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Design of Fixture for Welding of Socket Assembly for Sprinkler

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Abstract: ***This study examines the creation of a custom fixture designed to ease the welding process for connecting a saddle top to a socket in sprinkler irrigation systems. Traditional manual welding techniques often result in inconsistent weld quality, worker fatigue, and reduced efficiency, necessitating increased rework and longer production times. The engineered fixture tackles these challenges by firmly securing the workpiece, reducing manual adjustments, and ensuring accurate and uniform welds. Comprising a base plate, bracket, and M10 bolt, the fixture's components are precisely dimensioned to meet specific job requirements. The purpose of this paper is to provide a model and analyse a welding fixture by performing static load analysis. The results reflect that the designed fixture is safe to perform the given task as the analysed stresses are much lower than the strength of the material used. Softwares used for designing and analysis: Creo Parametric 11, Ansys 2024 R1.***

Keywords: Welding Fixture, Precision welding, Creo, Ansys, Manufacturing efficiency, Shear stress analysis, thermal analysis

1. Introduction

Metal fabrication relies heavily on welding, a critical process that ensures the quality and structural soundness of manufactured goods. While traditional manual welding is effective, it often faces issues such as inconsistent weld quality, worker exhaustion, and inefficiency. To tackle these problems and boost overall productivity, there's a growing trend towards implementing semi-automatic or automatic welding fixtures. The proposed solution aims to enhance welding precision, minimize human errors, and increase production output. Additionally, it's expected to optimize the welding process, cut production expenses, reduce material waste, and improve workplace safety.

Welding is a technique for fusing metal components by applying heat, and in some cases, pressure. Before designing a welded joint, it's crucial to consider factors such as the metal's melting point, thermal conductivity, electrical resistance, and surface condition. A flawless weld joint requires careful control of numerous parameters; otherwise, defects in the weldment or joints are inevitable. Proper welding technique is also essential to avoid issues like excessive fusion, lapping, undercutting, and inadequate fusion. Poor welding methods and metal behaviour during thermal expansion and contraction can lead to distortion or warping in welded joints. Once a weld joint is designed, the welder's skill and available equipment determine the execution. Proper work alignment is another critical aspect for the welder to manage. Misaligned parts and improper work holding can prevent the creation of suitable weld joints. To address these issues, fabrication industries employ specialized tools called welding fixtures. These devices provide accurate positioning and secure holding of parts for permanent joining through appropriate welding processes. Typically designed for specific weld parts, welding fixtures are used at various stages in fabrication shops to join diverse metal shapes, sizes, and types. They simplify job setup for welders and are cost-effective in mass production, especially for complex part profiles. The fixture design can range from simple to intricate, depending on the part geometry and welded joint design. In the past, welding research and applications were limited. However, due to its significance in sheet metal work for automotive and aerospace industries, welding has gained increased attention from designers, manufacturers, and researchers. Weld fixtures are often developed to minimize workpiece deformation caused by heat and residual stress during welding, thereby reducing dimensional variations in the assembly. Consequently, deformation analysis is necessary to enhance the fixture's ability to control deformation. [1]

While designing a welding fixture the following points are considered: [1]
1) Welding spatters should not be allowed to fall on the threaded parts of the clamping elements. Thus, the toggle clamps without threaded parts should be used in welding fixtures.
2) Care should be taken to check that the joined workpiece does not get stuck or locked in the welding fixture.
3) For workpiece which need welding from a number of sides, a provision for easy tilting or rotating the fixture should be made, to simplify welding from various sides.

Based on above mentioned design considerations, this paper aims at designing and analysing a welding fixture which can be used suitably weld a socket to a saddle which are components used in the assembly of Sprinkler Irrigation System.

2. Literature Review

Jan Semjon et al (2013), research investigated how to enhance welding operations by optimizing fixture design, aiming to improve accuracy, steadiness, and productivity. It emphasized the crucial role of fixtures in preserving weld quality by firmly securing workpieces and minimizing the need for operator intervention. Essential factors considered included the rigidity of fixtures, precision in dimensions, and dependable clamping systems to reduce the need for corrections and ensure proper component alignment. The investigation showed that well-designed fixtures lead to superior weld quality, shorter production times, and increased efficiency, providing valuable knowledge for achieving consistent results in industrial welding applications. [2]

Yogeshkumar K. S. et al (2013), tackling issues associated with manual welding, including worker exhaustion, variable weld quality, and extended production periods, researchers engineered an automated welding system. This apparatus, which integrates motors, pulleys, and a cam mechanism, enhanced weld precision, minimized the need for corrections, and boosted overall efficiency. The innovation demonstrated significant potential for reducing costs and increasing productivity, particularly in the manufacture of sprinkler systems. Suggestions were made for further enhancement and exploration of additional applications for the technology. [3]
Vetrivel A et al (2018), Researchers engineered a multifunctional, economical welding device capable of performing both rotary and vertical welds on cylindrical objects. The apparatus, which employs a lead screw mechanism, remains stationary during operation, thereby improving weld consistency and minimizing human-induced errors. This versatile tool can be applied to various welding tasks, providing an effective solution for sectors such as construction and petrochemical industries. [4]

Palesa S. Sibanda et al, (2023), Researchers created a custom welding fixture to tackle problems such as unreliable weld quality and inefficient traditional methods. The design prioritized accurate alignment and robust clamping mechanisms to enhance precision, minimize the need for corrections, and increase overall efficiency. This innovative approach demonstrated potential for wider industrial use across various sectors. [5]

Ashek Elahe (2017), The research presented a novel welding technique that integrates friction stir welding (FSW) and resistance spot welding (RSW) to address their respective shortcomings. This innovative approach resulted in improved joint strength, superior quality, and increased versatility. Experimental findings demonstrated enhanced mechanical properties and reduced defect occurrence. The study emphasized the technique's potential for industrial applications and opportunities for further development. [6]
Siddhart Patel et al, (2017), The study developed a cost-effective semi-automatic welding fixture to address issues in manual arc welding, enhancing precision, productivity, and weld quality. The motor-driven system offered reduced cycle times and labour requirements while ensuring consistent results. It highlighted automation's role in improving welding for small-scale industries. [7]

3. Methodology

The solution to the issues related to the rejection and improvement in productivity is achieved by systematic methodology for fixture design as shown in fig.1. The first step in the methodology is to identify the problem. Subsequently, designing and manufacturing the fixture to facilitate the welding process.

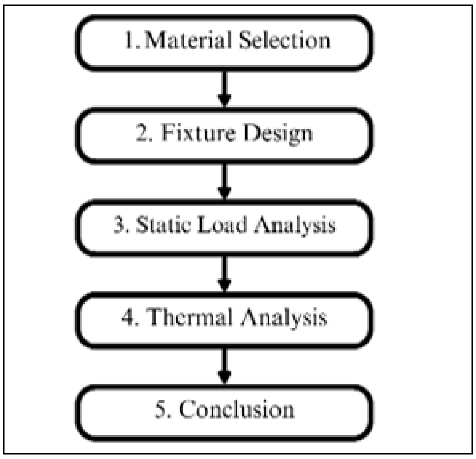

Figure 1: Methodology

Material Selection and Welding Process

Metal Inert Gas (MIG) welding using CO2 as the shielding gas, commonly referred to as CO2 welding, is a popular choice due to its many benefits. The affordability of CO2 combined with its superior shielding properties safeguards the molten weld pool from atmospheric exposure, resulting in robust, flawless welds. Furthermore, CO2 welding achieves greater weld penetration, making it particularly suitable for thicker materials and ensuring high structural integrity. This versatile and efficient process generates minimal spatter, thereby reducing the need for post-weld cleanup. These advantages make CO2 welding particularly well-suited for industrial applications, such as the production of irrigation systems and other metal structures. Table 1 shows the welding machine parameters used for the manuacturing.

Table 1: Process Parameters for CO2 Welding [8]

Diameter of Wire	1.2 mm
Standard Current	220 A
Voltage	24 V
Shielding Welding Gas	81% Ar + 19% Co2
Gas Pressure	0.4 MPa
Temperature	3000°C – 6000°C

Material selection is an crucial part of the design. For analysis it is another important aspect to consider in design phase. Mild Steel (MS) is selected for the purpose of fixture design due to its own advantages. Mild steel is a ductile metal at room temperature. It has adequate strength against loads as well as it is not costly. Thus for moderate strength mild steel can be easily used. Few of the important characteristics of mild steel are enlisted below in the table 2.

Table 2: Characteristics of Mild Steel [1]

Density	7800-7900 kg/m^3
Melting Point	1370° C
Carbon Content	0.08-0.25% wt
Elastic Modulus	2.1×10^5 MPa
Elongation	26-47%
Yield Strength	250-395 MPa
Tensile Strength	345-580 MPa
Coefficient of Thermal Expansion	7.2×10^6 / °C

Design Estimation and Fixture Design

Based on design considerations and the to be welded workpiece size, base plate diameter is estimated as 182 mm as shown in fig.2. Estimation of plate size is important

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because not only it has to rest and locate the workpiece but the same plate has to accommodate the bracket and the stoppers.

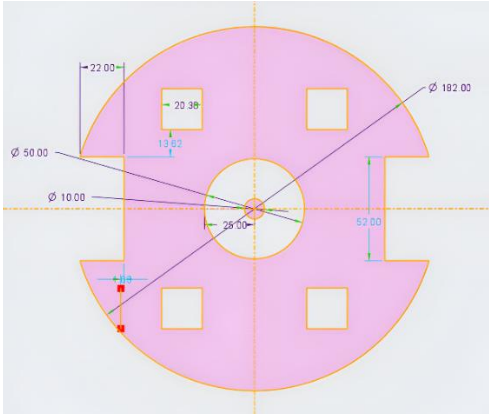

Figure 2: Base Plate Diamensions

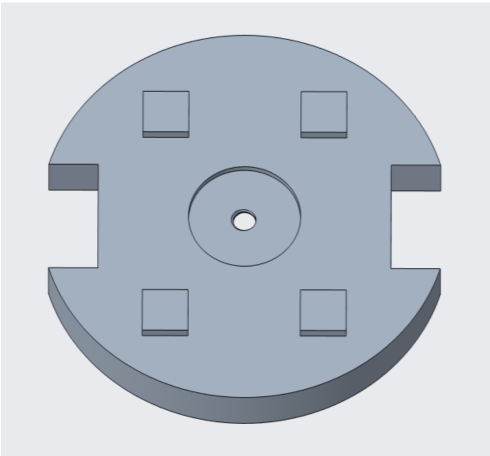

Figure 3: Base Plate Design

In the fixture assembly, the bracket design is essential for providing structural integrity and secure positioning of the workpiece during welding. Its purpose is to maintain a firm grip on the saddle top and socket, ensuring proper alignment and consistent weld quality. The bracket's dimensions are precisely engineered to meet job specifications, incorporating slots and mounting holes for reliable attachment to the base plate. Constructed from durable materials, the bracket's robust design ensures stability and reduces vibrations throughout the welding process. Furthermore, it features an effective clamping mechanism that prevents workpiece movement, thereby improving weld accuracy and minimizing the occurrence of defects.

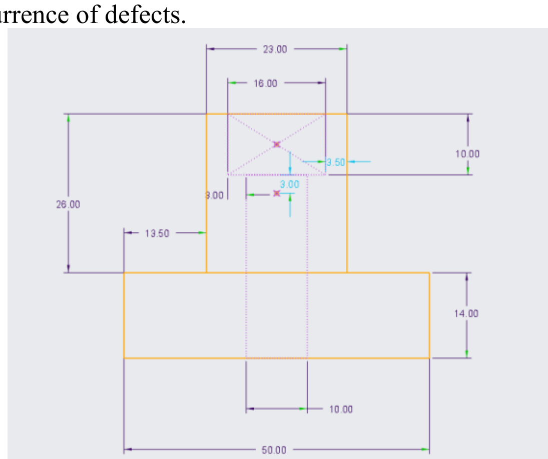

Figure 4: Bracket Dimensions

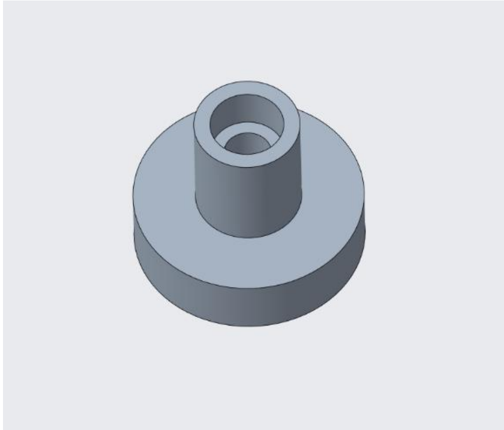

Figure 5: Bracket Design

Material Required for Fixture

Table 3: List of Material for fixture

Sr. No	Component Name	Dimensions (mm)	Material	Qty
1	Base Plate	Diameter: 185 mm Thickness: 16 mm	MS	1
2	Bracket	Diameter: 50 mm Thickness: 50 mm	MS	1
3	Bolt	M10	MS	1
4	Stopper	Length: 20 mm Breadth: 20 mm Thickness: 2 mm	MS	4

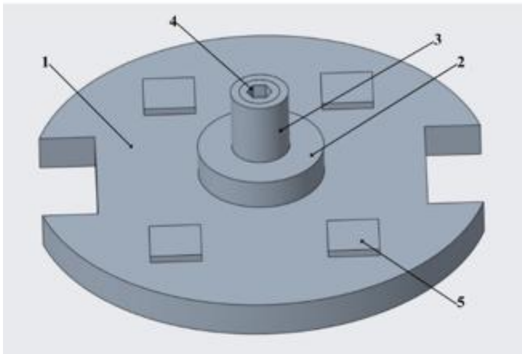

Figure 6: Fixture Assembly with all parts

Manufacturing cost of fixture

Plate Material	410/-
Plate Turning	200/-
Plate Milling	300/-
Bush Material	130/-
Bush Turning	150/-
Total	1190/-

Analysis

Static Load Analysis:

Static load analysis helps us to know deformation pattern of designed fixture under applied static loads. This analysis may further help us to estimate size and weight of workpiece to be accommodated over the fixture.

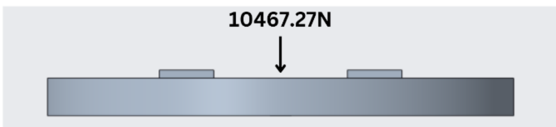

Figure 7: Loading Conditions for Static Load Analysis

Based on loading condition Equivalent Stress analysis, Shear stress analysis and deformation analysis is done for Base Plate. Figure 7 Figure 8 and Figure 9 indicates results obtained for Equivalent stress and deformation analysis respectively.

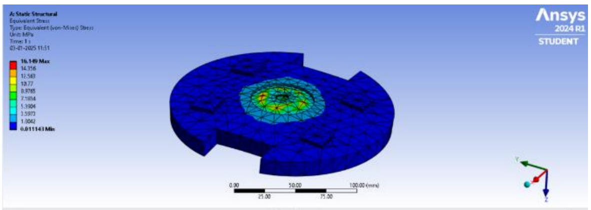

Figure 8: Equivalent Stress Analysis

Maximum Equivalent Stress: 16.149 MPa
Minimum Equivalent Stress: 0.011143 MPa

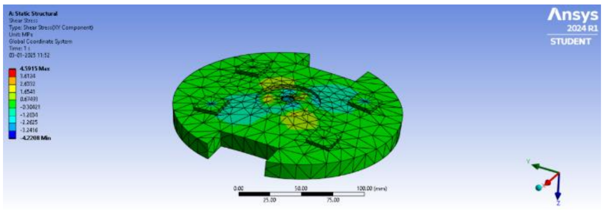

Figure 9: Shear Stress Analysis

Maximum Shear Stress: 4.5915 MPa
Minimum Shear Stress: -4.2208 MPa

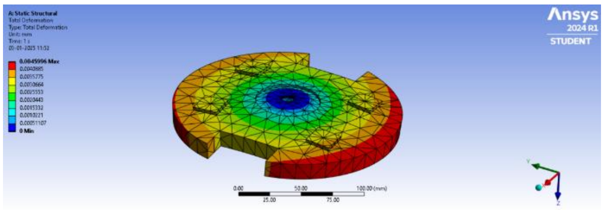

Figure 10: Total Deformation

Maximum Deformation: 0.0045996 MPa
Minimum Deformation: 0 MPa
Obtained results clearly indicate that there is no deformation in base plate and it is able to sustain the load of bracket and work piece.

Thermal Analysis
Thermal analysis helps us to know deformation pattern of designed fixture under applied temperature. This analysis may further help us to estimate if the fixture is safe and can sustain the heat developed during the welding operation without deformation.

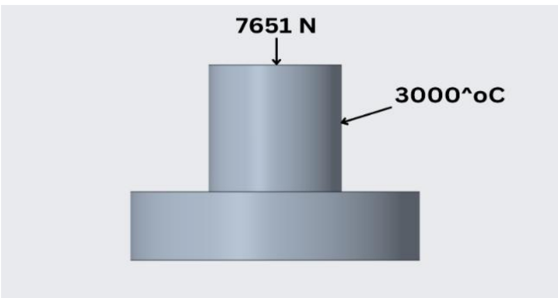

Figure 12: Loading Conditions for Thermal Analysis

Based on loading condition Equivalent Stress analysis, Shear stress analysis and deformation analysis is done for Bracket. Figure 13 Figure 14 and Figure 15 indicates results obtained for Equivalent stress and deformation analysis respectively.

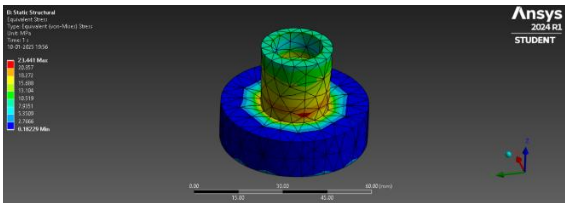

Figure 13: Equivalent Stress Analysis

Maximum Equivalent Stress: 23.441 MPa
Minimum Equivalent Stress: 0.18229 MPa

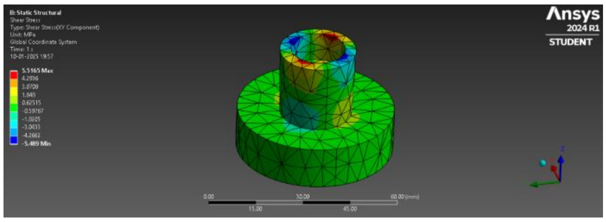

Figure 14: Shear Stress Analysis

Maximum Equivalent Stress: 5.5165 MPa
Minimum Equivalent Stress: -5.489 MPa

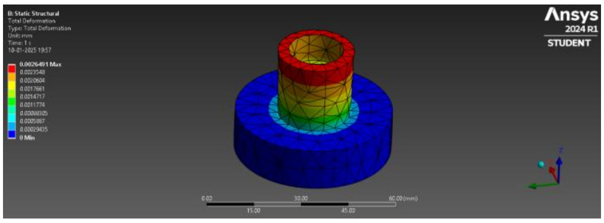

Figure 15: Total Deformation

Maximum Equivalent Stress: 0.0026491 MPa
Minimum Equivalent Stress: 0 MPa

The obtained results clearly indicate that there is no deformation in the Bracket when the maximum load and temperature applied and the stresses developed are also much lower as compared to the strength of the material hence the designed bracket is safe to use.

4. Conclusion

It has been concluded that with the help of fixture ensures correct loading of the component each time to obtain the repeatable accuracies, improved productivity and reduced cost of operation.

The analysis results indicate that the proposed fixture design is viable and practical. These fixtures are cost-effective to produce and user-friendly, making them suitable for implementation to reduce the workload of welders.

The simulations done in Ansys Software indicate that the designed fixture is safe to perform the given task as the obtained stresses are much lower than the strength of the material used.

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