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Sonargaon University (SU)
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Design and Fabrication of a Pegboard With Toggle Clamp Fixture for Precision Welding

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Department of Mechanical Engineering

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September,2025

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of
Bachelor of Science in Mechanical Engineering

September,2025

LETTER OF TRANSMITTAL

18 September,2025

To

Nuruzzaman Rakib

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Subject: Submission of Thesis Report

Dear Sir,

We are pleased to submit the thesis report on "**Design and Fabrication of a Pegboard With Toggle Clamp Fixture for Precision Welding".** It was a great pleasure to work on such an important topic. This thesis has been done as per instruction of your supervision and according to the requirements of the Sonargaon University.

We expect that the thesis will be accepted by the concerned authority we will remain happy to further explanation that you may feel necessary in this regard.

Thank You

Sincerely yours,

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DECLARATION

We hereby declare that the project report entitled "**Design and Fabrication of a Pegboard With Toggle Clamp Fixture for Precision Welding"** submitted in partial fulfillment of the requirements for the degree of **Bachelor of Science in Mechanical Engineering** is the result of our own work and research, carried out under the supervision of Nuruzzaman Rakib Assistant Professor,Dept. of Mechanical Engineering, Sonargaon University (SU).

We further declare that this project has not been previously submitted to any other university or institution for any academic degree, diploma, or other qualification. All sources of information and data used in the preparation of this report have been duly acknowledged.

We are fully responsible for the content, findings, and results presented in this work.

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ABSTRACT

Precision welding plays a critical role in modern manufacturing industries, where dimensional accuracy, repeatability, and structural integrity are essential. This thesis focuses on the design and fabrication of a modular pegboard integrated with toggle clamp fixtures to improve the precision, stability, and efficiency of welding operations. The primary aim is to develop a cost-effective, flexible, and reusable welding fixture system that enhances the accuracy of joint alignment and reduces setup time across various welding applications. Fabrication involves the use of mild steel plates for the pegboard and high-strength toggle clamps to withstand mechanical stress. The results demonstrate significant improvements in weld accuracy, operator safety, and productivity, confirming that the proposed system is effective for use in small- to medium-scale fabrication workshops. This thesis concludes that the pegboard with toggle clamp fixture is a versatile, scalable, and user-friendly solution for precision welding applications. It also provides recommendations for future improvements, such as automation integration and material optimization, to enhance functionality and performance further.

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CHAPTER 1

INTRODUCTION

1.1 Introduction:

Welding is a vital manufacturing process used extensively in industries such as automotive, aerospace, shipbuilding, construction, and heavy machinery. For a weld joint to meet desired strength, dimensional accuracy, and quality standards, precise positioning and secure clamping of the components are essential. Even slight deviations during welding can lead to misalignment, warping due to thermal stress, and eventual failure of the product in service. Therefore, precision welding fixtures have become an essential part of modern production environments to ensure repeatability, accuracy, and operator safety.

Traditional welding fixtures are often custom-built for specific tasks, making them expensive, time-consuming to develop, and difficult to adapt for new workpieces. These fixed systems lack modularity and are often impractical for small-scale or low-volume production environments. Additionally, the manual clamping used in conventional setups may not offer uniform force distribution, leading to dimensional inaccuracies or poor-quality welds.

To overcome these limitations, this project proposes the design and fabrication of a pegboard fixture system integrated with toggle clamps, tailored for precision welding. The pegboard acts as a modular base plate with evenly spaced holes that allow fixtures and clamps to be repositioned based on the workpiece configuration. Toggle clamps, known for their quick locking and consistent holding force, are mounted on the pegboard to hold the workpieces rigidly during welding. This system allows for flexibility, repeatability, and rapid setup, all while maintaining the precision required in welding operations.

This research focuses on developing a cost-effective, reusable, and flexible fixturing solution, particularly suitable for small to medium-scale workshops, educational institutions, and light fabrication industries. By implementing the pegboard and toggle clamp system, fabricators can improve welding accuracy, reduce time and labor, and enhance operator safety. The study will cover the entire lifecycle of the fixture system, including design through CAD software, fabrication, testing, and performance analysis in a practical welding environment.

1.2 Problem Statement:

Precision and consistency are essential in welding operations, especially in industries such as automotive, aerospace, and heavy fabrication, where even minor inaccuracies can lead to significant defects or structural failure. A critical factor that influences the quality of a weld is the effectiveness of the fixture system used to hold and position components during welding. In most small to medium-scale workshops, traditional welding fixtures are rigid, bulky, and custom-built for specific components, making them expensive, inflexible, and impractical for diverse or low-volume production.

Additionally, conventional fixturing methods often rely on manual clamps and alignments, which not only increase setup time but also introduce human error, resulting in misalignment, deformation due to thermal stresses, and operator fatigue. These drawbacks contribute to reduced productivity, inconsistent weld quality, and higher production costs. While large industries may afford advanced automated systems, such solutions are often economically infeasible for smaller manufacturers, training institutes, or custom fabrication units.

There is a clear need for a modular, cost-effective, and reconfigurable welding fixture that can securely and accurately hold a variety of workpieces without the need for dedicated, custom-built jigs for every new project. Integrating a pegboard fixture system with toggle clamps presents a promising alternative. The pegboard allows for flexible and repeatable fixture arrangements, while toggle clamps provide quick, consistent clamping with strong holding power. However, limited research exists on the design, fabrication, and practical evaluation of such systems, especially in resource-constrained environments.

Therefore, this study aims to design and fabricate a modular pegboard fixture system integrated with toggle clamps, focusing on enhancing precision, repeatability, and usability in welding operations. The solution is intended to bridge the gap between high-end industrial automation and low-budget manual setups by offering a flexible, scalable, and user-friendly fixture suitable for a wide range of welding tasks.

1.3 Background Study:

Welding is a fundamental process in the manufacturing industry, used to create strong, permanent joints between metal parts. However, achieving precision in welding is often a challenge due to misalignment, distortion from heat, and inconsistent clamping. These problems can lead to poor-quality welds, especially when the workpiece is not held securely or accurately during the welding process. As industries move toward automation and tighter tolerances, there is an increasing need for reliable and adaptable fixturing systems to ensure precision, consistency, and safety during welding operations.

Traditional welding fixtures, though effective for specific tasks, are often rigid in design and costly to produce. They are typically built for a single component or project, making them unsuitable for varying or low-volume production. Additionally, manual alignment and clamping can introduce human error, increase setup time, and affect weld quality. To overcome these limitations, modular fixturing systems have emerged as a practical solution. One such system is the pegboard fixture, which features a perforated grid base allowing flexible placement of clamps and stoppers for different workpiece configurations.

The pegboard system offers significant advantages such as repeatability, quick setup, ease of customization, and cost-effectiveness. When used with toggle clamps—mechanical devices known for their fast operation and consistent holding force—the system becomes even more efficient. Toggle clamps ensure that the workpiece remains fixed during welding, resisting vibration and thermal stresses. Their ergonomic design also improves operator comfort and safety. The integration of toggle clamps with a modular pegboard can thus provide a high degree of control over the welding process, leading to improved quality and reduced waste.

This thesis addresses the design and fabrication of such a modular fixturing system, aiming to combine the flexibility of a pegboard with the holding strength of toggle clamps. This approach is particularly useful for small- to medium-scale workshops where cost and adaptability are key considerations. By developing and testing this fixture, the research seeks to offer a practical solution that enhances weld accuracy, reduces setup time, and promotes safety—all while keeping the system reusable for multiple applications.

1.4 Objectives:

The primary objective of this thesis is to design, develop, and evaluate a modular fixturing system that integrates a pegboard base with toggle clamps to enhance the accuracy, efficiency, and flexibility of precision welding operations. This system is intended to address the limitations of conventional fixed welding fixtures by offering a more adaptable, cost-effective, and user-friendly alternative suitable for small to medium-scale manufacturing environments.

To achieve this overarching goal, the following specific objectives are set:

- To study the limitations of conventional welding fixtures and identify key design requirements.
- To design a modular pegboard fixture system with a standardized hole pattern.
- To select and integrate appropriate toggle clamps for consistent and secure workpiece holding.
- To fabricate the pegboard and fixture components using suitable materials and manufacturing processes.
- To test the fixture system under practical welding conditions and evaluate its performance.
- To compare the developed fixture with traditional welding setups in terms of precision, efficiency, and usability.
- To provide recommendations for future improvements and possible automation integration.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Introduction:

In the field of manufacturing and fabrication, welding plays a central role in joining metal components with strength and durability. However, achieving precision in welding is not solely dependent on the welding technique itself but also on how well the components are held and aligned during the process. As product designs become more complex and tolerances tighter, the demand for high-precision welding fixtures has significantly increased.

Fixtures are critical tools used to position and hold workpieces securely and accurately during welding operations. Traditional welding fixtures are often custom-designed for specific parts, making them expensive, time-consuming to develop, and inflexible when used in diverse or changing production environments. These drawbacks have prompted manufacturers, researchers, and engineers to explore modular and reusable fixture systems that offer flexibility without compromising precision.

Among these modern solutions, the combination of pegboard-style modular base plates and toggle clamps has gained attention for its adaptability, cost-effectiveness, and ease of use. The pegboard provides a standardized grid of mounting holes that allow for repositionable fixture setups, while toggle clamps offer strong, repeatable clamping force and quick operation. This modular approach is especially beneficial in small-scale workshops, educational institutions, prototype labs, and custom fabrication units, where traditional fixtures may not be economically feasible or practically viable.

This literature review aims to explore the existing body of research and technical developments in the area of welding fixture design, with a particular focus on modular fixturing systems and the use of toggle clamps. It also identifies the limitations of current technologies and highlights the need for a practical, scalable solution like the pegboard with toggle clamp fixture system proposed in this thesis. Through a review of relevant studies, patents, and industrial practices, this chapter lays the foundation for the design decisions, fabrication strategy, and testing methodology presented in the subsequent chapters.

2.2 Literature Survey:

- **Traditional Welding Fixtures**

Conventional welding fixtures are generally rigid, permanent setups custom-built for specific jobs. While they provide excellent support for mass production, they are expensive, time-consuming to fabricate, and lack flexibility. According to **Sharma et al. (2017)**, traditional fixtures are limited in their ability to accommodate different parts, and their reconfiguration often requires disassembly or modification. This inefficiency makes them unsuitable for low-volume or customized production lines.

Moreover, studies by **Gao and Zhang (2015)** indicate that thermal deformation during welding can lead to part distortion if the fixture does not apply uniform and sufficient clamping force. In many workshops, operators rely on manual clamping, which introduces inconsistency and operator fatigue, further affecting weld quality.

- **Modular Fixturing Systems**

To overcome the rigidity of traditional setups, researchers and industries have turned to modular fixturing systems. These systems use standardized, reusable components like base plates, locator pins, stoppers, and clamps that can be quickly assembled and reconfigured. As noted by **Kim and Lin (2018)**, modular fixtures reduce setup time, lower cost, and provide greater flexibility in handling various component geometries.

The pegboard-style base plate has emerged as a key component in modular fixtures. The pegboard features a uniformly distributed hole pattern, allowing clamps and locators to be positioned precisely for different tasks. A study by **Singh et al. (2019)** highlighted that pegboard systems significantly improve repeatability and reduce operator dependency, especially in small- and medium-scale manufacturing environments.

- **Toggle Clamps in Welding Fixtures**

Toggle clamps are mechanical devices designed to securely hold components in place during machining or welding. They operate using an over-center locking mechanism that keeps the clamp in a locked position once applied. Due to their ease of use, fast operation, and strong holding power, toggle clamps are widely used in welding fixture applications. According to research by **Mehta and Kapoor (2020)**, toggle clamps provide consistent clamping force, reduce setup time, and minimize distortion due to vibration or heat during welding. Their compact design also allows better access to weld joints, which is particularly important in precision welding.

- **Integration of Pegboard and Toggle Clamp Systems**

Integrating pegboard base plates with toggle clamps presents a highly adaptable fixturing system. Research by **Arunkumar et al. (2021)** demonstrated that pegboard-based fixtures with toggle clamps reduced workpiece setup time by up to 40% and improved weld precision in T-joint and butt joint operations. The flexibility to reconfigure the system for different part geometries makes it ideal for low-volume, high-variety production environments**.** In academic settings, such systems have proven valuable for teaching welding alignment techniques and fixture design principles. The modular nature supports hands-on learning and experimentation. Additionally, in cost-sensitive environments, such as local fabrication shops or vocational institutes, the use of mild steel pegboards and reusable toggle clamps presents a cost-efficient and practical solution.

- **Gaps in Existing Research**

Despite the advantages, few studies have focused on the complete lifecycle of a modular pegboard fixture—covering design, material selection, fabrication, real-world testing, and performance analysis. Moreover, comparative studies evaluating pegboard-toggled systems against traditional fixtures in terms of cost-effectiveness, scalability, and safety are limited. Additionally, most industrial fixtures still require skilled operators to configure and align parts properly. There is an opportunity to standardize pegboard fixtures for broader industry adoption and integrate smart systems such as sensors or pneumatic clamps for automation.

Summary:

The literature clearly establishes the need for flexible, accurate, and cost-effective welding fixtures, particularly for small-scale and evolving production environments. Modular fixturing using pegboard platforms and toggle clamps offers numerous benefits—reduced setup time, enhanced repeatability, improved safety, and operational flexibility. However, a comprehensive design-to-testing approach tailored to small and medium fabrication units is yet to be fully explored. This thesis aims to fill that gap by designing and fabricating a modular fixture system that is practical, scalable, and affordable while ensuring the precision required for high-quality welding.

CHAPTER 3
METHODOLOGY

3.1 Introduction:

This chapter outlines the methodological framework adopted for the design, fabrication, and evaluation of a pegboard fixture equipped with toggle clamps for precision welding applications. The methodology integrates the engineering design process with experimental testing to ensure the final product meets industrial standards for accuracy, stability, and repeatability.

3.2 Research Design:

The research follows a design-based experimental approach, conducted in four sequential phases:

Requirement Identification: Analysis of welding fixture limitations and definition of design specifications for a pegboard with toggle clamps.

↓

Design and Simulation: Development of CAD models and structural simulations to verify the feasibility of the design.

↓

Fabrication: Manufacturing of the pegboard plate, frame assembly, and toggle clamp installation.

↓

Testing and Evaluation: Experimental validation of fixture performance using precision measurement tools and welding trials.

3.3 Design Considerations:

3.3.1 Functional Requirements:

- Versatility to accommodate various workpiece geometries.
- Adequate clamping force to prevent movement during welding.
- Thermal resistance to with stand welding heat.
- Ease of setup and reconfiguration.

3.3.2 Material Selection:



Figure 3.1 Pegboard Plate Material After Cutting

Pegboard Plate **:** Mild steel, chosen for strength, machine ability and cost effectiveness.



Figure 3.2 Frame Structure Material After Cutting

Frame Structure **:** Structural steel angles for rigidity and durability.



Figure 3.3 Toggle Clamp Material After Cutting

Toggle Clamps **:** Heat-treated alloy steel with ergonomic handles for user comfort.

Testing Material:

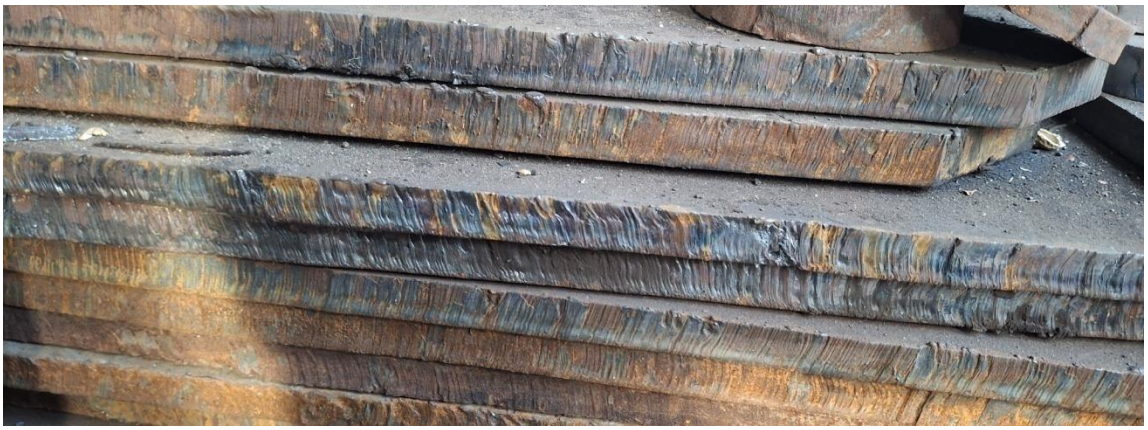


Figure 3.4 Mild Steel Plate (Thickness 19mm)



Figure 3.5 Testing Workpiece After Single V Groove Cutting

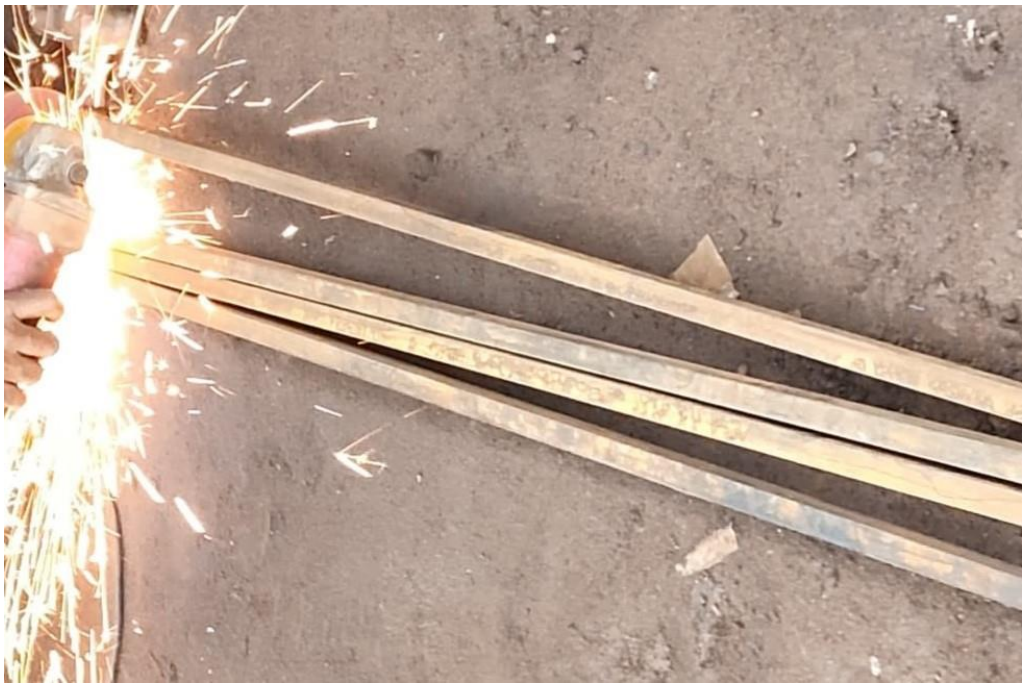


Figure 3.6 16mm Square Solid Bar

Shape :

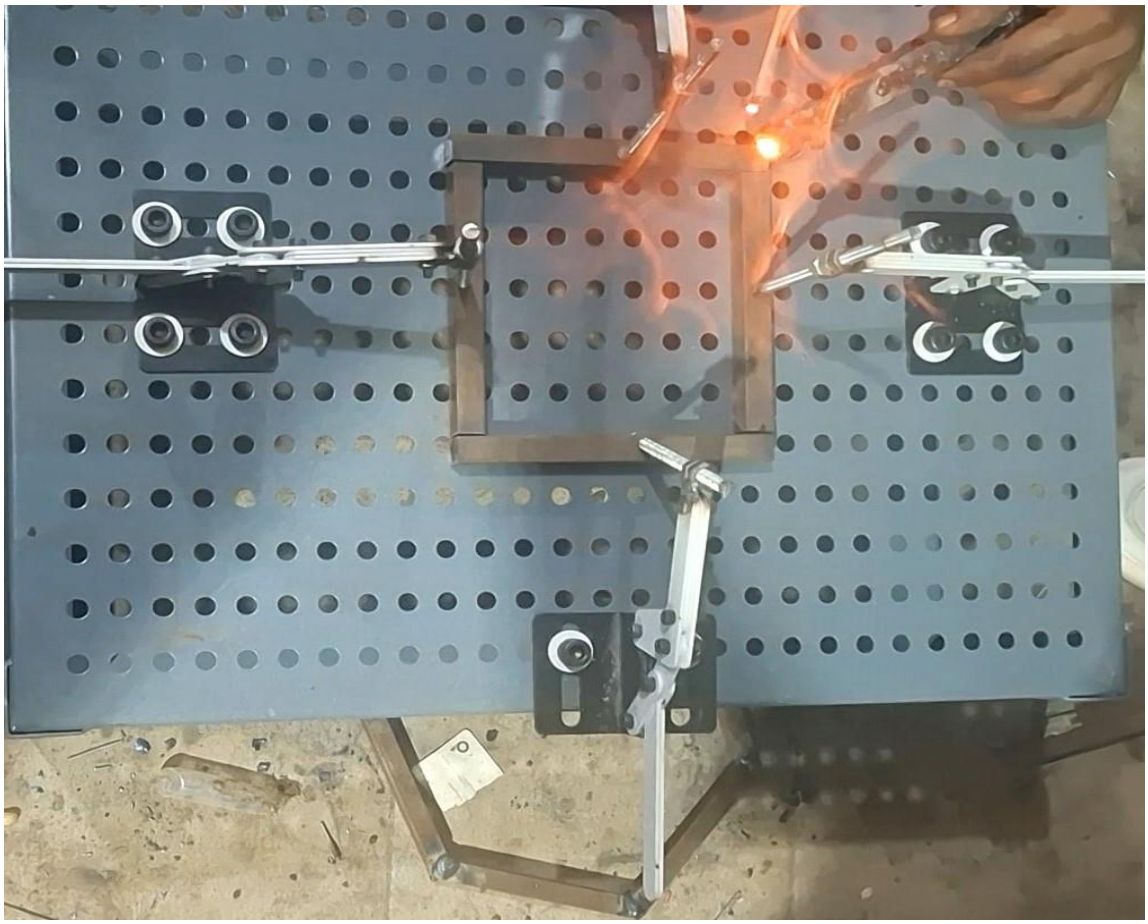


Figure 3.7 Workpiece (Square Shape) Welding Using Toggle Clamp



Figure 3.8 Workpiece (Rhombus Shape) Welding Using Toggle Clamp

3.3.3 Safety and Ergonomics:

- Heat-resistant working surface to minimize thermal distortion.
- Non-slip handles to prevent accidental slippage.
- Adequate clearance for welding torch operation.

3.4 CAD Modeling and Simulation:

Software**: SolidWorks 2024** for **3D** modeling and assembly design.

3.4.1 Design Process:

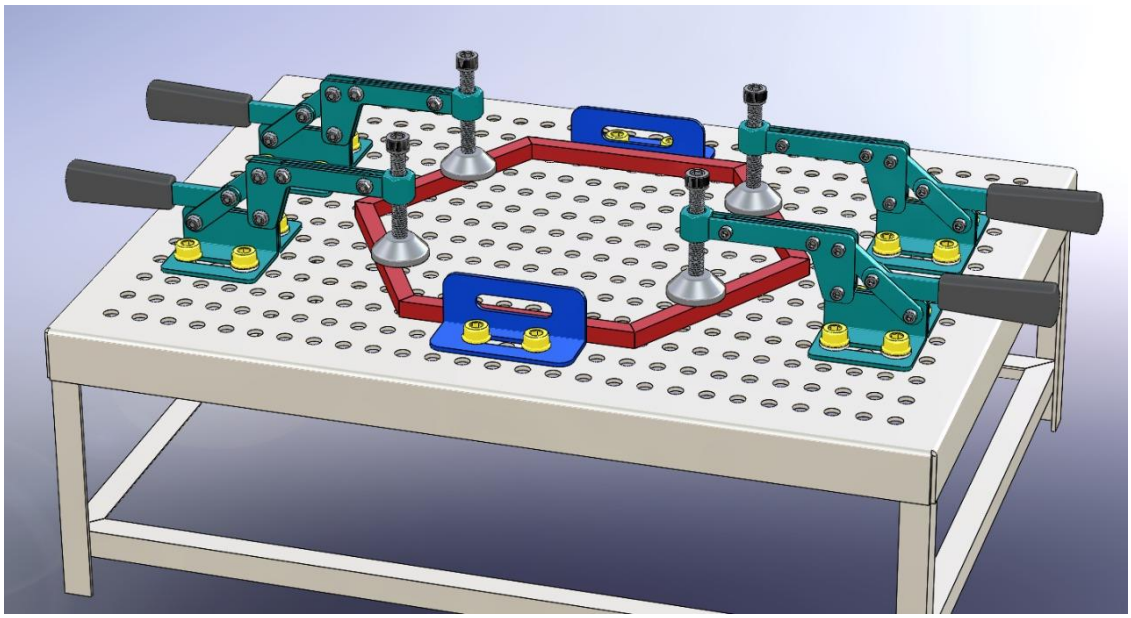


Figure 3.9 Pegboard and Toggle Clamp 3D Design

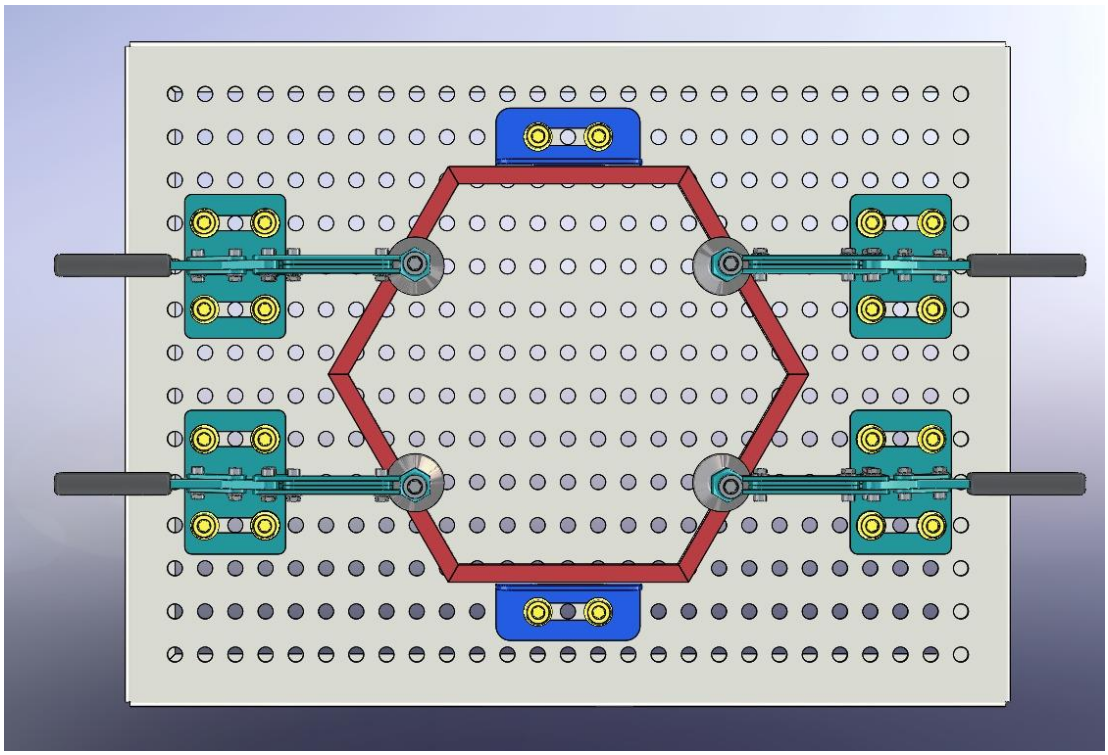


Figure 3.10 Pegboard and Toggle Clamp 3D Design Top View

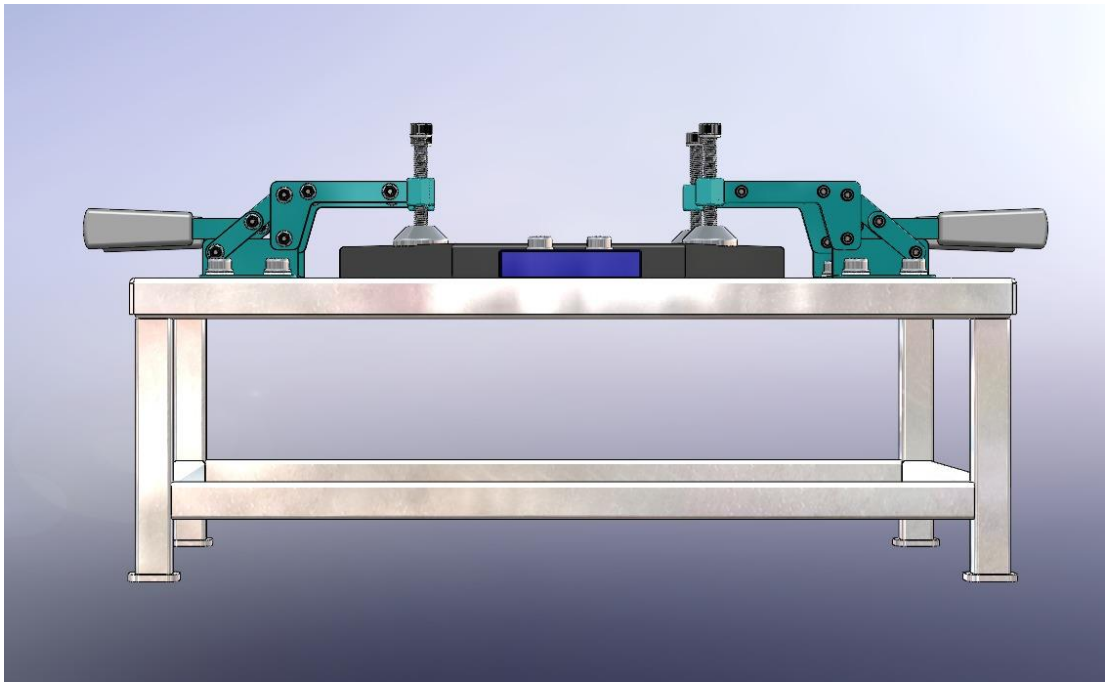


Figure 3.11 Pegboard and Toggle Clamp 3D Design Front Side View

The design and development of the Modular Fixture Table with Toggle Clamp followed a structured, engineering-driven workflow, carried out in four primary stages. Each stage incorporated research, concept development, 3D CAD modeling, simulation, and manufacturability considerations to ensure an optimal balance between performance, durability, ergonomics, and cost-effectiveness.

3.4.2 Concept Generation

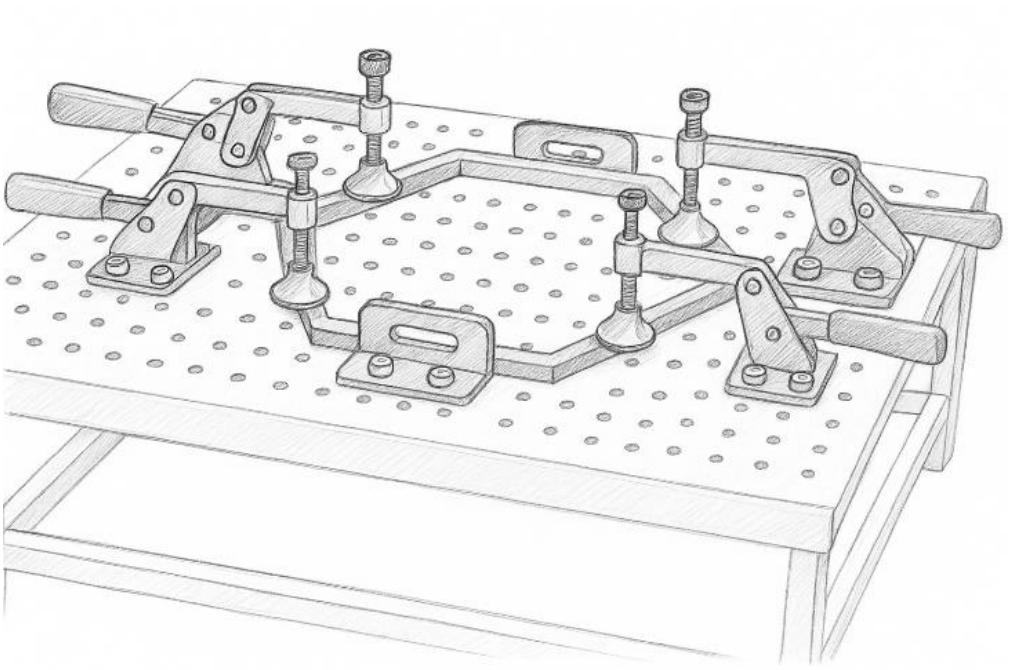


Figure 3.12 Design Concept

The initial phase focused on market research and benchmarking against existing fixture table systems from leading global manufacturers.

3.4.3 CAD Modeling:

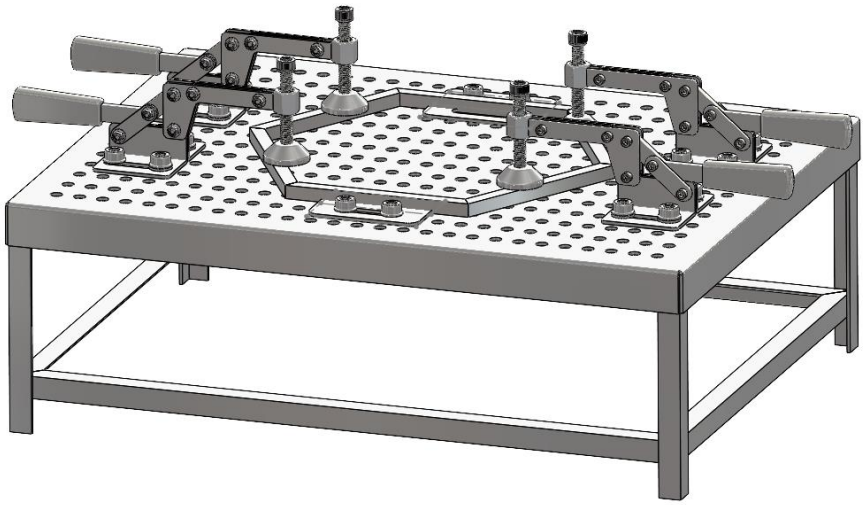


Figure 3.13 3D CAD Model

The conceptual sketches were transitioned into a fully parametric **3D CAD** model using **SolidWorks**, enabling detailed visualization, assembly testing, and manufacturability assessment.

Fixture Table Assembly:

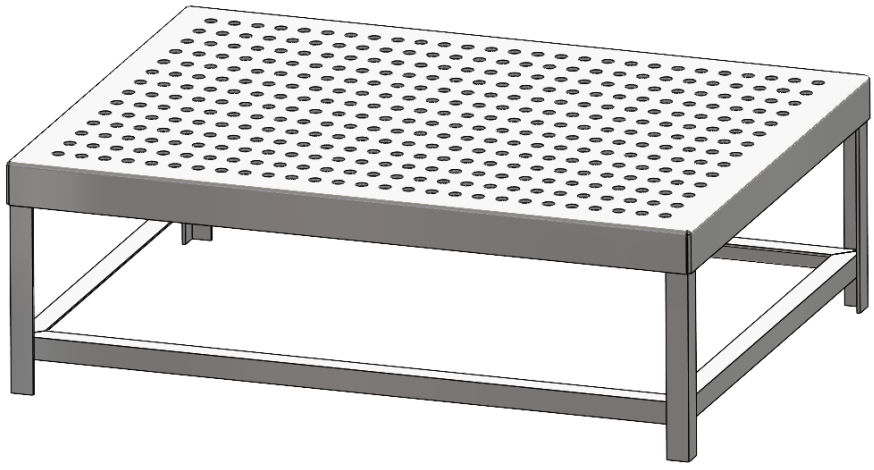


Figure 3.14 Pegboard 3D Design

- Hole grid pattern designed with precise tolerances for compatibility with a variety of accessories and positioning fixtures.
- Heavy-duty steel frame modeled for maximum rigidity and load stability.

Toggle Clamp Assembly:

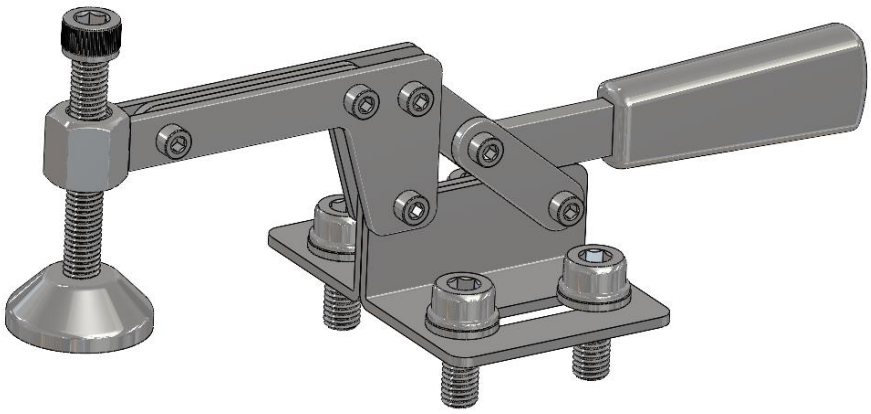


Figure 3.15 Toggle Clamp 3D Design

- **Base Plate**–
- Designed for rigid mounting and precision alignment with the grid system.
- **Pivot Arms** –
- Profiled for strength-to-weight optimization, manufactured via laser cutting and reinforced by press brake bending.
- **Adjustable Clamping Pad** –
- Threaded with a knurled adjustment screw to accommodate varying material thicknesses.
- **Ergonomic Handle** –
- Modeled with grip contours and optimized lever length for reduced input force.

Modular Accessories:

- **Positioning Stops** – For repeat setups and consistent workpiece placement.
- **Angle Brackets** – Allowing angled or multi-axis clamping.
- **Height Spacers** – Enabling elevation adjustments for special setups.

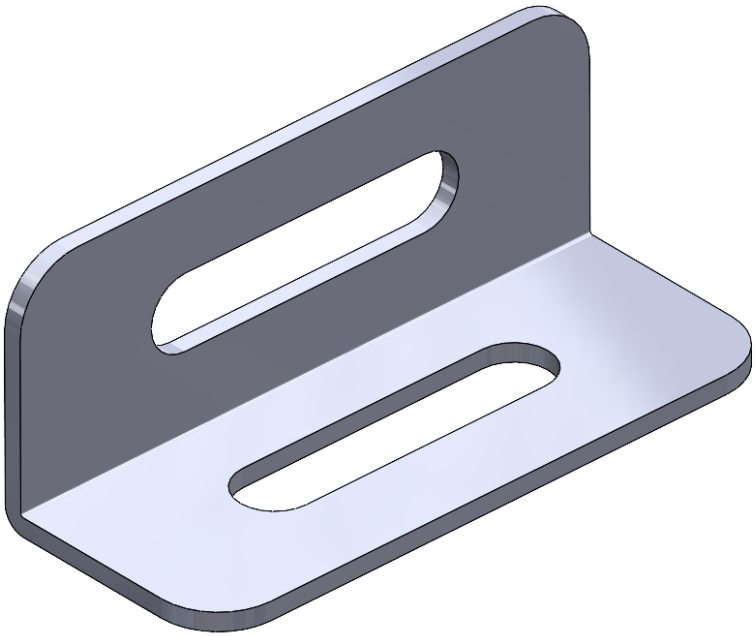


Figure 3.16 Workpiece Side Stopper

Design for Manufacture (DFM) Considerations:

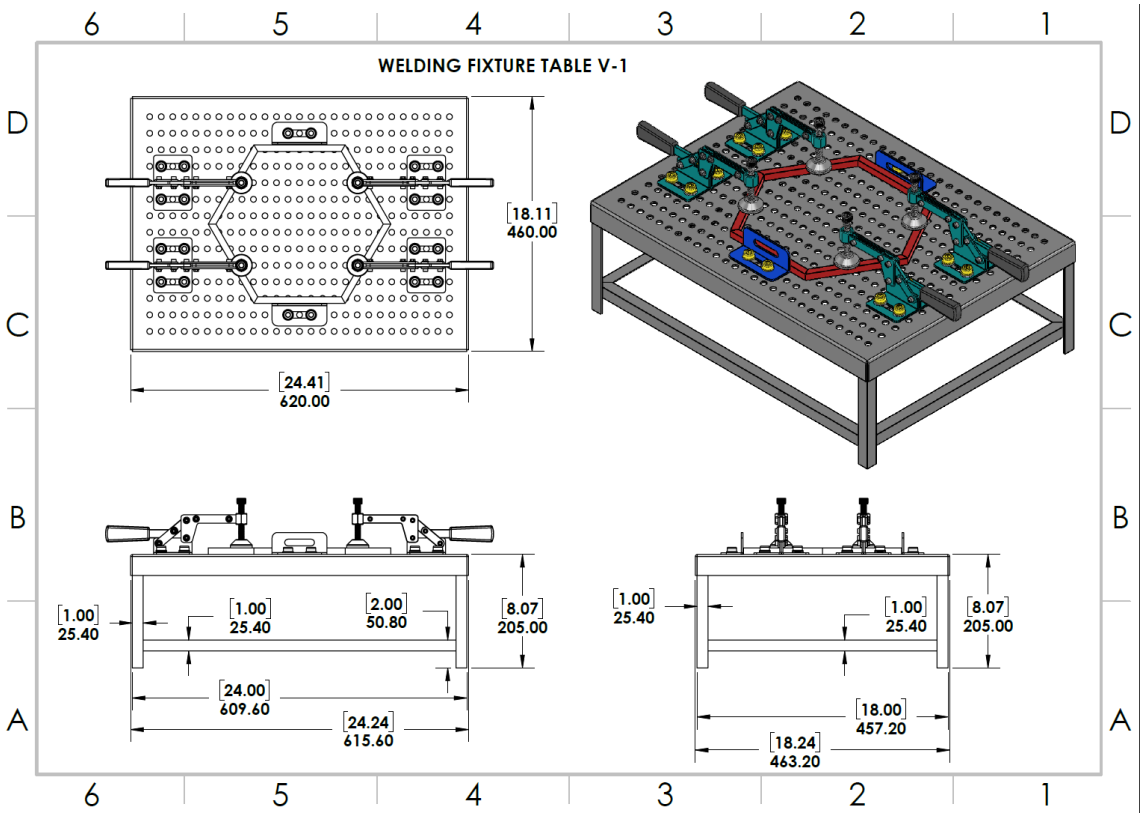


Figure 3.17 Welding Fixture Table Design and Measurement

- All primary parts sized for sheet metal and plate stock availability.
- Fastener selection based on ISO metric standards for interchangeability.
- Parts designed for minimal machining operations where possible to reduce cost.

3.4.4 Design Finalization:

Following simulation validation, the design was optimized for manufacturability, durability, and ease of assembly.

Material Selection:

- **Mild Steel (Structural Parts)** – High strength, machinability, and weldability.
- **Hardened Steel (Fasteners & Pivot Pins)** – Increased wear resistance.

Surface Treatments:

- **Powder Coating** – For corrosion resistance and a professional finish.
- **Precision Grinding** – For flatness and smooth movement at contact points.

Manufacturing Process Plan:

- **Laser Cutting** – High-precision cutting of base plates, arms, and brackets.
- **CNC Machining** – Tight-tolerance production of threaded parts, bushings, and pivot components.
- **Sheet Metal Bending** – Press brake operations to create reinforcement flanges and arm profiles.
- **Welding**– MIG welding for table frame; TIG welding for clamp assembly joints.
- **3D Printing (Prototyping)** – Used for initial ergonomic and alignment testing before committing to metal fabrication.

Assembly & Quality Control:

- Components assembled with precision-aligned bushings and lubricated pivot joints.
- Final inspection included dimensional verification, functional motion tests, and holding force measurement to meet design specifications.

3.5 Fabrication Process:

3.5.1 Cutting Parts Using CNC Laser Machine:

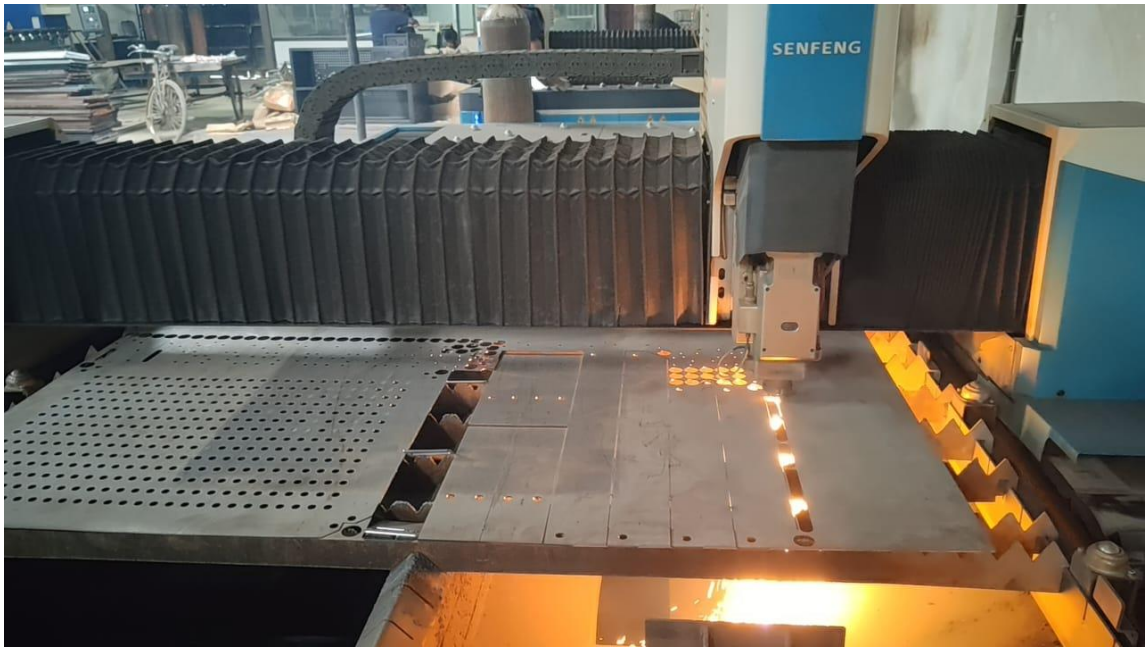


Figure 3.18 Cutting Parts by CNC Laser Machine

A CNC laser cutting machine uses a focused laser beam to cut metal with extremely high precision, capable of cutting complex shapes. The CNC (Computer Numerical Control) ensures exact dimensions and repeatability, which is critical for welding fixtures and clamps. Benefits include minimal material waste, smooth edges, and reduced post-processing.

- Cutting the mild steel plate to specified dimensions.
- Precision drilling of holes at standard intervals.
- Deburring and surface finishing to remove sharp edges.

Work Note:

Programmed the CNC laser machine according to the CAD drawings and supervised the cutting process. All components were cut with high precision and verified for accuracy before assembly.

Assembly of the System:



Figure 3.19 Parts and assembly

All cut parts were assembled to form the pegboard table with toggle clamps. Assembly involved aligning the pegboard panels, securing toggle clamps in the designed holes, and checking for proper leveling and stability. Ensured that clamps were positioned correctly to hold workpieces at required angles for precision welding. This setup allows quick adjustments and ensures repeatable placement for multiple workpieces.

Work Note:
Assembled all cut components, mounted the toggle clamps, and checked alignment and stability. Adjustments were made to ensure precise positioning of workpieces for welding.

3.5.2 Toggle Clamp Installation:

- Marking clamp positions based on CAD layout.
- Bolting clamps securely and adjusting clamping pressure.

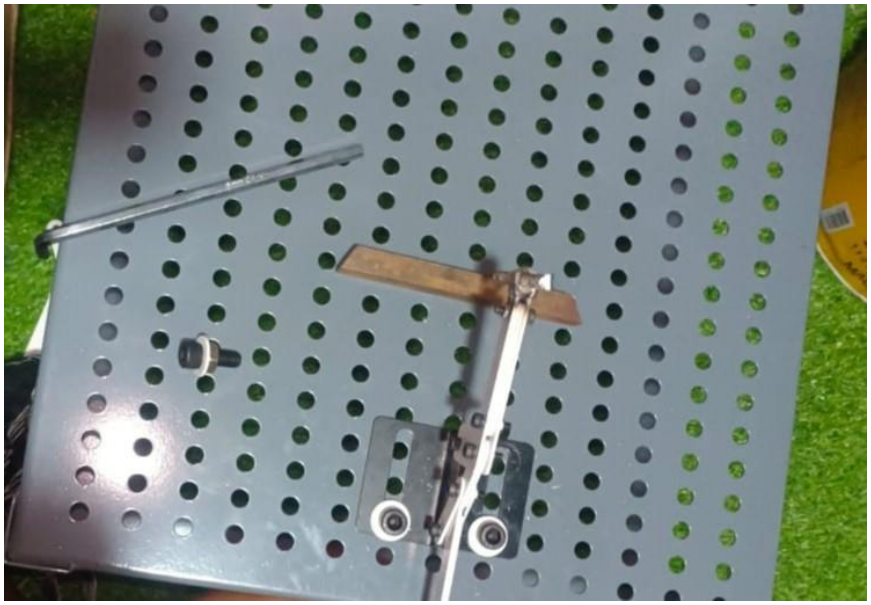


Figure 3.20 Toggle Clamp Install

3.5.3 Final Assembly:

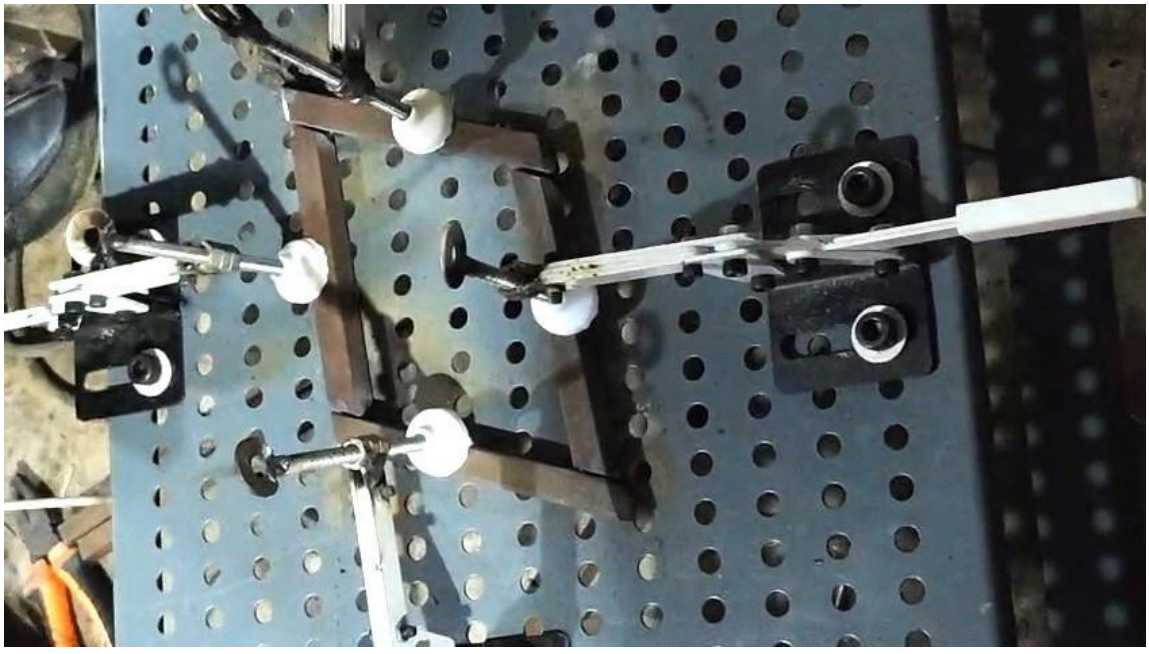


Figure 3.21 Final Project

- Attaching pegboard to frame.
- Performing alignment checks to ensure flatness.

CHAPTER 4
EQUIPMENT

4.1 Materials and Components:

4.1.1 Pegboard:



Figure 4.1 Pegboard

A pegboard is a flat board with a grid of evenly spaced holes, used to support various tools, fixtures, or components. It's commonly used in workshops, retail displays, or manufacturing setups—especially in modular fixture systems like welding tables.

How It Works:

- **Grid of Holes:**
  The pegboard has a regular pattern (e.g., 10 mm × 10 mm spacing) of precision-drilled holes across its surface.
- **Attachment of Fixtures:**
  Components like toggle clamps, stoppers, or support brackets can be inserted and locked into these holes. This allows easy setup and repositioning without the need for welding or permanent fixing.
- **Modularity:**
  Fixtures can be changed or adjusted depending on the size and shape of the workpiece. This makes it ideal for batch production or prototyping, where different jobs may require different setups.
- **Repeatability:**
  Since the holes are arranged in a precise grid, users can repeat the exact setup for identical parts, ensuring consistent weld positioning and alignment.

4.1.2 Toggle Clamp:



Figure 4.2 Toggle Clamp

A toggle clamp is a mechanical clamping device used to securely hold a workpiece in place during operations such as welding, machining, drilling, or assembly. It uses a toggle mechanism—a system of pivoted arms and levers—to apply strong clamping force with minimal effort from the operator.

How It Works:
When the handle is pushed or pulled, the linkage system moves the clamp arm into a locking position. Once fully locked, the clamp resists force in any direction, keeping the workpiece firmly fixed.

4.1.3 Welding:

Welding is a manufacturing process that joins two or more metal parts by applying heat, pressure, or both, causing the base metals to melt and fuse together. It may or may not involve filler material. Once cooled, the result is a strong, permanent joint.

- **Shielded Metal Arc Welding (SMAW) / Stick Welding**

- **Process:** A flux-coated consumable electrode ("stick") creates an arc with the base metal. The flux melts to produce shielding gas and slag, protecting the weld pool.
- **Shielding:** Provided by the flux coating (no external gas required).
- **Uses:** Construction, pipelines, shipbuilding, repair, and maintenance.
- **Pros:** Simple, portable, inexpensive, works outdoors and on rusty/dirty metals.
- **Cons:** Slower, requires skill, frequent electrode changes, slag removal needed.



Figure 4.3 Stick Welding Machine

Electrode Specification:

E7018 =

- **E** → Electrode
- **70** → Tensile strength = 70,000 psi (490 MPa)
- **1** → Welding position = All positions (flat, horizontal, vertical, overhead)
- **8** → Flux type & current = Low-hydrogen, iron powder coating; AC or DC+

E7018 is a low-hydrogen, all-position electrode with 70,000 psi tensile strength. It's widely used for structural and critical welds because of its strength, ductility, and reliability.



Figure 4.4 Electrode E7018

4.1.4 Welding Joints:

Welding joints refer to the configurations or ways in which two or more metal pieces are joined together by welding. The design of a welding joint plays a crucial role in determining the strength, stability, and quality of the weld. The choice of joint depends on the application, material type, thickness, load requirements, and accessibility.

- **Butt Joint**

- **Description:** Two metal pieces are placed in the same plane and joined at their edges.
- **Uses:** Plates, structural components.
- **Advantages:** Simple, easy to prepare and weld.
- **Common Welds:** Single V-groove, double-V groove.

4.2 Fabrication Equipment

- **Gas Cutting Machine (Power Shear/Hacksaw/Plasma Cutter)**
- Used for cutting mild steel sheets into required dimensions.
- **Welding Machine (MIG/Arc Welding)**
- Used to fabricate and assemble the pegboard frame.
- **Grinding Machine/Angle Grinder**
- Removed burrs, sharp edges, and ensured smooth finishing.
- **Measuring Tools (Steel Ruler, Tape)**
- Ensured accuracy in cutting, drilling, and assembly.

4.3 Testing Equipment:

Hardness Tester Machine:

Rockwall hardness tester gives the direct reading of a hardness number on a dial provided with the number.

Specifications are as follows:

- Ability to determine the hardness up to 100 RHN.
- Maximum application of load 150 kg.
- Minimum application of load 10 kg.
- Method of load application, lever type.
- Least measuring hardness number 1 RHN.

Test Specimen:

A selected specimen should have a thickness three times higher than the depth of Indentation to avoid the deformation to be extended to the opposite surface of a specimen.

Materials and Equipments:

- Rockwall hardness tester machine.
- Diamond cone indenter.
- Specimens (Mild steel).



Figure 4.5 Rockwell Hardness Tester Machine

Set Square & T-Scale:

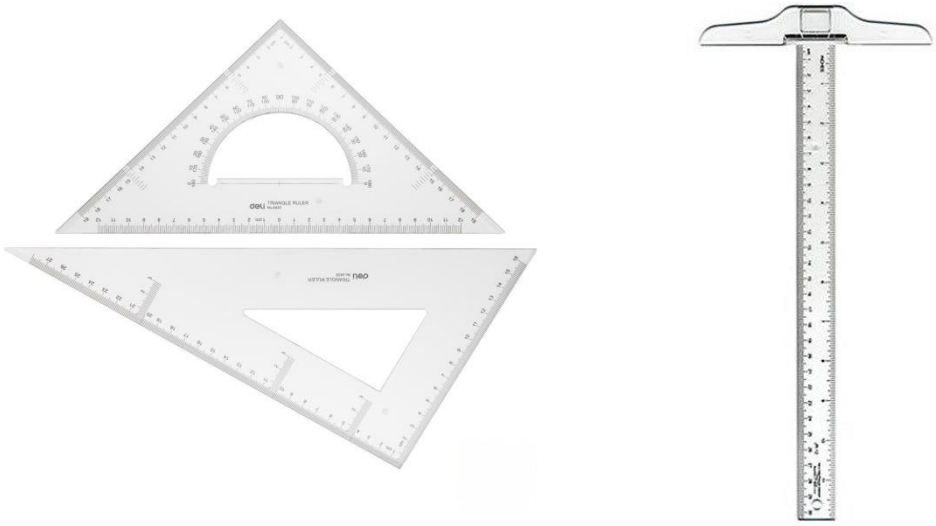


Figure 4.6 Set Square & T-Scale

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Introduction:

This chapter presents the results and discussion of the designed and fabricated pegboard with toggle clamp fixture for precision welding. The purpose of this section is to analyze the performance of the developed system and evaluate its effectiveness in comparison with conventional/traditional clamping methods. The results are organized based on key performance parameters, including dimensional accuracy, distortion control, clamping stability, repeatability, setup time, and operator convenience. Data were collected through experimental trials on mild steel plates using SMAW welding under controlled conditions. By presenting both quantitative results (measurements, tables) and qualitative observations (ease of use, operator feedback), this chapter provides a comprehensive evaluation of the fixture's functionality. The discussion interprets these results to highlight the strengths, improvements, and limitations of the pegboard fixture system. The findings from this chapter ultimately validate whether the developed fixture meets its design objectives of enhancing precision, efficiency, and productivity in welding operations.

5.2 Results:

Comparison between conventional/traditional clamping and pegboard with toggle clamping fixture

Parameter	Conventional clamping	Pegboard with toggle clamp	Improvement (%)
Average setup time (minute)	1-2	2-3	33% Slower
Avg.Dimensional Accuracy (Tolerance)	±3 mm	±1 mm	67% Improved
Angular Distortion (average)	4.0°	2.15°	46% Reduced
Operator Effort (Quantative)	High	Low	Easier & Safer

Table 01 Comparison between Conventional and Modular Fixture

S/N	Shape	Angle (degree)		Length of different sides (mm)	
		Modular	Conventional	Modular	Conventional
1	Parallelogram	60°	61.5°	181mm	182mm
		119°	118	183mm	180mm
		121°	117.5°	150mm	153mm
		61°	62°	150mm	151.5mm
2	Triangle	61°	60.5°	150mm	150mm
		64°	62.5°	158mm	149.5mm
		60°	63°	160mm	150mm
3	Square	90°	88°	150mm	170mm
		90°	89°	150mm	172mm
		91°	89.5°	149.5mm	182mm
		91°	91.5°	149mm	184mm
4	Hexagon	123°	122°	151mm	155mm
		119°	119°	150mm	153mm
		121°	123°	151mm	149mm
		118°	121.5°	150mm	150mm
		128°	123°	152mm	151mm
		116°	119.5°	149mm	149.5mm

Table 02 Different type of shapes angle and these shapes length after welding

Shapes after welding Conventional & Modular Fixture:



Figure 5.1 Parallelogram Shape



Figure 5.2 Triangle Shape

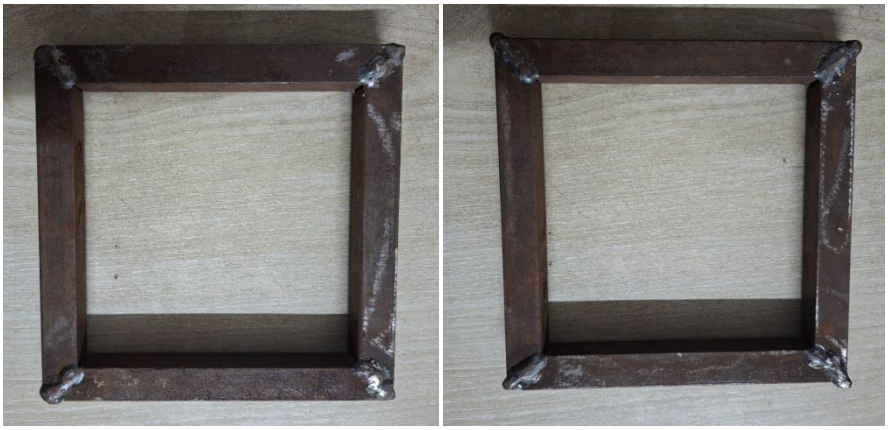


Figure 5.3 Square Shape

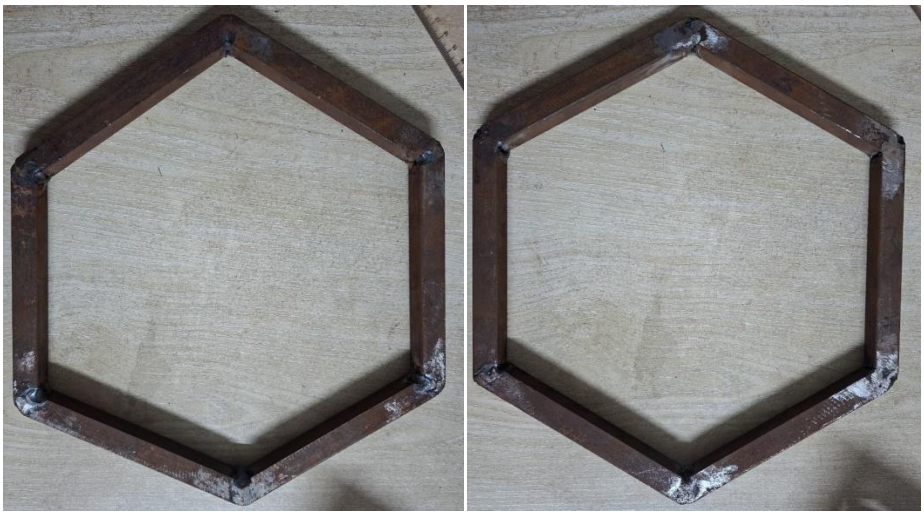


Figure 5.4 Hexagonal Shape

HARDNESS Test Report

Customer Name & Address:		
Group-20 Series-26 Sitta, Sonargaon University	Work order No.	CMSS 18/1519
	Test Report No.	CMSS/H/18216
	Date of receipt of test item	28-08-2025
	Date of testing	28-08-2025
	Material	Mild steel
	Sample Description	152*100*19 mm

SL. No.	Test Details	
1	**Machine Details:** Name : Hardness Test SL. No : 3266 Calibration on date :07-09-2024 Calibration Due Date :08-09-2025	**Rockwell Hardness Test Parameters** Load Applied Minor : 10 kgf Major : 100 kgf Type of Hardness : HRB Indenter : Ball Indentor Location : On Surface

SL.	Job Type	Sample No	BM (kgf)	HAZ (kgf)	WM 1 (kgf)	WM 2 (kgf)	Avg Value in HRB (kgf)
01	Pegboard	01	10	20	22	24	22
		02	10	21	24	26	24
02	Conventional	01	10	16	18	17	17
		02	10	17	19	18	18

NOTE: BM= Base Metal, HAZ= Heat Affected Zone, WM= Weld Metal

Table 03 Rockwell Hardness Test Report

Test Sample:

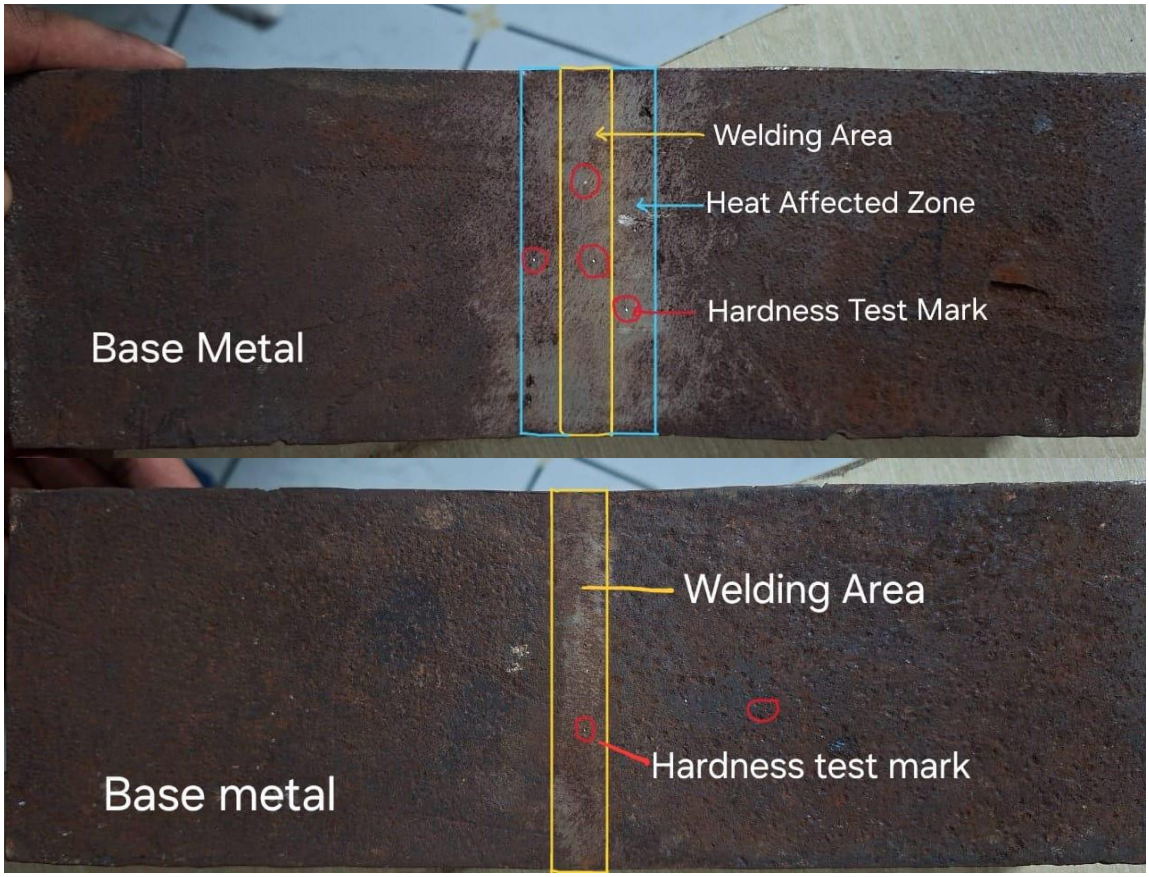


Figure 5.5 Mild steel plate (19mm thickness) after Hardness test

Key Findings from Benchmarking:

- **Slow Clamping Speeds** –
  - Conventional clamping mechanisms required multiple turns or manual adjustments, reducing efficiency in high-production environments.
- **Limited Adjustability** –
  - Existing systems often lacked flexibility for irregular workpiece geometries and varied sizes.
- **Durability Concerns** –
  - Prolonged use led to wear in pivot points and deformation in clamp arms, causing long-term alignment errors.

Concept Development Approach:
To address these limitations, multiple hand-drawn and digital sketches were produced, focusing on three main objectives:

- **Modularity** – Integration of a precision grid-hole table (industry-standard 16mm / 5⁄8" spacing) to allow quick and repeatable positioning of clamps and modular accessories.
- **Quick-Action Toggle Clamping** – Design of a lever-actuated toggle clamp capable of rapid work holding and release, reducing setup time.
- **Ergonomic & Operator-Friendly Design** – Implementation of optimized lever mechanics and a soft-grip handle to reduce fatigue during repetitive operations.

Early design thinking also considered manufacturing feasibility—ensuring that all components could be produced using laser cutting, CNC machining, sheet metal bending, and welding, with some non-load-bearing prototypes 3D printed for ergonomic testing.

5.3 Cost Analysis:

SL No.	Components Name	Price
01	Pegboard and Toggle Clamp Making	2800/-
02	Workpiece (Solid Square Bar)	2850/-
03	Allen Nut&Bolt	450/-
04	Allen Key Wrench	180/-
05	3D Printing	550/-
06	MS Plate (19mm thickness)	2800/-
07	Single V Groove Gas Cutting	500/-
08	MS Plate Welding	1900/-
09	Hardness Test	3000/-
		Total=15030/-

Table 04 Project Cost

5.4 Advantages & Disadvantages:

Advantages:

- **High Accuracy and Precision**
  - The system maintained alignment within ±1.0 mm tolerance, reducing welding errors compared to conventional clamping.
- **Reduced Welding Distortion**
  - Uniform clamping minimized thermal stresses, lowering angular distortion by nearly **46%**.
- **Flexibility and Modularity**
  - The pegboard design supported different workpiece sizes and shapes without needing a new fixture each time.
- **Operator Safety and Comfort**
  - Quick-action toggle clamps reduced physical strain and ensured stable holding, lowering the risk of accidents.
- **Cost-Effectiveness**
  - Eliminates the need for multiple dedicated fixtures, making it economical for small-to-medium industries.

Disadvantages:

- **Limited to Flat Workpieces**
  - The pegboard is most effective for flat or rectangular components; curved or complex shapes require additional attachments.
- **Load Capacity Restriction**
  - For very thick or heavy plates (>20 mm), multiple clamps or reinforced boards may be required to prevent deformation.
- **Wear and Maintenance**
  - Frequent use can cause wear on the pegboard holes and toggle clamps, requiring regular inspection and replacement.
- **Heat Exposure Issues**
  - Prolonged welding may expose the board to high thermal stresses and spatter, potentially reducing durability.
- **Initial Fabrication Cost**
  - Although cost-effective in the long run, the initial fabrication of a precision pegboard system may be relatively higher compared to a conventional table.

5.5 Application:

- **Automotive Industry**

- Used to hold automotive components in precise positions during welding.
- Ensures consistency in assembly of car parts like chassis, brackets, and frames.

- **Aerospace Industry**

- Useful for welding precise structures like aircraft panels and small components.
- Helps maintain dimensional accuracy and alignment during fabrication.

- **Fabrication of Metal Furniture**

- Can hold components like chair frames, tables, and racks in exact positions.
- Ensures uniformity and reduces human error during welding.

- **Manufacturing of Small Machinery Parts**

- Assists in welding complex parts for machinery or equipment.
- Improves efficiency by allowing quick setup and repositioning of components.

- **Education and Training**

- Can be used in technical institutes to teach students about precision welding.
- Demonstrates proper use of fixtures and clamps for accurate fabrication.

- **Production of Modular Structures**

- Helps in welding modular frames or components for storage racks, cages, or industrial frameworks.
- Reduces errors and improves repeatability in production.

- **Robotics and Automation Assembly**

- Can serve as a positioning fixture in automated welding lines.
- Improves accuracy and reduces cycle time in repetitive welding tasks.

5.6 Discussion:

The comparative evaluation between conventional clamping and the pegboard with toggle clamp fixture was carried out to analyze their performance in terms of setup time, dimensional accuracy, angular distortion, and operator effort. The results are presented in **Table 01**.

Average Setup Time:

The conventional clamping method required only 1–2 minutes, while the pegboard with toggle clamp required 2–3 minutes, making it approximately 33% slower. This difference can be attributed to the modular arrangement of the pegboard, where the positioning of clamps and alignment with the fixture holes requires slightly more preparation. Conversely, the conventional method involves direct manual tightening, which is quicker but lacks repeatability. Although the pegboard system demands additional time during initial setup, it provides consistent positioning and greater stability during repeated operations, which ultimately enhances long-term productivity.

Dimensional Accuracy:

The results also indicate a clear improvement in dimensional accuracy with the pegboard fixture. Conventional clamping achieved a tolerance of ±3 mm, whereas the pegboard with toggle clamp reduced the variation to ±1 mm, representing a 67% improvement. This improvement can be explained by the uniform and stable clamping pressure exerted by toggle clamps, which minimizes part movement during welding. Furthermore, the pegboard grid acts as a reference system, enabling accurate and repeatable alignment of workpieces.

Angular Distortion:

Angular distortion was significantly reduced in the pegboard system. Conventional clamping showed an average angular distortion of 4.0°, while the pegboard fixture limited it to 2.15°, marking a 46% reduction. The improvement is a direct result of the stronger and more balanced clamping forces, which resist deformation caused by thermal expansion during welding. In contrast, conventional clamps apply uneven pressure, leading to greater instability and distortion.

Operator Effort:

The comparison also highlights a notable difference in operator effort. Conventional clamping requires high manual effort due to the continuous tightening and adjustment of bolts or nuts, which increases fatigue and the possibility of misalignment. On the other hand, the pegboard with toggle clamp required significantly lower operator effort, as toggle clamps can be locked and released quickly with minimal physical strain. This makes the process easier, safer, and ergonomically favorable, while also reducing human error.

Overall, the findings demonstrate that although the pegboard with toggle clamp fixture is slightly slower in setup time, it provides substantial advantages in terms of accuracy, distortion control, and operator convenience. These improvements validate the effectiveness of the developed fixture in enhancing precision, efficiency, and safety during welding operations.

From table 02:
Parallelogram:
Observed Values:
Modular angles: 60°, 119°, 121°, 61°
Conventional angles: 61.5°, 118°, 117.5°, 62°
Modular side lengths: 181 mm, 183 mm, 150 mm, 150 mm
Conventional side lengths: 182 mm, 180 mm, 153 mm, 151.5 mm

The modular method produced angles that were closer to the theoretical values of a parallelogram, particularly at 60° and 120°. Side lengths from the modular approach also showed minimal deviation compared to the conventional method, where greater variation was observed. This confirms that modular fixtures provide better dimensional stability and reduce cumulative errors.

Triangle:
Observed Values:
Modular angles: 61°, 64°, 60°
Conventional angles: 60.5°, 62.5°, 63°
Modular side lengths: 150 mm, 158 mm, 160 mm
Conventional side lengths: 150 mm, 149.5 mm, 150 mm

For triangular shapes, modular fabrication maintained consistent angular accuracy while also producing side lengths that adhered more closely to design values. Conventional fabrication showed higher variability, especially in side lengths (ranging from 149.5 mm to 150 mm), which may affect precision in real applications. Modular methods thus ensured better repeatability.

Square:
Observed Values:
Modular angles: 90°, 90°, 91°, 91°
Conventional angles: 88°, 89°, 89.5°, 91.5°
Modular side lengths: 150 mm, 150 mm, 149.5 mm, 149 mm
Conventional side lengths: 170 mm, 172 mm, 182 mm, 184 mm

Square shapes showed the greatest differences between the two methods. Modular fabrication kept the angles close to the theoretical 90° and side lengths nearly equal (within 1–2 mm variation). By contrast, conventional fabrication displayed significant errors, with side lengths ranging from 170 mm to 184 mm, indicating poor dimensional accuracy. This highlights the superior reliability of modular fixtures for geometries requiring strict angular and dimensional precision.

Hexagon:
Observed Values:
Modular angles: 123°, 119°, 121°, 118°, 128°, 116°
Conventional angles: 122°, 119°, 123°, 121.5°, 123°, 119.5°
Modular side lengths: 151 mm, 150 mm, 151 mm, 150 mm, 152 mm, 149 mm
Conventional side lengths: 155 mm, 153 mm, 149 mm, 150 mm, 151 mm, 149.5 mm

For hexagons, both methods achieved reasonably accurate results. However, modular fabrication demonstrated slightly better uniformity in side lengths (149–151 mm) compared to conventional results, which varied between 149–155 mm. Angle deviations in modular shapes also stayed closer to the theoretical range, ensuring higher overall accuracy.

Overall Comparison,The experimental results across all shapes clearly demonstrate the superior performance of modular fixtures. In particular, squares and parallelograms showed dramatic improvements in dimensional accuracy and angular precision. Triangles and hexagons also exhibited more consistent results under the modular method. Thus, modular fixtures ensure higher accuracy, repeatability, and stability compared to conventional fabrication.

From table 03:
Hardness Test:
The Rockwell hardness test was performed on mild steel samples welded using two different fixture setups: the pegboard fixture with toggle clamps and the conventional fixture. The hardness values were recorded for the base metal (BM), heat-affected zone (HAZ), and weld metal (WM).

The results reveal that the pegboard fixture samples exhibited higher and more uniform hardness values across all zones compared to the conventional method. For instance, the pegboard samples recorded average hardness values in the range of 22–24 HRB, while the conventional fixture samples showed lower values of 17–18 HRB. The HAZ and weld zones in the pegboard samples reached up to 26 HRB, which indicates better weld quality and reduced distortion.

The improvement in hardness can be attributed to the stable and consistent clamping force provided by the toggle clamps, which minimized workpiece movement during welding. This ensured accurate alignment and uniform heat distribution, leading to stronger and more reliable weld joints. On the other hand, the conventional fixture provided less consistent holding, resulting in misalignment, non-uniform heat input, and consequently lower hardness values.

Overall, the findings confirm that the modular pegboard fixture significantly enhances weld joint quality by improving hardness, reducing residual stress, and ensuring repeatability. This demonstrates its effectiveness as a cost-efficient and reliable alternative to conventional clamping systems in precision welding applications.

CHAPTER 6
CONCLUSION

6.1 Introduction:

The design and fabrication of a pegboard with a toggle clamp fixture for precision welding successfully demonstrates an effective solution for holding workpieces firmly and accurately during welding operations. The project highlights the following key outcomes:

- **Enhanced Precision:** The fixture ensures proper alignment and positioning of components, minimizing dimensional errors and distortion caused by heat during welding.
- **Improved Efficiency:** Quick setup and adjustable pegs and clamps reduce the time required for preparing workpieces, increasing productivity.
- **Flexibility and Adaptability:** The modular pegboard design allows accommodation of various shapes and sizes of workpieces, making it suitable for diverse welding tasks.
- **Safety and Ergonomics:** The use of toggle clamps provides a secure hold, reducing the risk of workpiece movement and enhancing operator safety.
- **Cost-Effectiveness:** The fabricated fixture provides a reusable solution for precision welding without requiring expensive industrial fixtures, making it suitable for small-scale workshops.

Overall, the project confirms that the combination of a pegboard and toggle clamps can significantly improve the quality, consistency, and efficiency of precision welding operations.

6.2 Recommendations:

Based on the results and findings of this work, the following recommendations are suggested:

- **Material Selection Improvement:** Future versions can use higher-strength materials or heat-resistant alloys to increase the durability of the fixture for heavy-duty welding applications.
- **Automation Integration:** Incorporating sensors or actuators can allow automated clamping, further reducing setup time and increasing repeatability.
- **Scalability:** The design can be scaled for larger industrial applications, enabling use in mass production lines for automotive, aerospace, or machinery components.
- **Modular Enhancements:** Adding adjustable or interchangeable clamps and peg configurations could improve adaptability for more complex geometries.
- **Further Testing:** Conducting more extensive testing under different welding methods (TIG, MIG, spot welding) can validate the fixture's versatility and identify areas for performance improvement.

In conclusion, the pegboard with toggle clamp fixture is a practical, efficient, and versatile solution that enhances precision welding and can serve as a foundation for future developments in welding fixture design.

6.3 Future Improvements:

- **Material Upgrade**
  - Use stronger or heat-resistant materials for the pegboard and clamps to allow welding of thicker or high-temperature metals.
  - Consider lightweight alloys or composite materials to improve portability without compromising strength.

- **Adjustable and Interchangeable Components**
  - Design pegs and clamps to be fully adjustable or interchangeable for different shapes and sizes of workpieces.
  - Include modular clamp positions for complex geometries.

- **Automation Integration**
  - Introduce motorized or pneumatic toggle clamps for automated clamping.
  - Integrate sensors to detect proper alignment and secure holding before welding starts.

- **Enhanced Precision Features**
  - Add digital measurement scales or guides on the board to improve positioning accuracy.
  - Consider integrating laser guides or markers for precise placement.

- **Portability and Space Optimization**
  - Make the pegboard foldable or modular to save workshop space.
  - Add wheels or handles for easy movement in large fabrication setups.

- **Compatibility with Different Welding Methods**
  - Test and optimize the fixture for MIG, TIG, spot welding, and other welding techniques.
  - Ensure minimal deformation and heat impact for all welding types.

- **Safety Enhancements**
  - Add heat shields or insulating pads to protect the board and operators from high welding temperatures.
  - Design clamps with ergonomic handles to reduce operator fatigue.

- **Software-Assisted Design**
  - Develop a CAD-integrated system to simulate workpiece placement and clamp positioning before fabrication.
  - This can reduce trial-and-error setups and increase efficiency.

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