DESIGN AND ANALYSIS OF MODULAR FIXTURE FOR FLEXIBLE MANUFACTURING

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Abstract

This project, "Design and Analysis of Modular Fixture for Flexible Manufacturing" addresses the need for adaptable fixtures in mechanical engineering. With the growing demand for customized and efficient manufacturing, the project focuses on creating a flexible fixture system that can easily adapt to different production requirements. The primary goals of the project are:

1. Reduce the time needed for handling and assembling real products after material handling, streamlining manufacturing processes.
2. Improve the fixture's ease of operability, making it simple to adjust for various manufacturing tasks.

By using advanced design and analysis techniques, such as computer-aided design (CAD) and finite element analysis (FEA), the project aims to optimize the fixture's strength, precision, and versatility.

Additionally, the project contributes to the broader goal of improving sustainability in manufacturing and reducing environmental impact.

The expected outcome of this research is to enhance manufacturing flexibility, shorten production times, improve usability, and increase the overall efficiency and cost-effectiveness of manufacturing in different industries.

Keywords: modular fixture, flexible manufacturing, adaptability, operability, Finite Element Analysis (FEA) optimization, sustainability, and efficiency.

1. INTRODUCTION

Fixture is to provide a secure mounting point for a work piece, allowing for increased accuracy, precision, reliability, and interchangeability in the completed parts. Batch production is the commonly used method in various small and large manufacturing industries. At assembly an angle surface over another angle surface is very challenging so is positioning the components Because of the manual process, positioning a task in mass Production takes a lot of time.

Fixtures must correctly locate a work piece in each orientation with respect to tool or measuring device or with respect to another component, as in assembly. An assembly fixture is a device used in the process to reduce the setup time for each job operation and ensure the accuracy of the size. Fixture improves production efficiency by allowing for smooth operation and quick transitions from part to part, reducing labor work by simplifying the mounting of work pieces, and improving conformity across a production run.

Fixture design and development is a complex process that various knowledge of a broad array of topics, including geometry, tolerances, specifications, procedures, and manufacturing processes. The clamping and holding devices for the work piece in that position during the processing operation must be invariant. Clamps produce clamping forces so that the work piece is pushed firmly against locators, whereas locators are used to determining the position and orientation of a work piece. Clamping must be properly considered for the development of the assembly fixture.

The costs associated with fixture design and manufacturing can account for 10%–20% of the total cost of a manufacturing system. The motivation for undertaking this project is to enhance the assembly process by designing a fixture with the target of decreasing production cycle time. Presently there are many fixtures available, those are very time-consuming for clamping product or part. Assembly fixture allows workers to adjust and fix all sides of part with the angle of the upper and lower sides of the product exposed during the process. Clamping is difficult at a certain level of the frame’s height.

Fixtures are used to secure and stabilize parts within a solid assembly. Their purpose is to obtain the best possible accuracy in the mutual positions of the individual connected components, as well as to eliminate the forces generated by these components. Internal tensions in welds and compressive pressures in the assembly process another crucial criterion is a quick modification of the situation. Changes to the welded components.

Aim and Objectives

The aim is to create detailed fixture designs that completely specify the locating/clamping units based on a thorough understanding of each unit's function. The main objective fixture is to adjust and all sides of product with the angles of both the upper and lower sides. Part holds a certain level of height and are easy to hold with another clamp. There is a need for fixture to simply hold the product and a single setup to assemble different parts.

- Conceptual designing and modelling of fixture for assembly product.
- To fabricate fixture and investigate its effectiveness in actual application.
- To measure the reduction in assembly cycle time compared to previous system.
- Improve the fixture's ease of operability, making it simple to adjust for various manufacturing tasks.
- Reduce the time needed for handling and assembling real products after material handling, streamlining manufacturing processes.

Expected outcome.

- Avoid positioning cycle time in assembly.
- Easily mounting on table and adjust clamp.
- Clamping and releasing should be easy and less time consuming.
- Fixture will reduce the error due to lack of labour work.
- Fixture arrangement design locating and clamping unit.
- Fixture body development

2. METHODOLOGY

1. The following methodology is to find out all the processes of report work and different theories and practical data like literature review, research, cope of work, modeling, design, modification, and finalization. Methodology to find out all the process of fixture design and assembly so complete process in the required time.

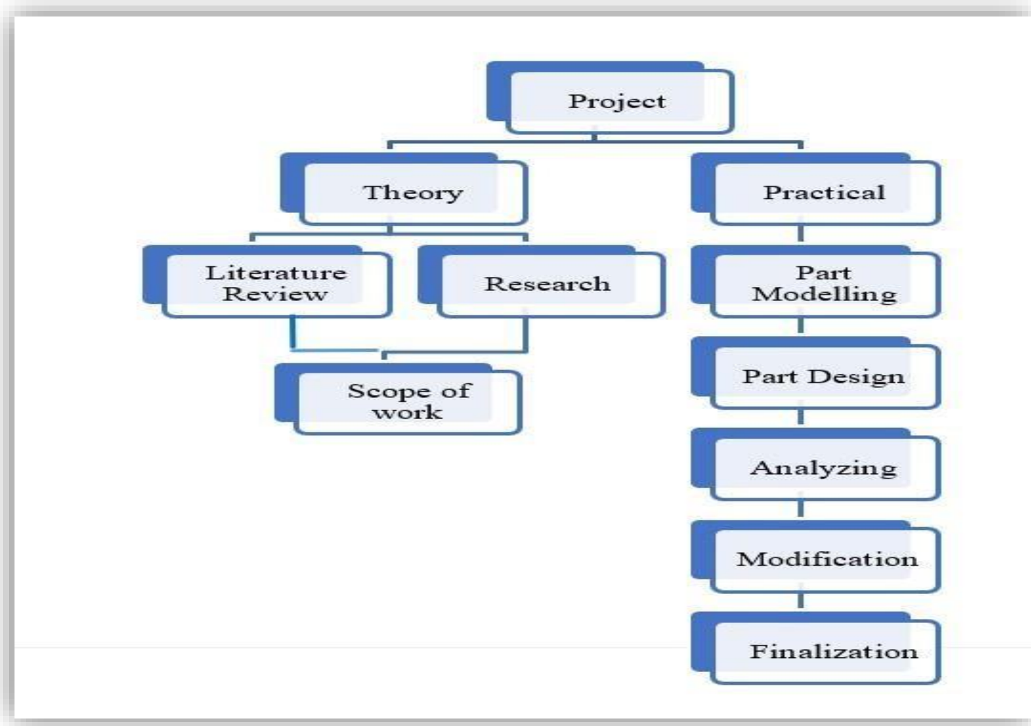


Figure 1.1 Methodology

3. DATA COLLATION AND STEP OF FIXTURE DESIGNPROCESS OF FIXTURE DESIGN

A rational and methodical strategy is the basis for excellent fixture design. Few design issues arise when the functional needs of the fixture are well analyzed. The proper planning required will depend on the workpiece, processing, tooling, and accessible machine equipment. For more intricate fixture designs, the preliminary analysis design is to be done. To start the fixture-design procedure, explicitly define the problem that needs to be solved or the requirements that must be accomplished. Designing fixture depends upon several factors such as.

- Analysis of the component.
- A study of the loading and unloading arrangements.
- Study of clamping arrangements.
- Table fixing arrangement studies.
- Study manufacturing expected.
- Easy to clamp in required position.
- The problem of stiffness and vibration is being investigated.

Basics of Fixture Design

This section will introduce necessary fundamentals regarding fixture design. The aim of this part is to give a brief overview on fixture design a better understanding of what a fixture is. Also, this part is vital in making platform for rest of the project, as it will shows the main elements that project is involved in and specifically how much they can be categorized and classified. Finally at the end of the chapter a new discussion will be opened about the main differences between fixtures regarding their application. The aim of this part is to brighten the points that should be focused on without losing the generality of this research. Generally, fixtures are categorized as a tool used in production line to assist manufacturing. Among all other tools such as machines, transport devices, cutting tools, etc.; fixtures are also another type of resources that can be accessed by process planners in order to plan the production sequence. By production sequence' or production plan' we mean the list and methods of operations, sequences, and specifications (type, size, number…) of the resources that should be used to produce a part. Fixtures are tools mainly used to manufacture or process duplicate parts accurately by holding, supporting, and locating parts in front of other resources such as milling machines, cutting machines or welding robots. To point the problem, each part demands its own special type of fixture and in addition; the operation that should be performed on the part is also affecting the design of the fixture. This fact made the fixture a unique type of resource. Besides, the fixture is not part of the final product, so the shape, material and geometry are not important if it satisfies the goals of fixturing. So, the potential for changing exists in the design of the fixture itself which means the potential for iteration between design and manufacture planning engineers.

Dedicated Fixtures vs Modular Fixtures

The “dedicated fixtures" refers to fixtures that are often made specifically for a certain workpiece. Due to the current trends in manufacturing pushing a greater product adaptability, and quality, many organizations are expecting fixturing systems to be easier and Flexible systems minimize the expense of producing each fixture and the storage of several fixtures by allowing a range of different pieces to be held during machining or assembly (Grippo et al. 1987). Flexible fixturing has the potential to have a significant economic impact, as specialized fixtures typically cost between 10% and 20% of the overall production expenses (Gandhi and Thompson 1986). For a long as there have been machining operations, manufacturers have been creating fixtures.

Fixtures are necessary to hold workpieces and parts throughout certain production processes. Traditionally the process has involved designing and building a "dedicated" fixture with the specific goal of manufacturing a large number of the same product. Nonetheless, there are now more multipurpose fixtures due to the tendency toward more flexibility in production volume and product diversity. Since they can support a wide range of workpieces, flexible fixtures for rotating components have been in use for many years (Ridanda and Muralikrishnan 1992). A workpiece is mounted in place with the use of centers, usually one at each end. A mandrel is a tool used to retain the workpiece while machining operations are carried out inside certain areas of the component. Collets are tapered bushings that are commonly used to hold bar stock with hexagonal, square, and circular cross sections. Chucks are typically furnished with three or four jaws, are the most often used fixture for rotating components, particularly for lathes. The majority of turning machine tools also offer capabilities for holding workpieces in various position. Conventional prismatic part fixtures are made of steel base plates with clamping and locating components. Typically, these components were focused to provide consistency, facilitate loading and unloading, and adhere to strict design requirements tolerances. These criteria were partially met by the fittings, which were location and hardened. Modular fittings have become popular due to the demand for flexibility and the growing complexity of product designs. A modular fixture seeks to provide flexibility via multifunctional fixturing pieces. Numerous common fixturing components, including base plates, locators, clamps, and supporting parts, make up a modular fixturing system. Elements are chosen to construct a fixture arrangement to hold the workpiece using these basic components. Once disassembled, modular fixturing pieces may be reused for various products. They are made with tolerances to ensure that the workpiece meets specifications to hold work piece. The necessity for modular fixtures has also been largely driven by two other factors: the increasing use of multiple-axis CNC machine tools and reduced batch sizes in production. These tendencies are supported by the modular fixture pieces' interchangeability. The majority of modular fixtures fall into the category of that include base plate fixtures with dowel pins, grid holes, or T-slots. All of the base plate's faces have T-slots, grid holes, or dowel pin holes for fixture assembly.

The other hand, base plates with grid holes have better positional precision and strength than those with T-slots, and modular fixtures are often larger than specialized fixtures. Compared to dedicated fixtures, modular fixtures require less storage space, while designing dedicated fixtures takes less time and labour. These benefits have been repeatedly shown by machine shops (Friedmann 1984). The V-Block Jig Technology from Japanese business MAO Corporation (b) Yuasa Modular Flex System, based in the USA (3) Bluco Technik, a German company Dowel Pin Base Plate (a) (a) SAFE (Self Adapting Fixture Element) System, developed in the USA The location features, geometrical, dimensional, and positional accuracy of these fixtures develop to an order of +0.01 mm. However, modular fittings are frequently larger than specialized fixtures, and base plates with grid holes offer greater positional precision and strength than those with T-slots. Modular lighting take require less storage space than dedicated fixtures, yet dedicated fixture design requires less effort and time. The workpiece is held in place by the solid substance through specific production procedures, and it is removed by changing it back into a liquid. The method, which has been used for products like turbine blades in the aerospace industry, only requires light-cutting operations. This contains the potential for some in-line equations to be turned into display equations in order to improve paragraph flow. Display equations will also be altered if they cannot fit in the two-column format.

Fixture Elements

Despite vast range of fixture types and applications, the common building industrial elements of fixtures are certain and limited. This is good news, because a good categorization of these elements can lead to deep understanding of the types and possibility to automating the design process. These elements usually named according to their function in the fixture and then also divided into different sub-categories. Basic category of fixture elements can be seen in Figure:3.1

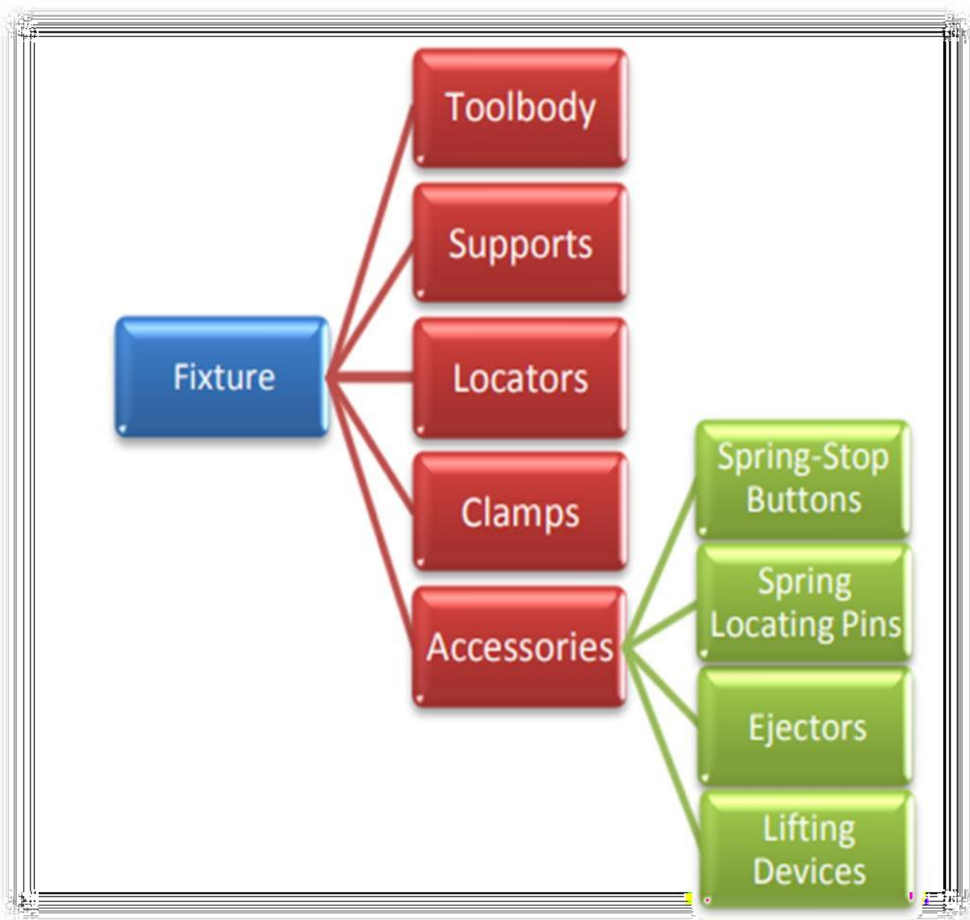


Figure 3.1 fixture elements

The foundation frame that holds the entire fixture assembly will be mounted is called the tool body. It forms the fixture's main mass and can be made from a range of materials and techniques. The components of accepting the force are supports. These forces consist of the part's mass, any appropriate machining forces, and clamping forces. The part that is opposed to these forces is supported by supports in a suitable way with appropriate contact points. Locators are utilized to maintain the right location of the part. They work in tandem with support to devise a special method for maintaining the part's proper orientation and position. As the name implies, clamps are the fixtures' holding elements. They are guaranteeing that the component will be maintained firmly and securely in the fixture throughout the procedure. Optional parts include lifting devices, ejectors, spring-stop buttons, and spring-locating pins. Their use is dictated by the fixture's size, cost, and purpose for being used.

Each of these categories is made up of a number of smaller sections that are actually a range of elements that can be used and employed. Given Figures illustrate a few of these sub-groups:

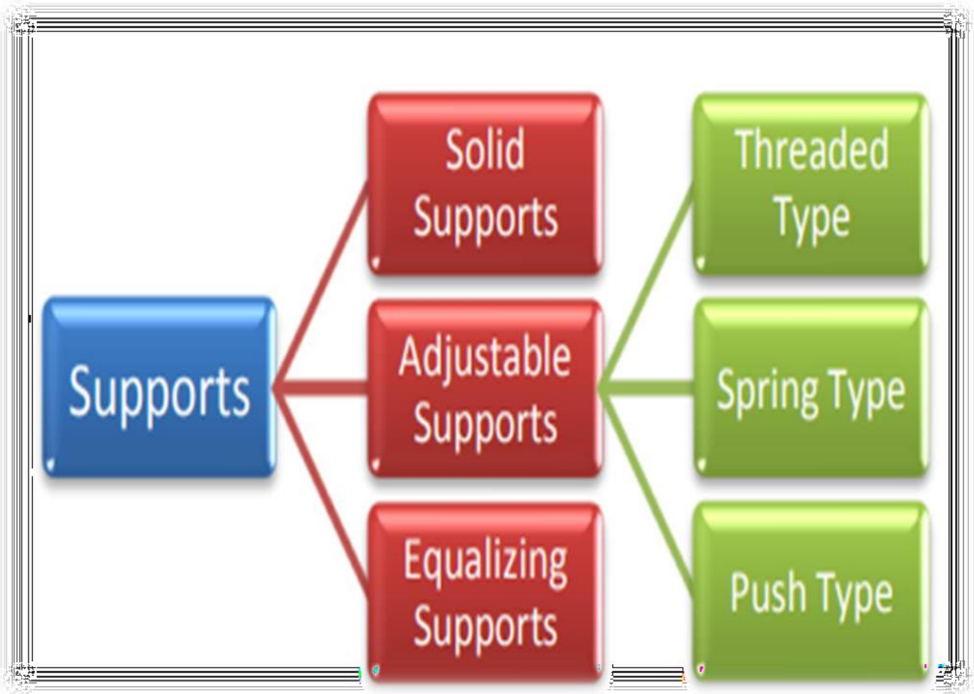


Figure 3.2 Type of support

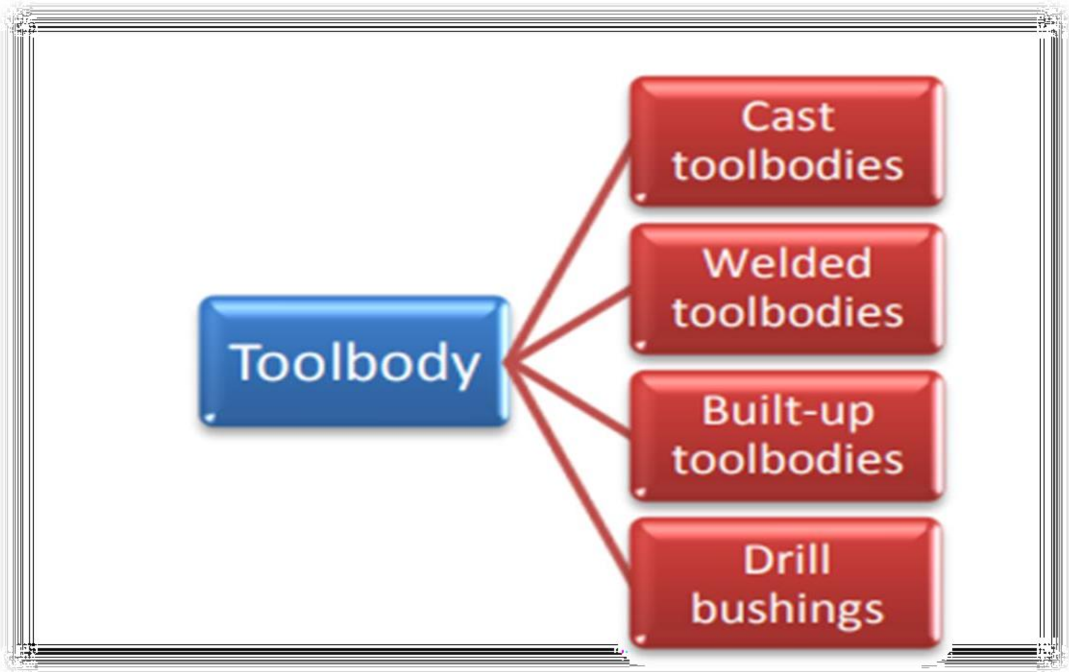


Figure 3.3 Type of Tool body

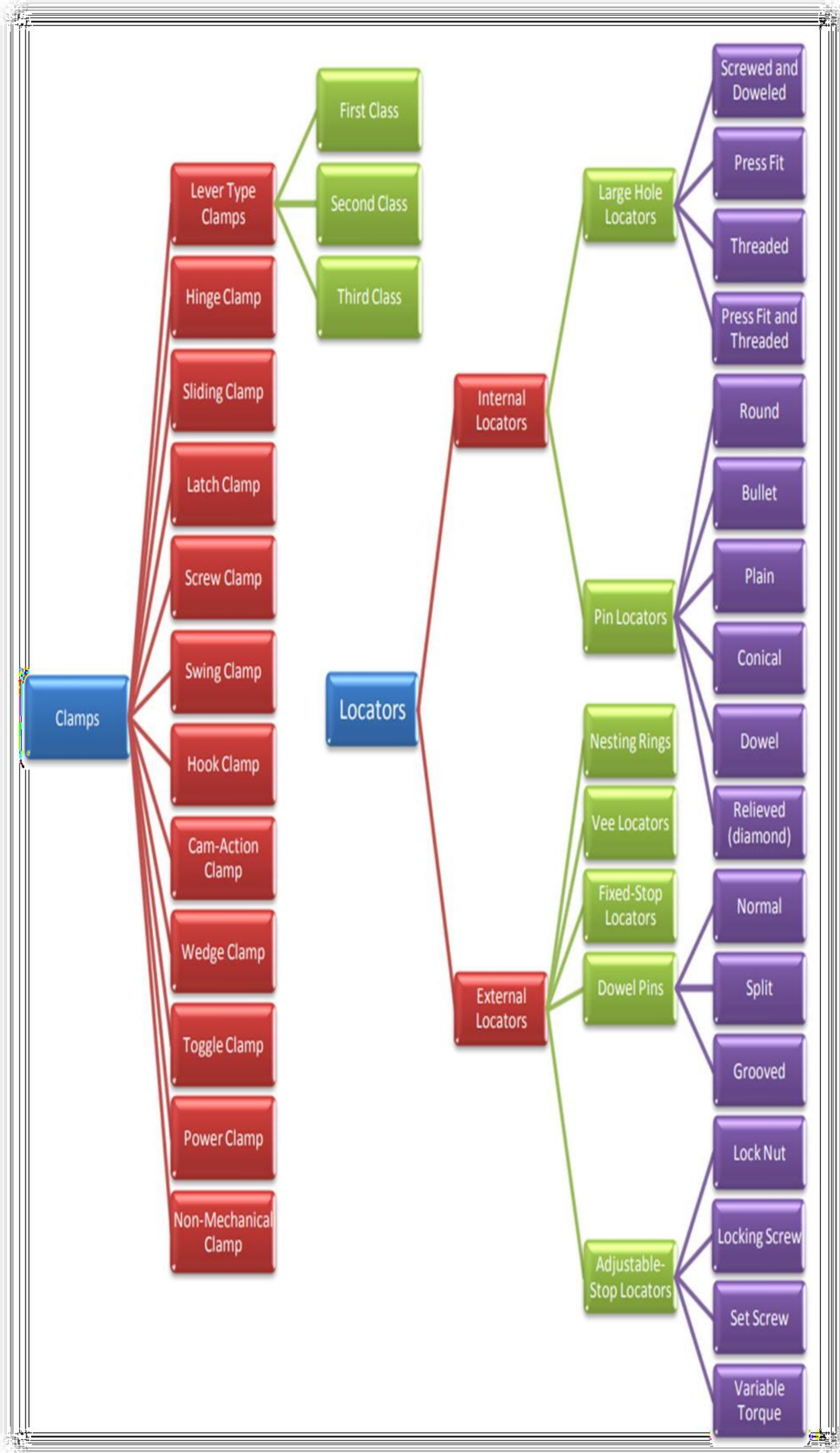


Figure3.4. Locating and Clamping Considerations

As stated by (Koji Teramoto, Masahiko Anasoto, and Kazuaki Iwata) have stated that there is a mutual reliance between Fixturing Plan (FP) and Machining Plan (MP). Create a good design, a designer must rely on their expertise and implicit knowledge when creating machining fixtures. First of all, and essentially it is necessary to explicitly define the fixture design process and the information required in order to enable its use. A key and well- known technical principle must be taken as well into account: the first input to any design process should be the functional requirements and the constraints that go alongside them. Giving straightforward descriptions to the two key concepts, functional necessity (FR) and constraint (C), is crucial when contemplating needs as an entire system. Various authors have defined Functional Requirement (FR) as "what the product has to or must do independent of any possible solution." "A restriction that generally affects a particular type of requirement, and therefore limit the range of choices while satisfying the criteria" is a definition of constraint (C). Work holding is a crucial component of machining, and fixtures are the parts that make up this overarching objective. A fixture solution frequently consists of one or more physical components; as a whole, the fixture solution design must satisfy all of the FRs, and related Cs. Fixtures must be able to center, locate, orient, clamp, and support. These are illustrations of their functional requirements. There are several aspects to take seriously when it comes to limits, namely with: The physical shape and dimensions of the component that needs to be machined, tolerances, the order in which the operations are performed, machining tactics, cutting forces, the volume of material needs to be removed, the number of setups and setup cycles, batch size, volume of production, process morphology, machine capacity, cost, etc. Ultimately, the characteristics that follow of the solution can be identified: economy, simplicity, rigidity, precision, and reliability (2). Two stages take place in the fixture design approach that is being presented. The first step denotes a comprehension of the objects, containing the functional and detailed fixtures design, part geometry, machining procedure, and fixture resources. The inference technique (design and interpretation of rules) used for determining the original machining fixture solution is explained in the second action. Errors in the location and alignment of a machined element on a workpiece result from inaccurate workpiece placement. The elasticity of loaded fixture-workpiece connections results in rigid body removals of the workpiece, which have a significant impact on the workpiece's ability to be precisely located in a machining fixture. The capacity of the machining fixture to precisely position the workpiece concerning the machine's axes determines the accuracy of the placement of a machined feature. Localized elastic distortion of the workpiece between the fixturing points greatly affects the workpiece placement in a fixture. The clamping force(s) utilized on the workpiece are what produces these deformations. Therefore, it's critical to avoid these effects by designing the fixture architecture optimally. Four general needs are identified by

S. K. Hargrove and A. Kusiak for a fixture:

Precise workpiece position.

Complete workpiece constraint during machining.

Minimal workpiece deformation; and

Absence of machining interference.

The fixture layout design must, in general, meet four functional requirements. if. Finding equilibrium: The design of a fixture plan that can give a workpiece static equilibrium when it is mounted on fixtures is connected to locating stability. Since a workpiece must meet this criterion before meeting other functional requirements, locating consistency is one of the most crucial requirements in fixture design. The static balance under the specified fixturing scenario in a condition of manufacturing forces is the primary consideration while locating stability. Furthermore, it is imperative that the fixture arrangement design guarantees that every locator stays in contact with the work piece during the manufacturing process. When the workpiece is set on locators, which support it over gravity forces until it is processed, problems with locating stability arise. Fixture strength and kinematic analysis are thus also required for locating stability in order to determine the clamping forces required to keep a workpiece in balance. ii. Dependable workpiece location: To guarantee position accuracy during operation, the fixture shall supply the predictable location for the workpiece. Designing locator

locations or fixture layouts to give a workpiece a distinct and precise position and orientation with regard to its fixture reference frame is known as deterministic workpiece location. Assembly accuracy, which is susceptible to random manufacturing errors of fixture elements, mathematical variability of the workpiece, and workpiece positioning errors caused by fixture position are frequent difficulties in creating a fixture configuration that will meet this functional need. Generally speaking, the statistical description of the dimensioning and precision scheme applied to the fixtures and their contact sites on the workpiece can be used to anticipate the location variability of the workpiece. Thus, workpiece positional variability can be reduced by figuring out the fixture layout, which is insensitive to various causes of variation. iii. Clamping stability: This refers to figuring out the clamping sequence and arrangement so as not to interfere with the precision and stability of a workpiece's position, which was determined by locators in the preceding two functional criteria. The part locating instability and position accuracy of the workpiece given by the locators are unaffected by clamping stability and complete restraint, which are functional criteria linked to establishing the clamping positions and forces. Provide complete restraint, clamps apply pressures to the workpiece in opposition to any external force. Minimizing workpiece deformities under clamp and external pressures is a difficulty in clamping location design. iv. Complete moderation: For the workpiece to endure any stresses and to be kept in an exact position, clamps must totally constrain it. Furthermore, dynamic machining circumstances arise when a work part is subjected to machining forces that travel through or along its surface, as explained by R. T. Meyer and
F. W. Liou (6). The work part must always be restrained, the clamping forces must not be excessively large or small, the fixture must be deterministically positioned, accessible, stable within the fixture when no external forces are applied, and the clamping sequence must be positive in order for the fixture to be considered viable for a work part undergoing dynamic machining. The precision of the workpiece position and, consequently, the quality of the machined component are impacted by workpiece motion that results from localized deformation due to elastic forces at the workpiece/fixture contacts as a result of machining and clamping pressures. When designing a fixture configuration, the tangential friction force is crucial because it can be used to minimize the number of fixture components, making the workpiece more accessible for machining operations and acting as a damping mechanism to remove input energy from machining processes forces from the workpiece/fixture. The fact that the surface of contact may slip, slide, roll, or release tension depending on the strength of the normal and tangent pressures at the contact interface often makes contact issues involving friction more difficult (7).One of the most important steps in process planning is designing a fixture that allows precise machining of the workpiece by maintaining the workpiece/fixture elastic deformation contribution to the machining error within the designated tolerance. The locations of locators and clamps, as well as the clamping forces used, are crucial considerations in fixture design because they reduce workpiece deformation brought on by machining and clamping pressures.

Fixture Design Process

Fixture design, which involves determining the locations and positions of parts during assembly processes and providing physical support, is one of the most crucial design tasks throughout process design for new product development. This is because it can have a significant impact on process yield and product dimensional variations. The fixture design process is often broken down into three phases. if. Fixture planning: Concerns about the quantity and kind of fixtures required, their orientation in relation to position, and the connecting or machining functions that fixtures must perform are determined at this phase.
ii. Fixture setup: To completely constrain the workpiece, a series of locators and clamps are arranged on its surface in this configuration step. iii. Fixture construction: Building and installing fixture components to support the workpiece completes the fixture-building step. Fixture layout design, which is under the purview of the fixture planning and fixture arrangement stages, is particularly important for complex assemblies like car bodies, ship hulls, and aircraft fuselages. It entails modifying the design nominal measurement of locator positions to remove mean shifts. Research efforts may be easily

classified into one of the groups listed in Table 1 by carefully reviewing the literature. Production requirements include batch sizes, machine types, labor resources, and total cost at the fixture planning stage. Evaluation and tolerance specifications are examples of functional concerns that may be governed by other criteria like quality standards. Production planning optimization strategies, such as planning models and algorithms, are the main emphasis of this field of study. There are two sub-phases in the design phase, which have been the focus of most of the reported research. A thorough 'analysis' is looked at throughout the design process to find and place the workpiece. The "synthesis" subphase is the following. Another name for this stage is "fixture representation." To meet the specifications and accurately depict the fixture arrangement, the fixture elements must be chosen. Assembly is the last stage. Assembling can be done in essentially two ways: manually or automatically. The findings of this study can be applied to the field of fixture design, even though it may be explored in other domains. Fixture design tools are categorized and organized by the taxonomy, which is also a useful categorization system for future study. It offers a perspective with respect to various study topics and a visual presentation of findings in the fixture design field. In this context, "fixture planning and design" refers to all the activities and data needed to create a work holder that will locate, hold, and support a workpiece while it is being machined. The expertise, abilities, and experience of the tool designer are critical to the planning and design of fixtures. While it is seen as a separate task, the tool designer needs knowledge from earlier and later processes to identify and retain the workpiece during machining operations. In line with the above-described categories of fixture design research, three subfunctions for fixturing are recognized. The planning of fixture design is the initial task. The engineering drawing, manufacturing data, and process plan are required inputs. Information on batch sizes and manufacturing costs per piece are included in production information. The process planner, a manufacturing engineer, and a fixture designer usually carry out this role. Their assistance is crucial in determining the type of fixtures to be utilized. For instance, at this point, it is decided whether to employ modular fixturing or create a permanent fixture based on product details such as production volume. Permanent fittings are often utilized for large volume manufacturing, whereas modular fixtures are typically used for lower volume production. A description of fixturing options and features for three different types of fixtures is shown in Table 2. Universal work holders, including chucks, collet chucks with no and vices, machining vices, and global work holding systems, are examples of general-purpose fixtures and tools (8). Workpieces with regular or symmetrical forms, including squares, rectangles, cylinders, hexagons, and similar component shapes, are typically held in them. Computer-aided fixture design systems are used by some industrial businesses. The majority of these 'interactive' solutions just let the user choose and specify the parameters needed for design and planning. The kind of fixtures that are available, the facilities' resources, and the machine tools all influence fixture planning. The total number of directions and orientation of the machine tool, for instance, may be limited for machining; this will dictate the fixture's construction. The sort and kind of fixtures that are needed are the result of this subfunction. When it comes to product descriptions, the fixture design subfunction is the most active. The primary purpose of the fixture parts, their contact surface, and their capacity to limit degrees of freedom to confine the workpiece are factors that influence the selection and placement procedure. The production characteristics of the workpiece dictate the fixture parts and their respective positions and placement to confine the workpiece after the type of fixture to utilize (permanent, general-purpose, or modular) has been decided. Once more, the necessary machining features and the machine tool's accessibility dictate this fixture setup. The main person involved in creating the fixture is the fixture designer. In smaller businesses, nevertheless, the fixture's development and design may fall under the purview of the machinist. The result is a listing of the components together with an explanation of the fixture design that includes the parts' locations and positions. The assembling of fixtures is the final subfunction. The machine technician or the fixture designer usually conduct this task, which may take place in parallel with fixture design. A robotic assembly might be employed in sophisticated manufacturing processes. The activity is dictated by the quantity of setups needed, the fixtures that are available, and the fixture design activity's plan. The finished product is the fixture/workpiece assembly, which is prepared for machining. Table 3 presents an integrated approach of fixture planning and design. Important information shared between the functions would also be shown by lower-level interactions. While the actions and information conveyed are identified by the model, Table 3 also specifies each level of data that facilitates functional connections and is required to accomplish each main function. It is acknowledged that fixture design is both an art and a science. The quantity of fixture design methods under development and the variety of optimization strategies for work holding element configuration, placement, and positioning serve as examples of the science of fixturing. Over time, the fixture designer gains these skills and knowledge by trial and error, which is how the art of fixturing is learned. Table III illustrates the use of both approaches in fixture planning and design, as well as the significant role that each methodology plays in the construction of the final fixture/workpiece assembly. Positive response forces at the locators always, predictable placement, robust accessibility, durability of the work part in the fixture in the absence of external pressures, and a positive clamping sequence are all desirable attributes of a fixture.

Steps of Fixture Design

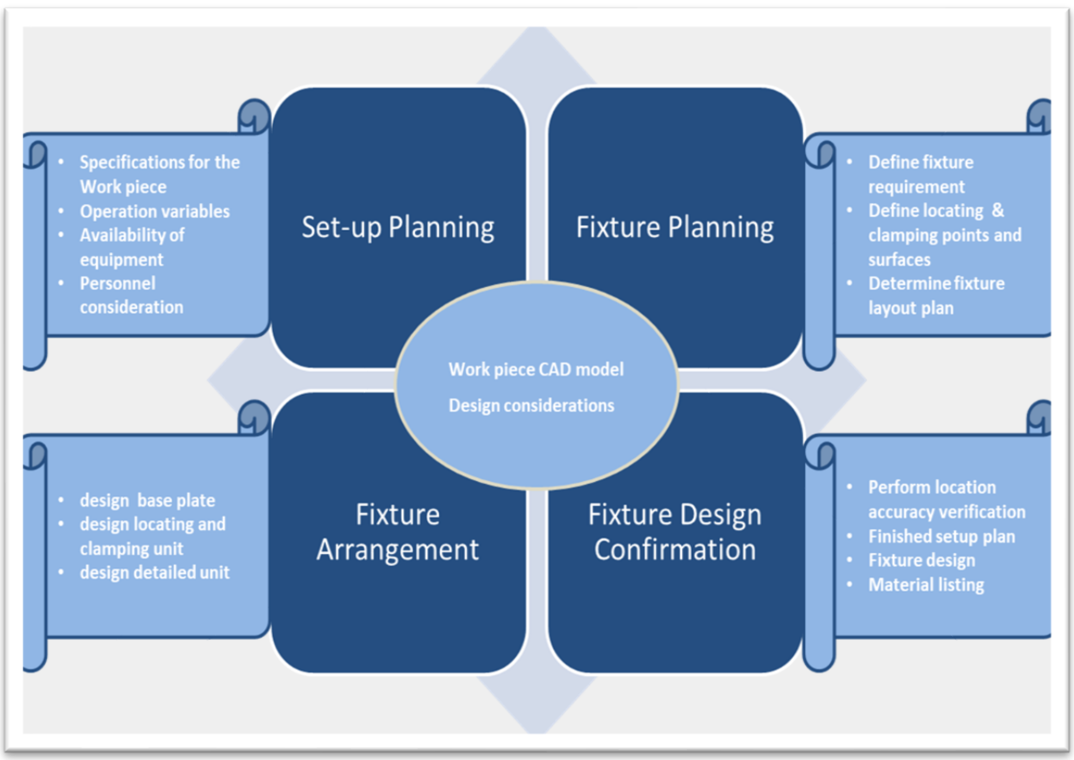


Figure 3.5 Steps of Fixture Design

4. RESULT AND DISCUSSION

4.1 fixture Design

This fixture for securely holding a product in a CNC lathe chuck from all four sides. This type of fixture is commonly known as a "four-sided clamp" or "four-jaw chuck fixture. “Here’s a basic description of how such a fixture might work:

The fixture would likely have a sturdy base plate that can be securely mounted to the CNC lathe chuck. these are the key components of the fixture. Each arm would be adjustable and capable of moving independently to clamp the product from one side. The clamping arms should be adjustable to accommodate products of various sizes and shapes. This adjustability ensures versatility in the types of products that can be held securely.

The fixture should be designed to provide maximum stability and rigidity to minimize vibrations during machining processes, ensuring precision and accuracy in the finished product. The fixture should be made from durable materials such as structural steel withstand the forces exerted during machining operations and to ensure longevity. It should have a reliable mounting mechanism that allows easy and secure attachment to the lathe chuck. Consideration should be given to accessibility for tooling and cutting tools during machining operations. The fixture should not obstruct access to critical areas of the product being machined.

Designing such a fixture would require careful consideration of the specific requirements of the machining process and the products being manufactured. It's often beneficial to work closely with engineers and machinists to develop a fixture that meets the exact needs of the application. Completed assembly in solid works 2019.

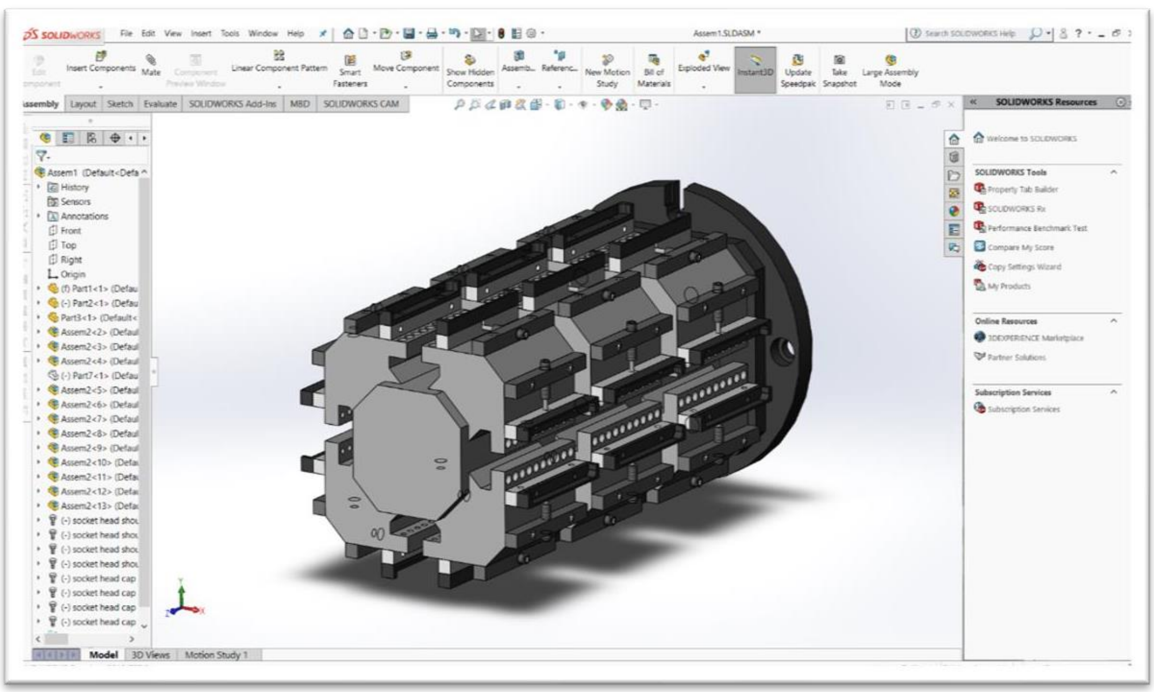


Figure 5.1. Assembly

Clamp Design

a fixture clamp assembly used to secure a product between two plates, with an adjusting mechanism to control the clamping force. Here’s a breakdown of the components you mentioned:

This is the stationary plate that remains in place during the clamping process. It provides a stable base for the product to be held securely.

This plate moves to apply pressure to the product, holding it firmly in place between the fix plate and itself. This pin is used to control the movement of the moving plate. By adjusting the position of this pin, you can regulate the clamping force applied to the product.

This is the base plate onto which the entire assembly is mounted. It provides stabilityand support for the fixture clamp assembly. With this assembly, you can effectively hold a product securely in place between the fix plate and the moving plate, with the ability to adjust the clamping force as needed using the adjusting pin. The towertype base plate ensures that the entire assembly is stable and can be securelymounted to a surface. This assembly use easily to mount on tower type base plate with LN bolt.

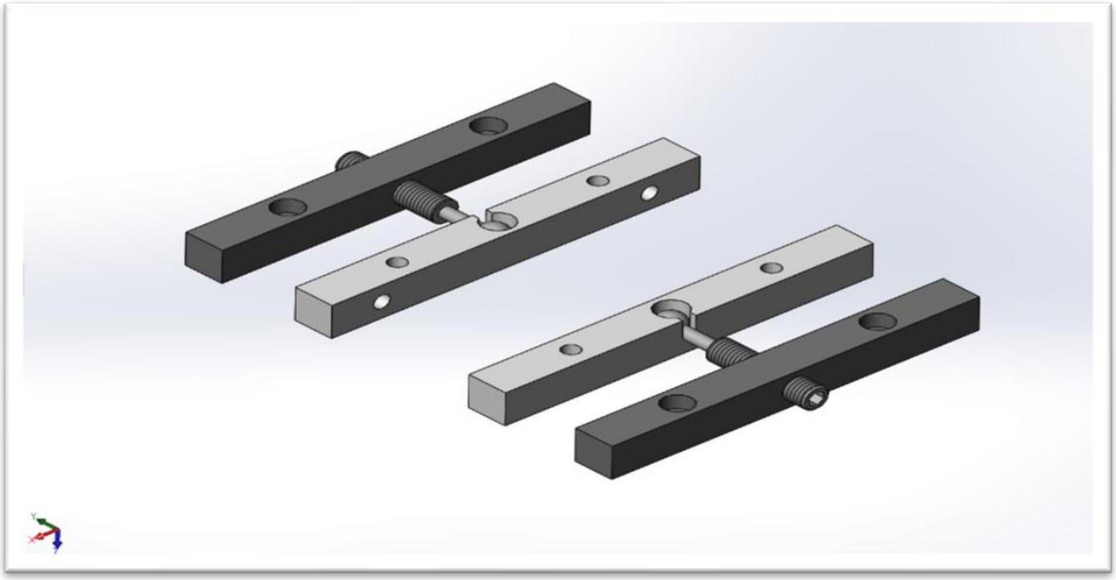


Figure 5.2. clamp assembly.

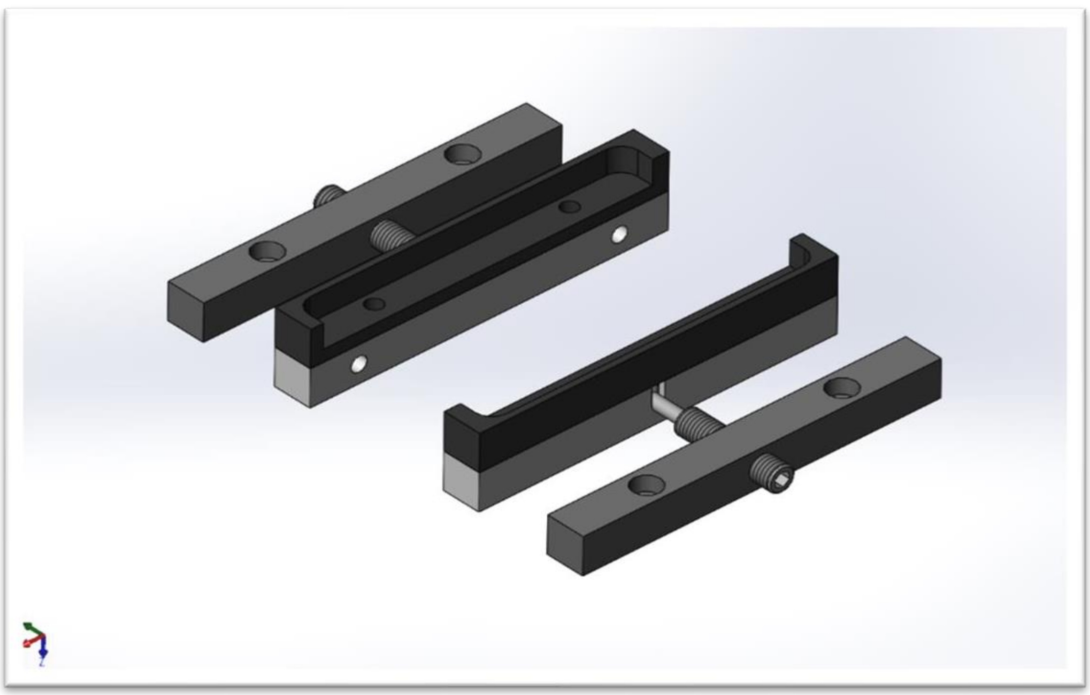


Figure 5.3. clamp assembly with extendable plate.

Assembly component

1. Tower base plate

Tower base plate used as a foundational component for a tower structure or fixture.

This circular plate serves as the central point where various components are assembled and mounted. The slots on the plate allow for the attachment of side plates, while the holes are used to secure both the side plates and other components in place. This configuration provides stability and support for the overall structure or fixture. If you need more detailed assistance or have specific questions about this type of base plate.

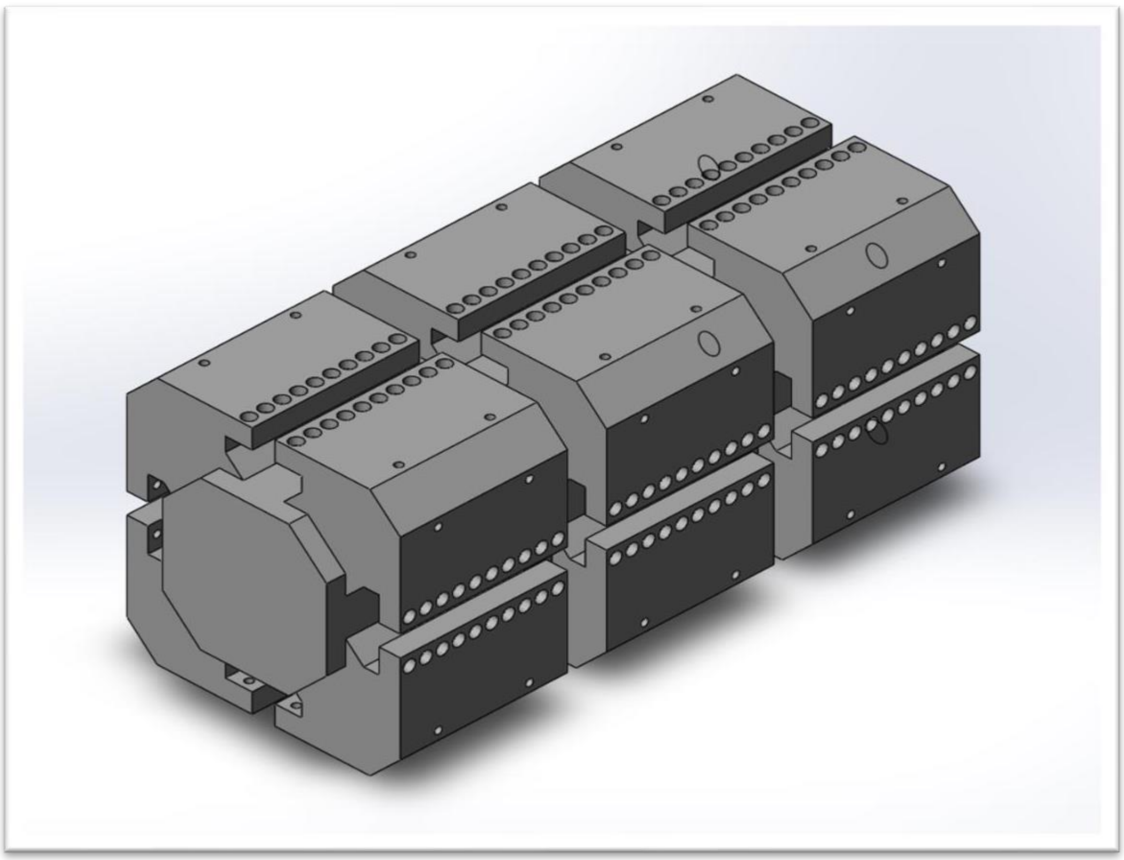


Figure 5.4. Tower base plate

2. Fix plate.

A plate is fixed onto a tower plate using bolts. If the plate is stuck or improperly fixed, here are some steps you could take to fix it Check if the bolts are properly tightened. If they're loose, tighten them using the appropriate tools.

Ensure that the plate is aligned properly with the tower plate. Misalignment can cause issues with tightening and clamping. After making any adjustments or repairs, reassemble the clamping assembly carefully, ensuring that all components are properly aligned and tightened. Once everything is reassembled, test the clamping assembly to ensure that it's functioning correctly and securely holding the desired components in place.

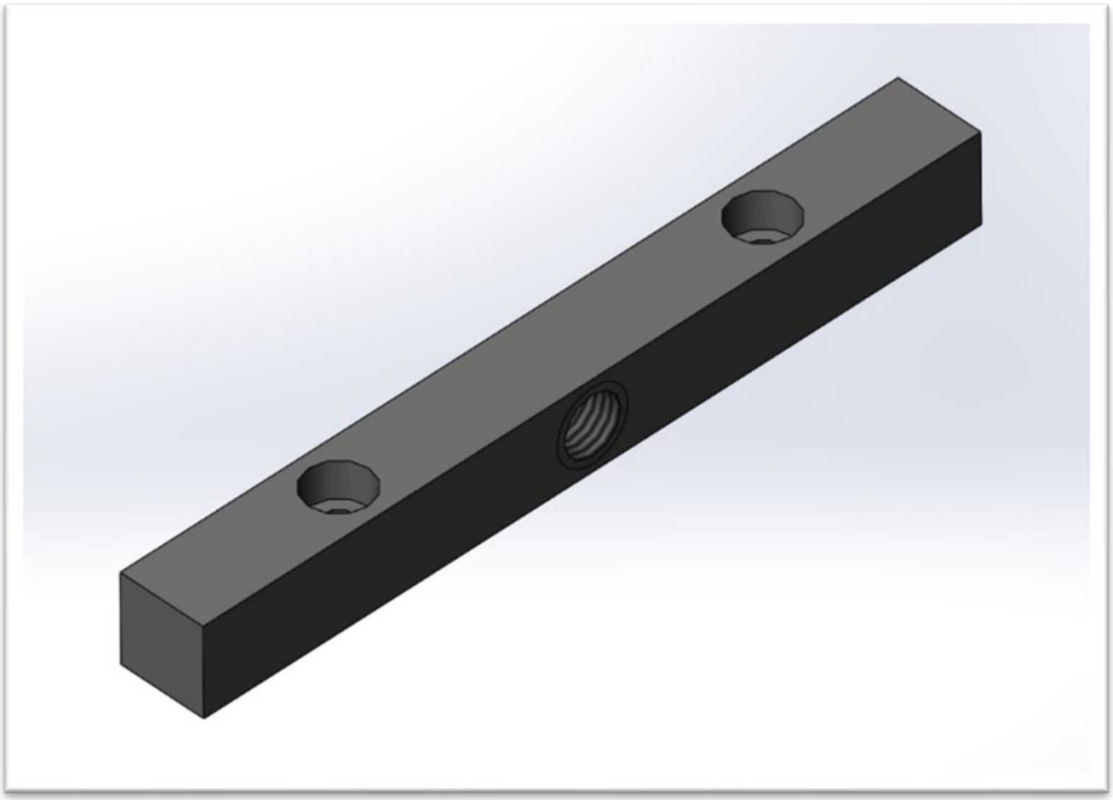


Figure 5.5 Fix plate

3. Moving plate

The moving plate is connected to a ball pin, allowing for easy adjustment to clamp products of various dimensions. Additionally, there are holes provided on the extended plate for mounting purposes. This setup seems quite versatile and adaptable for different sizes and shapes of products that need to be clamped securely.

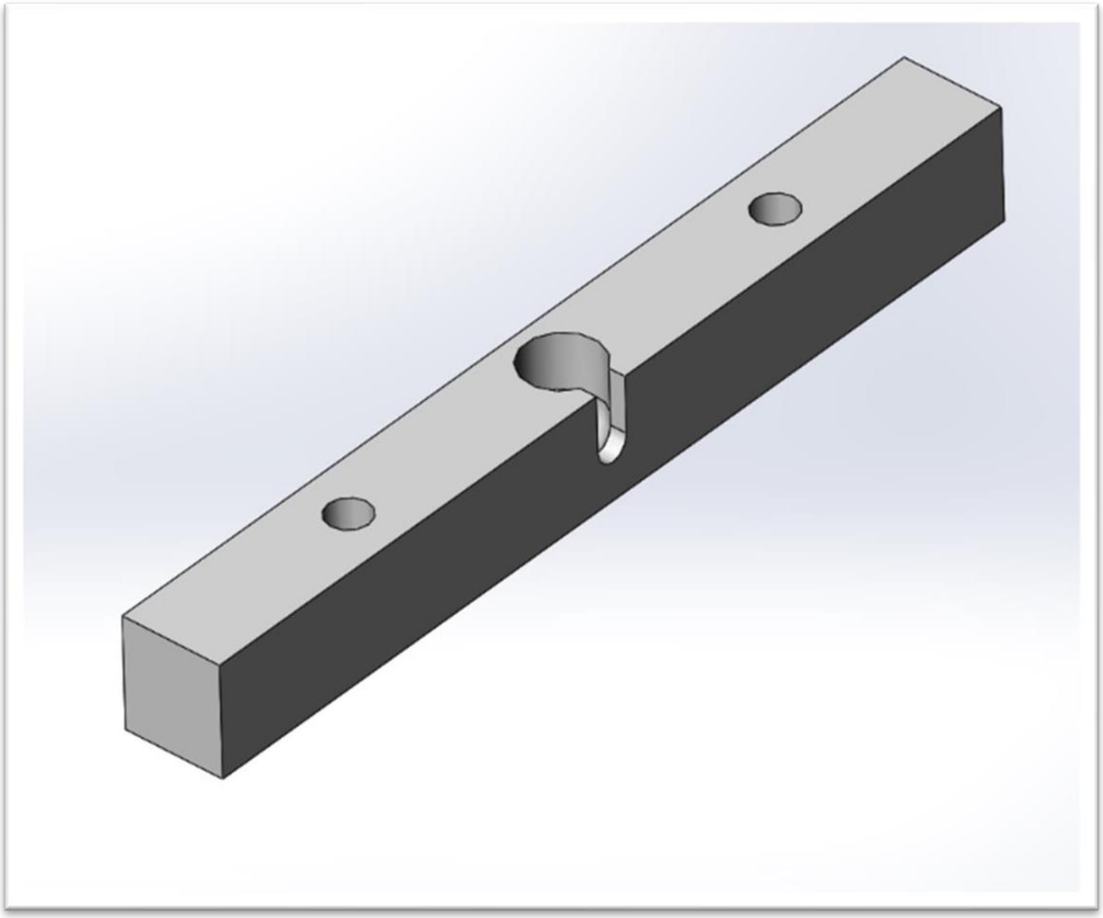


Figure 5.6. Moving plate

4. Ball pin

Which connects a fixed side plate to a moving plate. This setup allows for movement between the two plates while maintaining stability and control. The threaded portion of the ball pin would be secured to the fixed side plate, providing a stable anchor point. The ball portion would be attached to the moving plate, allowing for smooth movement and rotation.

This type of mechanism is used in various applications where controlled movement between two components is required, such as in machinery, automotive systems. The threaded connection ensures a secure attachment, while the ball portion allows for flexibility and smooth motion.

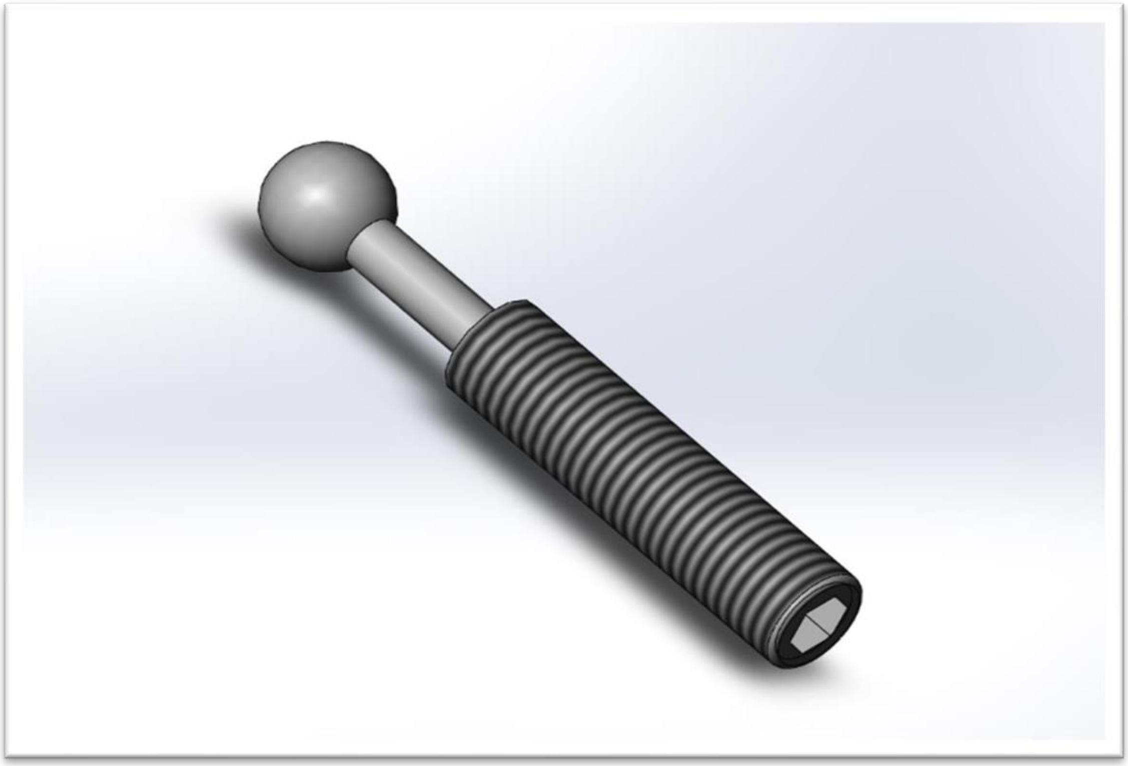


Figure 5.7. Ball pin

5. Circular plate

The circular plate designed to connect a tower-type base plate to a lathe chuck. Typically, such a plate would have multiple holes for mounting purposes, allowing for secure attachment between the base plate and the chuck.

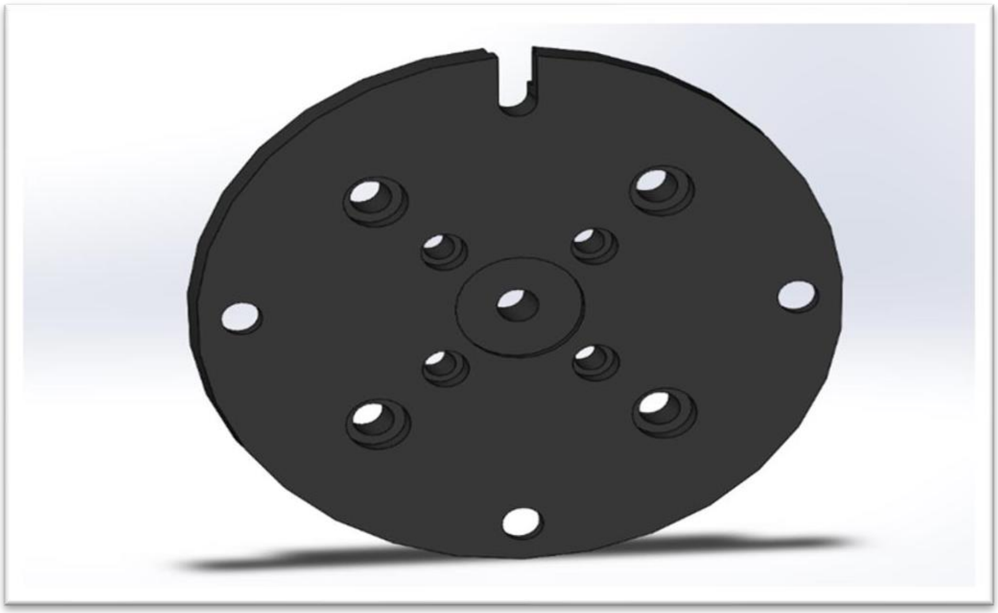


Figure 5.8 Circular plate

6. Side plate

The side plates can be slid onto a tower base plate slot and easily secured due to their actual size fitting perfectly. This method offers a convenient and efficient way to assemble or attach side plates to the tower base. The side plate against the fixture in the desired position and mark the locations holes for mounting. After mounting the side plate, test the fixture to ensure that it functions correctly and that the side plate does not interfere with operation.

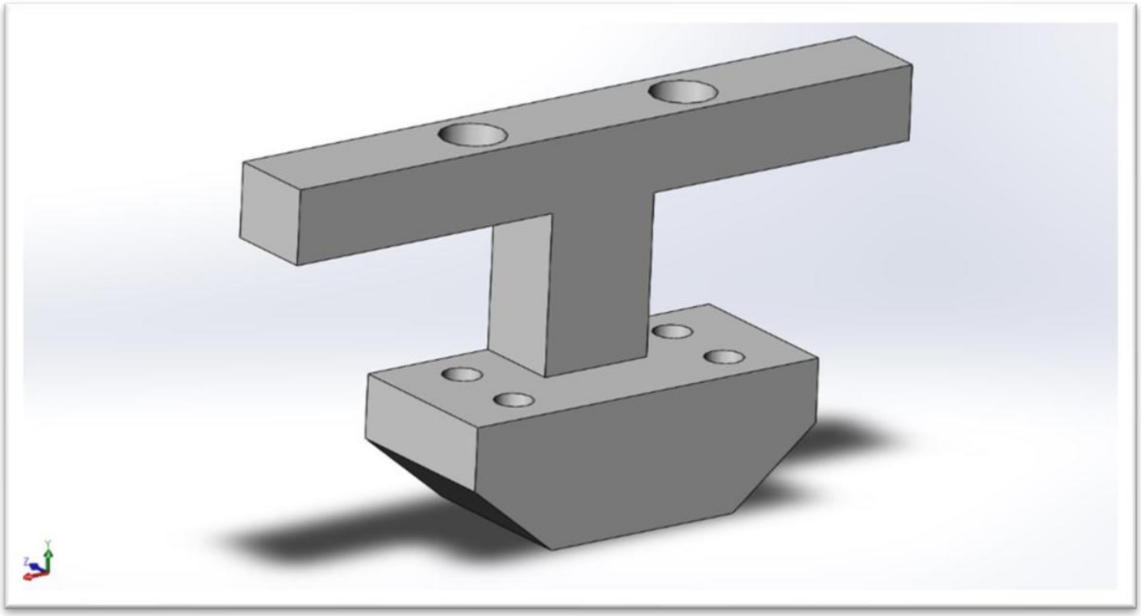


Figure 5.9. Side plate

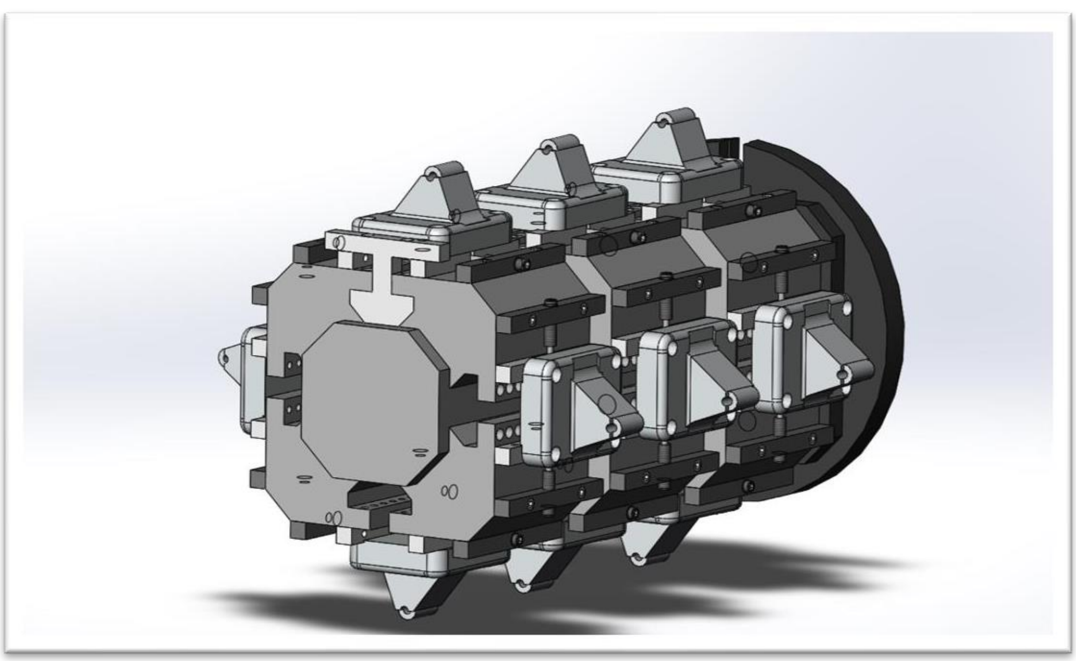


Figure 5.10 Assembly with workpiece

Material selection

Structural steel (Tower type plate)

The fixture has different component applications wise different materials are selected for each component. Our fixture holds the plate, component in four ways so the fixture has required stiffness, lower wear resistance, lower Thermal expansion. This type of material properties is used for making fixture components. The fixture material should not be affected in the machining zone and should prevent rapid heatdissipation from area.

The selection of material for modular fixtures is governed by these factors:

- Tolerances for part printing
- Heat resistance of the material
- The fixture stiffness necessary to ensure work piece alignment precision, aswell as the heat transfer properties.
- Structural properties
- Density 7850 kg/m³
- Melting point 1350-1530˚C
- Thermal expansion coefficient 12 $\times 10^{-6}$ ˚C

EN10025-2 Hot rolled products - non-alloy structural steels					
Symbol	Description	S235	S275	S355	S450
f_y(MPa)	Yield strength	235	275	355	440
f_u (MPa)	Ultimate strength	360	430	490	550

Table 5.1. material properties

Material Property	Value
Density "ρ"	7850 Kg/m^3
Unit weight "γ"	78.5 KN/m^3
Modulus of elasticity "E" (Young's modulus)	210000 MPa
Shear modulus "G"	G = E / [2 · (1 + ν)] ≈ 81000 MPa
Poisson's ratio in elastic range "ν"	0.30
Coefficient of linear thermal expansion"α"	12×10^{-6}

Table 5.2. material properties

Mild steel (circular plate and other component)

EN24T, also commonly referred to as 817M40T is a high strength engineering steel that has nickel, chrome, and molybdenum as its alloying elements. The addition of nickel gives the steel toughness, the chrome provides a depth of hardness, and the molybdenum reduces the risk of temper brittleness that may occur during some temperature intervals.

The physical properties of EN24T makes this grade suitable for use in high strength machine parts, axles, components for plate machining component manufacture of punches and dies, gears, shafts.

PROPERTY	VALUE	UNIT
Density	7840	Kg/m^3
Melting point	1500	°C
Modulus of elasticity	207	GPa
Thermal conductivity	41.9	W/m°k
Yield strength	650	N/mm^2
Shear modulus		GPa
Hardness Vickers	252-303	Vickers - HV
Tensile strength	850-1000	N/mm^2
Impact / Izod	54	J

Table 5.3 material properties

This use of carbide tipped HSS tools is recommended to give the best milling, grinding, and machining results to deliver high dimensional tolerances and good surface finishes. Best results are achieved with slower speed and a higher feed at initial roughing out stage, followed by high speed and moderate feed to finish off. Machined components that require extra resistance to wear can be case hardened to enhance performance.

Analysis and Topology Optimization of Fixtures

Simulation FEA model

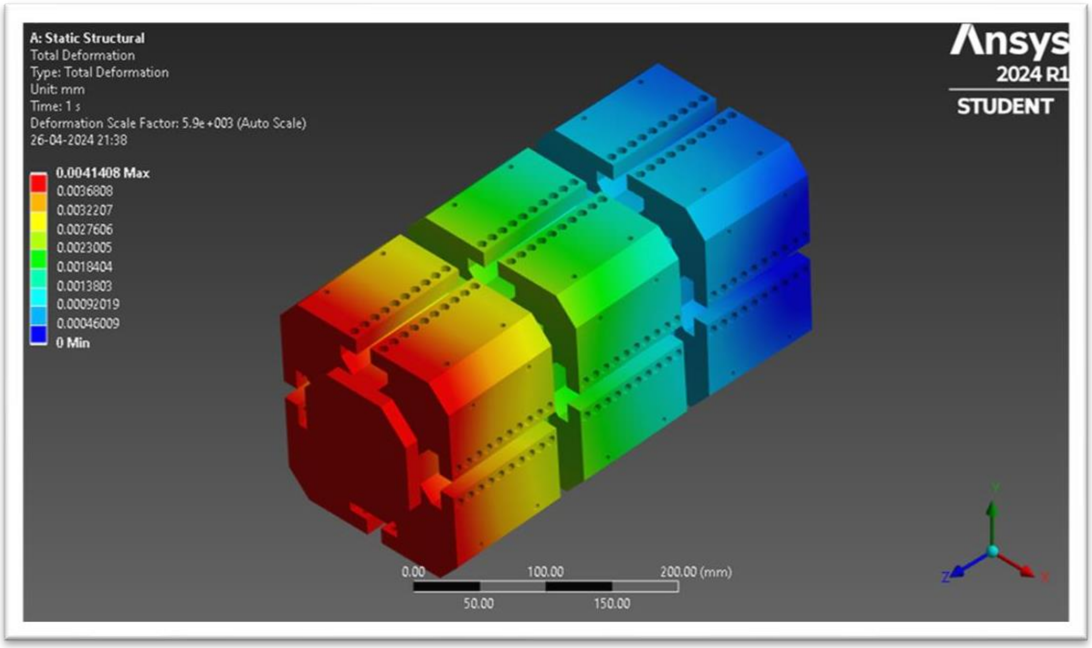


Figure.6.1 Total Deformation

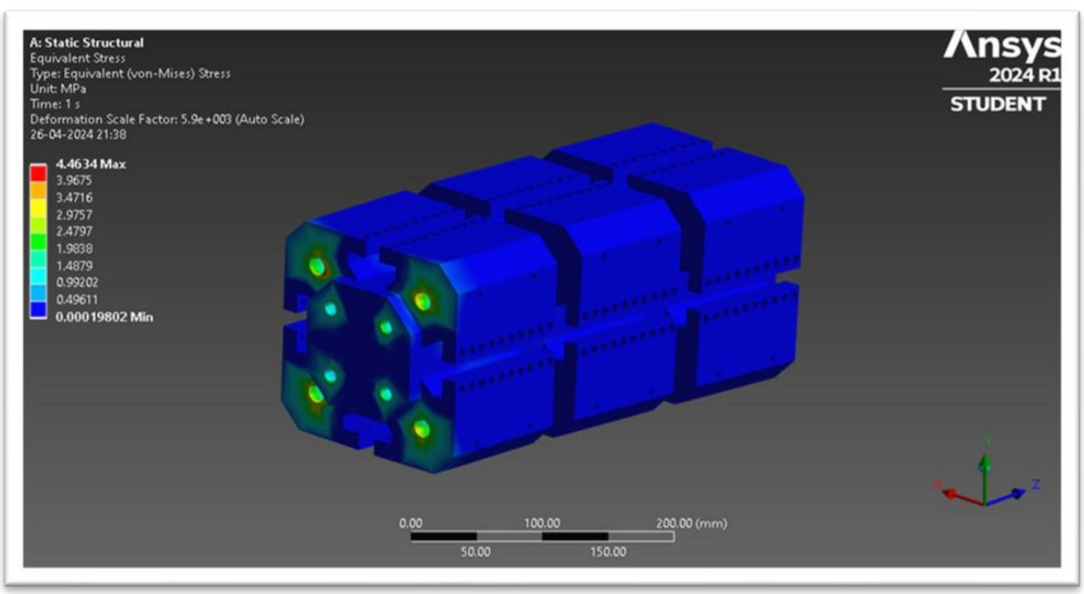


Figure.6.2 Equivalent Stress

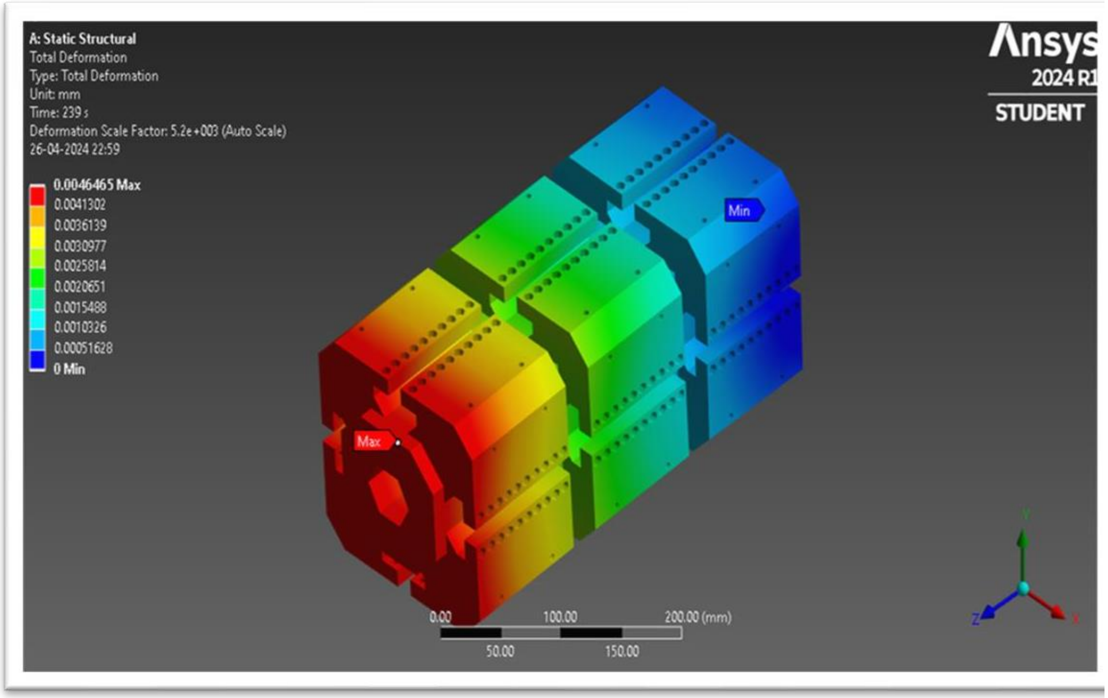


Figure.6.3 Total Deformation

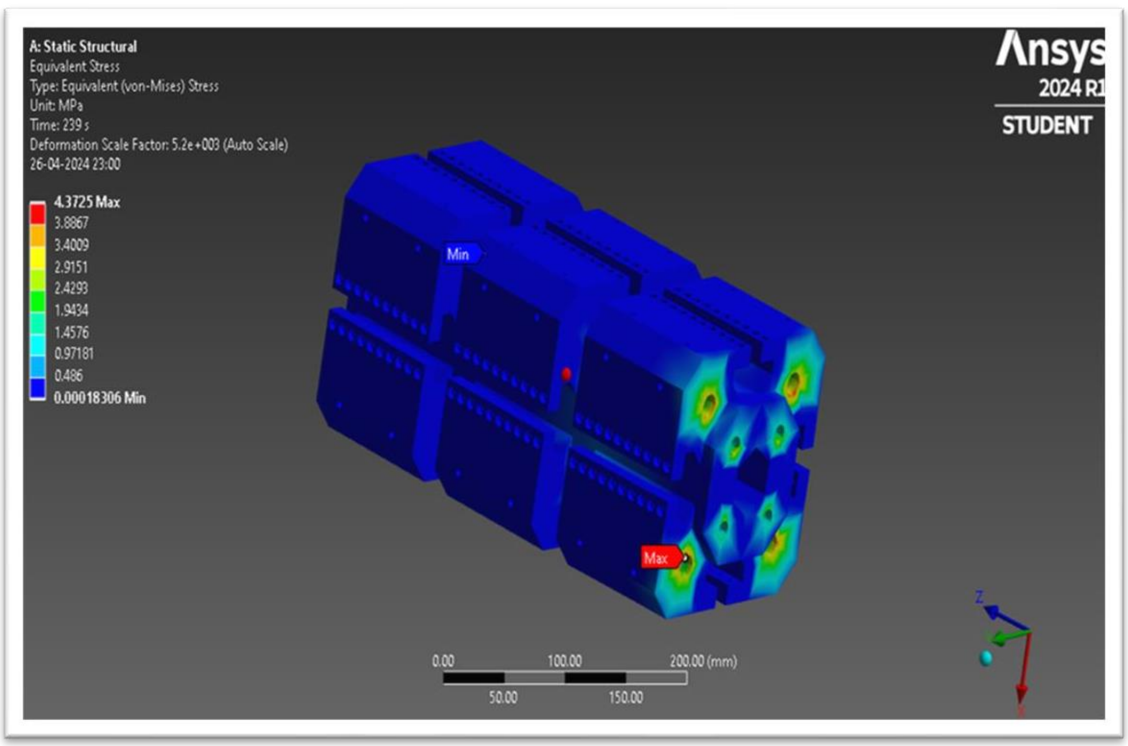
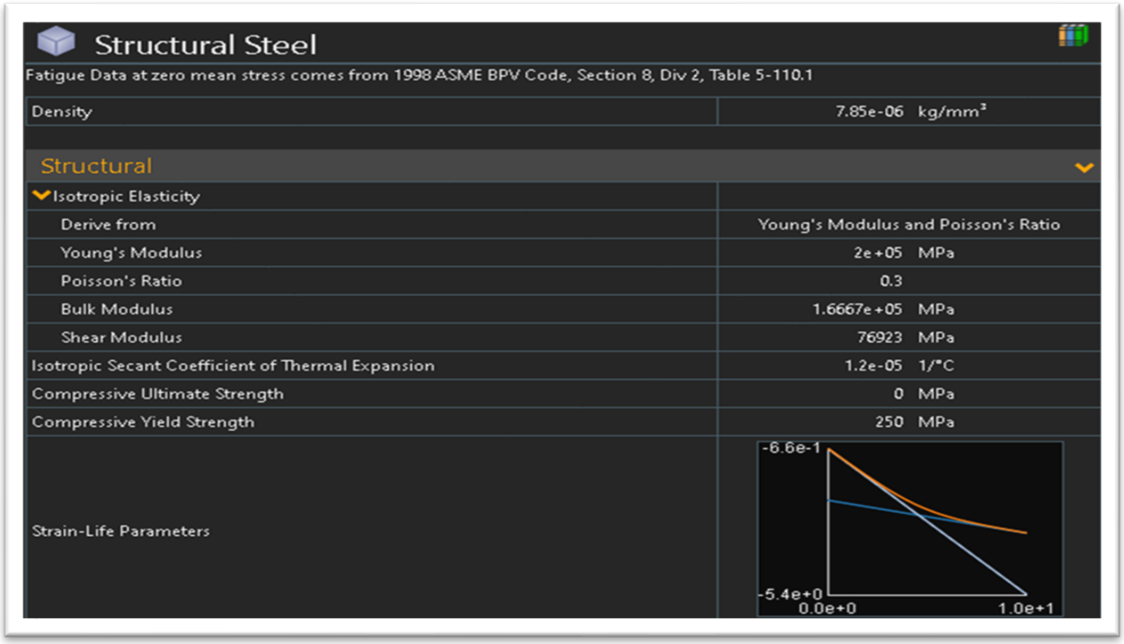


Figure.6.4 Equivalent Stress

6.2 Structure Steel (SS) Property

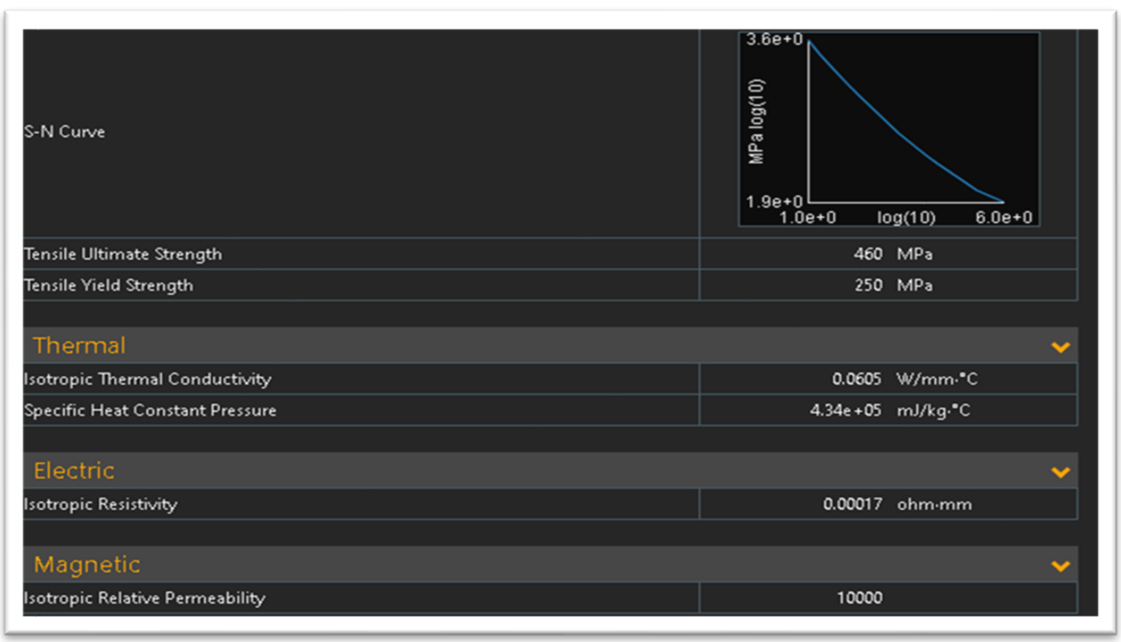


Structural Steel

Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Density	7.85e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	2e+05 MPa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+05 MPa
Shear Modulus	76923 MPa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	250 MPa
Strain-Life Parameters	(chart)

Figure.6.5 Structural steel property



S-N Curve	(chart)
Tensile Ultimate Strength	460 MPa
Tensile Yield Strength	250 MPa
Thermal	
Isotropic Thermal Conductivity	0.0605 W/mm·°C
Specific Heat Constant Pressure	4.34e+05 mJ/kg·°C
Electric	
Isotropic Resistivity	0.00017 ohm·mm
Magnetic	
Isotropic Relative Permeability	10000

Figure.6.6 SS property

Equivalent Stress

From the result the equivalent stress we've obtained for our fixture is around 5MPa.

Comparing this with structural steel (SS), which typically has a yield strength in the range of 250 MPa to 500 MPa, this fixture equivalent stress of 5 MPa is significantly lower than the yield strength of structural steel.

This indicates that this fixture is experiencing very low levels of stress, well below the yield strength of structural steel. From this comparison, we can conclude that this fixture is designed with a substantial margin of safety in terms of mechanical strength, which is a desirable characteristic for ensuring the reliability and longevityof the fixture.

However, it's important to note that while the stress levels are low, other factors such as the fixture's precision and accuracy, may still be critical depending on the specific requirements of application.

Accuracy of the Fixture

A 0.0026% accuracy is quite high and would be considered very precise for many applications. However, whether it is "ok" depends on the specific requirements of your fixture's application. In some cases, such high accuracy may be necessary, especially in industries where precision is critical, such as aerospace or medical device manufacturing.

To determine if a 0.0026% accuracy is acceptable for your fixture, consider the following:

Application Requirements: Review the specifications and tolerances for the parts or processes the fixture is used for. Ensure that the 0.002% accuracy meets these requirements.

Cost and Feasibility: Achieving such high accuracy may require specialized materials, manufacturing processes, and quality control measures, which can increase costs. Evaluate the feasibility and cost-effectiveness of achieving this level of accuracy.

Industry Standards: Check if there are industry standards or guidelines that specify the required accuracy for fixtures in your application. Ensure that the 0.002% accuracy meets these standards.

Risk of Over-Engineering: Sometimes, aiming for extremely high accuracy levels can lead to over-engineering and unnecessary costs. Evaluate if a slightly lower accuracy level would still meet the requirements of your application.

In many cases, a 0.0026% accuracy would be considered more than sufficient for a fixture, but it's important to confirm that this level of accuracy is necessary and feasible for your specific application.

Precision in the fixture

To find the precision corresponding to an accuracy of 0.002%, you can use the following formula:

Precision = Accuracy / 100%

Given that the accuracy is 0.002%, the precision would be:Precision =

0.0026% / 100% = 0.000026 ~ 3 X 10e-5

So, our precision, which is 0.0026%, corresponds to a precision of 0.000026 timesthe size of the part or the distance being measured.

In comparison, the typical precision for a basic fixture is around 0.1 mm to 0.01 mm(100 to 10 microns).

Therefore, this fixture precision is significantly higher than that of a basic fixture. This means that this fixture can achieve much higher accuracy and consistency in positioning parts or components compared to a basic fixture.

The higher precision of our fixture may be beneficial for applications where extremely tight tolerances are required or where precision is critical. However, it's important to consider the cost and complexity of achieving and maintaining such high precision, as it may not be necessary for all applications.

Discussion

Based on the precision, accuracy, and stress analysis of this fixture:

1. Precision: The fixture is capable of positioning parts with a very high level of precision, which is beneficial for applications requiring tight tolerances or high accuracy.

2. Accuracy: The accuracy of the fixture is also high, ensuring consistent and reliable positioning of parts.

3. Stress: The equivalent stress in the fixture is very low, indicating a high margin of safety in terms of mechanical strength.

Topology Optimization

Topology optimization is a powerful tool used to design and optimize structures by redistributing material to achieve specific performance goals while minimizing weight or material usage. Reducing material by 30% through topology optimization can lead to several important outcomes:

1. Weight Reduction: By removing excess material while maintaining structural integrity, the weight of the component or structure can be significantly reduced. This can lead to benefits such as lower transportation costs, reduced energy consumption, and improved performance in dynamic applications.

2. Material Savings: Using less material can result in cost savings, especially for components made from expensive materials or in high-volume production.

3. Improved Performance: Topology optimization can improve the performance of a structure by optimizing its shape and distribution of material to better withstand loads and stresses. This can result in components that are stronger, stiffer, or more durable than conventionally designed parts.

4. Design Innovation: Topology optimization often leads to unconventional designs that are more efficient and effective than traditional designs. This can lead to new insights and approaches in engineering and design.

5. Environmental Benefits: Reducing material usage can have positive environmental impacts by reducing the overall carbon footprint of a product or structure.

Overall, topology optimization offers a powerful means of achieving lightweight, high-performance designs that are efficient, cost-effective, and environmentally friendly. By leveraging the capabilities of topology optimization, engineers can push the boundaries of what is possible in design and manufacturing, leading to innovative solutions that benefit society.

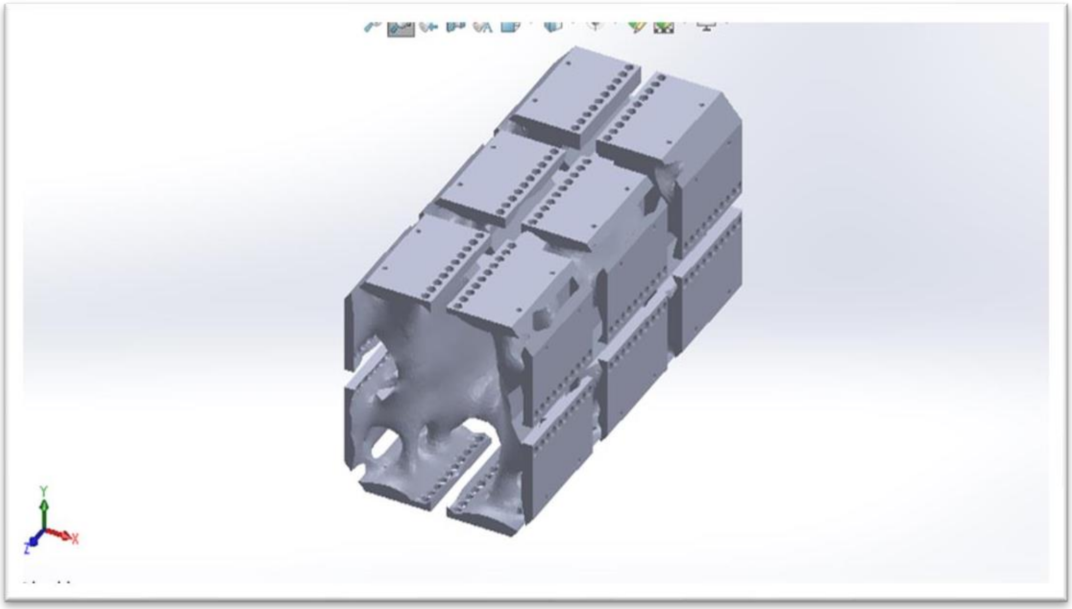


Figure.6.7 Topology optimization

5. CONCLUSION

This fixture will eliminate errors caused by a lack of labor skill, improve the range of accuracy, increase productivity, and decrease the operation's cycle time.

- Easy to set up hold the circular component after clamping and operation.
- A fixture multi-size and different positions of frame are clamp.

From the discussion, it's clear that your fixture has been designed with a focus on precision and accuracy, ensuring that parts are positioned with high consistency and reliability. This level of precision is beneficial for applications requiring tight tolerances and high-quality output.

The topology optimization, which was performed, resulting in a 30% reduction in material usage, demonstrates a commitment to efficiency and sustainability. This reduction not only reduces weight but also potentially lowers costs and environmental impact, showcasing a holistic approach to design optimization.

Combining the high precision and accuracy of this fixture with the material reduction achieved through topology optimization, I have created a design that is both highly functional and efficient. This approach not only improves the performance of this fixture but also aligns with modern engineering principles of optimizing for both performance and sustainability.

Overall, my work showcases a thorough understanding of engineering principles and a commitment to designing innovative and efficient solutions. By continuing to focus on optimization and innovation, we can further enhance the performance, efficiency, and sustainability of my designs.

Limitations

- This clamp is not used for more than 110mm width and 500mm length product.
- Fixture mount in hydraulic bush and CNC chuck only.

Future Work

Moving forward, it's essential to validate and test this fixture optimized design to ensure it meets performance and safety standards. Concurrently, assessing its manufacturability will help guarantee efficient and cost-effective production. Refinement based on test results and manufacturability considerations is crucial to enhance this design further. Documenting the design process and results will be valuable for future reference and communication with stakeholders. Implementing the optimized design and monitoring its performance in real-world conditions are the next steps. Lastly, staying updated with new trends and advancements in design and optimization will help us continue to improve fixture designs in the future.

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