularly beneficial in dynamic environments where tasks may vary, and quick adjustments are necessary.

Task-specific adjustments further highlight the customization capabilities of flexible grippers. Users can make on-the-fly modifications to parameters such as grip strength, compliance, and finger configuration, tailoring the gripper's behavior to suit the specific demands of different tasks. This adaptability is essential in environments where the characteristics of the objects being handled can change rapidly.

Moreover, the ease of integration with tools and accessories enhances the overall adaptability of flexible grippers. These grippers are often designed to work seamlessly with various tools, expanding their functionality and allowing users to customize the gripper for specific applications. This integration capability ensures that the gripper can be adapted to perform a wide range of tasks beyond basic object manipulation.

In conclusion, the customization and adaptability of flexible grippers empower users with the flexibility to tailor the gripper's behavior and configuration, making them indispensable tools in industries that require versatile and efficient manipulation of objects with diverse shapes, sizes, and materials.

5.5 MATERIAL SELECTION FOR 3D PRINTING

MATERIAL	FEATURES	APPLICATIONS
ABS (acrylonitrile butadiene styrene)	Tough and durable Heat and impact resistant Requires a heated bed to print Requires ventilation	Functional prototypes
PLA (polylactic acid)	The easiest FDM materials to print Rigid, strong, but brittle Less resistant to heat and chemicals Biodegradable Odorless	Concept models Looks-like prototypes
PETG (polyethylene terephthalate glycol)	Compatible with lower printing temperatures for faster production Humidity and chemical resistant High transparency Can be food safe	Waterproof applications Snap-fit components
Nylon	Strong, durable, and lightweight Tough and partially flexible Heat and impact resistant Very complex to print on FDM	Functional prototypes Wear resistant parts
TPU (thermoplastic polyurethane)	Flexible and stretchable Impact resistant Excellent vibration dampening	Flexible prototypes
PVA (polyvinyl alcohol)	Soluble support material Dissolves in water	Support material
HIPS (high impact polystyrene)	Soluble support material most commonly used with ABS Dissolves in chemical limonene	Support material
Composites (carbon fiber, kevlar, fiberglass)	Rigid, strong, or extremely tough Compatibility limited to some expensive industrial FDM 3D printers	Functional prototypes Jigs, fixtures, and tooling

Table 5.1 :- Material Selection For 3D Printing

MATERIALS USED IN FDM FOR 3D PRINTING

POLYLACTIC ACID (PLA)

Polylactic Acid (PLA) is different than most thermoplastic polymers in that it is derived from renewable resources like corn starch or sugar cane. Most plastics, by contrast, are derived from the distillation and polymerization of non-renewable petroleum reserves. Plastics that are derived from biomass (e.g. PLA) are known as “bioplastics.”

Polylactic Acid is biodegradable and has characteristics similar to polypropylene (PP), polyethylene (PE), or polystyrene (PS). It can be produced from already existing manufacturing equipment (those designed and originally used for petrochemical industry plastics). This makes it relatively cost efficient to produce. Accordingly, PLA has the second

Largest production volume of any bioplastic (the most common typically cited as thermoplastic starch).

Figure 5.1:- POLYLACTIC ACID (PLA)(biobasedpress.eu)

PROPETY OF PLA

Property	Value
Technical Name	Polylactic Acid (PLA)
Chemical Formula	(C3H4O2)n
Melt Temperature	PLLA: 157 - 170 °C (315 - 338 °F)
Typical Injection Moulding Temperature	PLLA: 178 - 240 °C (353 - 464 °F)
Heat Deflection Temperature (HDT)	49 - 52 °C (121 - 126 °F) at 0.46 MPa (66 PSI)
Tensile Strength	PLLA: 61 - 66 MPa (8840 - 9500 PSI)
Flexural Strength	PLLA: 48 - 110 MPa (6,950 - 16,000 PSI)
Specific Gravity	PLLA: 1.24
Shrink Rate	PLLA: 0.37 - 0.41% (0.0037 - 0.0041 in/in)

Table 5.2:- Property Of Polylactic Acid (PLA)

5.6 3D PRINTING PROCESS

Step 1: ON the 3D printer.

Step 2: Select the Setting and click on the Leveling Method ,lift the panel to the center of Leveling.

Figure 5.2 :- Home Page(the3dprinterbee.com/ender-5-s1)

Step 3:Now keep the A4 size paper between the nozzle and the panel to set the level of Nozzle to panel ,move the paper to different points until the setting Completes as shown in the figure .

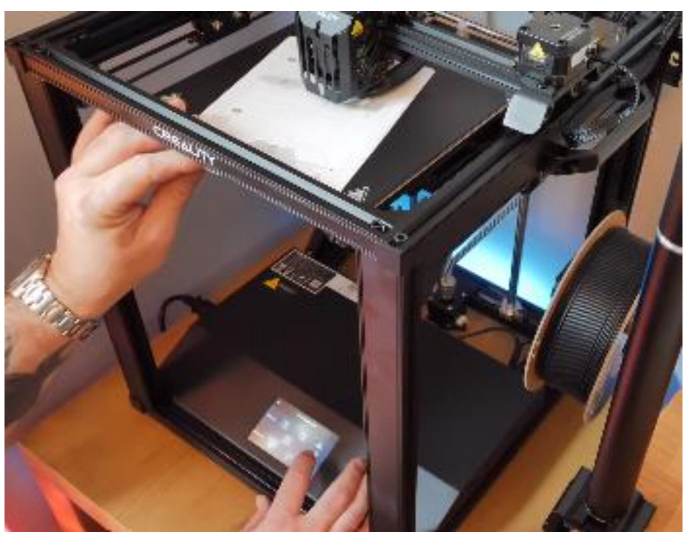


Figure 5.3 :- Leveling Method(the3dprinterbee.com/ender-5-s1)

Step 4: Now press the auto leveling and press start , then with the help of nozzle sensor The auto leveling is done as show in figure 5.2.

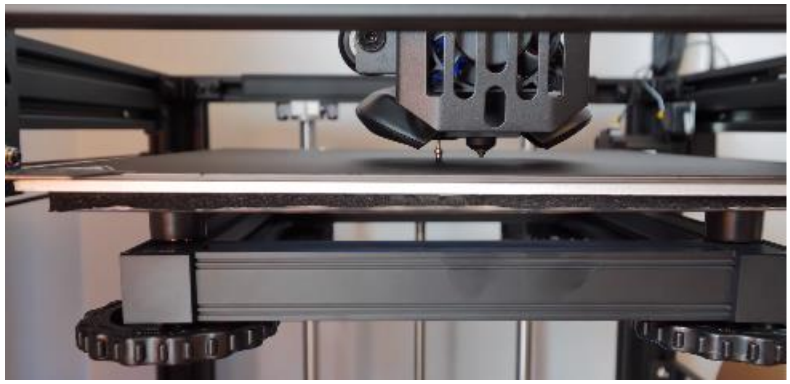


Figure 5.4 :- Auto Leveling(the3dprinterbee.com/ender-5-s1)

Step 5:- now click on the prepare and select the temperature setting .

Figure 5.5 :- Prepare setting(the3dprinterbee.com/ender-5-s1)

Step 6:- Set the nozzle temperature 205, H&B temperature 60.

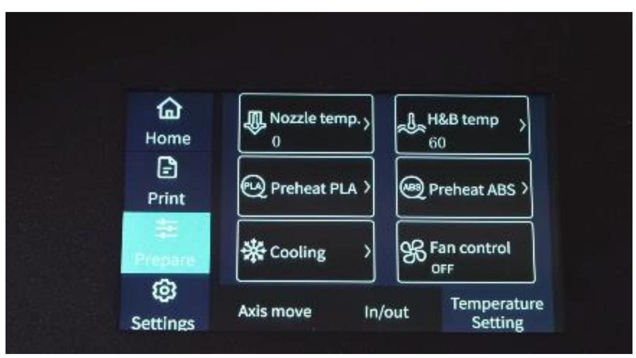


Figure 5.6 :- Setting the temperature(the3dprinterbee.com/ender-5-s1)

Step 7:- click on home

Figure 5.7 :- home page(the3dprinterbee.com/ender-5-s1)

Step 8:- Now copy the Flexible Gripper components in SD card and Insert the SD card in 3D printer

Figure 5.8 :- SD card(the3dprinterbee.com/ender-5-s1)

Step 9:- now click on the print and select the file .

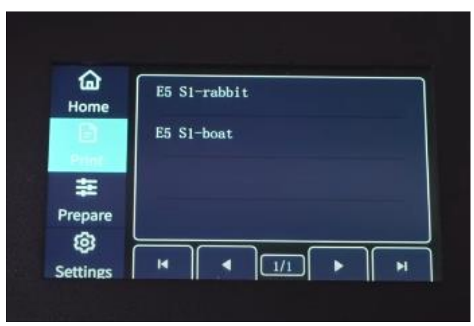


Figure 5.9 :- Selecting the folder(the3dprinterbee.com/ender-5-s1)

Step 10 :- print the components and then complete the post process as shown in below Figure.

Figure 5.10 :- Post processing

Step 11:- final product

Figure 5.11:- Final product

CHAPTER 6

RESULTS AND DISCUSSIONS

The culmination of the design and prototyping phases leads to a comprehensive evaluation of the flexible gripper's performance. This section delves into the results obtained from SolidWorks, the assessment of the 3D printed prototype, and a comparative analysis against traditional gripper designs.

A comparative analysis is conducted to benchmark the flexible gripper against traditional gripper designs prevalent in industrial settings.By contrasting the flexible gripper's performance with traditional counterparts, the project aims to showcase its advantages and highlight areas where it outperforms or offers unique benefits. This comparative discussion contributes valuable insights for potential adopters seeking to enhance their automation systems.

The results and discussions in this section provide a comprehensive understanding of the flexible gripper's capabilities, bridging the gap between theoretical design and practical implementation. The combination of solid works results, prototype evaluation, and comparative analysis forms a robust foundation for assessing the project's success in achieving its objectives and contributing to the field of flexible gripper technology.

The 3D printed prototype represents the physical manifestation of the virtual design. This section evaluates the prototype's real-world performance and functionality. Factors such as material compatibility, precision in printing, and the gripper's response to different tasks are scrutinized. The evaluation includes practical testing under simulated operational conditions to assess the gripper's adaptability and reliability. Any discrepancies between the simulated model and the physical prototype are addressed, and adjustments may be made for optimization.

CONCLUSIONS

The development of a flexible gripper with SolidWorks software and subsequent prototyping through 3D printing addresses the current limitations of rigid gripper systems in the realm of industrial automation. By achieving the outlined objectives, this project aims to contribute to the evolution of robotics and automation, providing industries with a more adaptable and cost-effective solution. The use of SolidWorks for design ensures precision and accuracy in the virtual model, while 3D printing offers a rapid and customizable prototyping process.

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