iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68291

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Automatic Welding Fixture for Special Purpose Mechanism

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***Abstract:** In recent times, manufacturing industries have increasingly prioritized automation to enhance efficiency and precision. This project focuses on designing a fixture for a rotary welding machine using a Special Purpose Machine (SPM) to improve accuracy and productivity in mass production. The fixture is specifically designed to secure components while performing rotary welding of a circular rod over a lever. Maintaining high accuracy in manual welding processes is challenging, particularly in mass production. This project addresses that challenge by introducing a new fixture design that ensures precise angular positioning and rotary movement, achieving an accuracy of 0.1 mm—all without the use of robotic automation. In the field of welding engineering, where high-quality, cost-effective production with maximum efficiency is crucial, this fixture-based approach offers a reliable, scalable, and economical alternative to robotic welding systems. The proposed design ensures consistent weld quality while reducing manual errors, making it an ideal solution for industrial welding applications.*
***Keywords:** Fixture; SPM; Welding; Fixture; Rotary Fixture; High Accuracy; Reliable; Scalable.*

I. INTRODUCTION

Welding is an essential process for joining metals that entails the melting of work pieces and filling in with filler material to create a ductile joint. In contrast to soldering and brazing, which join material without melting it, welding depends on several energy sources like gas flames, electric arcs, lasers, electron beams, friction, and ultrasound. Forge welding was traditionally the only method used by blacksmiths for many centuries to heat and hammer metals together. In due course, improved technologies in welding have resulted in automated systems to increase efficiency, accuracy, and consistency.

Within the manufacturing industry, automation has transformed production processes, especially in welding engineering, where precision and reliability are of utmost importance. Conventional manual welding techniques are usually unable to ensure consistency during mass production, resulting in flaws and higher operation costs. In response to these issues, this project suggests an automatic rotary welding system with a special-purpose fixture. The fixture holds components in place, allows controlled rotation, and provides precise welding of round rods onto levers.

This study examines the mechanical design, sensor integration, control algorithms, and industrial feasibility of the system proposed. The findings prove its capability to improve weld accuracy, operational efficiency, and cost-effectiveness, making it a suitable alternative to robotic automation in industrial welding applications.

Through the minimization of human intervention and the enhancement of production quality, this system is a major improvement in modern welding automation.

A. Fabrication

Fabrication is the construction of metal structures through cutting, bending, and assembly operations. Cutting is achieved through sawing, shearing, or chiselling. Bending is achieved through hammering or through press brakes and other tools. Press brakes are used by contemporary metal fabricators to either coin or air-bend metal sheet into shape.

CNC-Controlled back gauge uses hard stop to set cut parts in a position to put bend lines in the right place. Off-line programming software today makes it possible to program the CNC-controlled press brake in hassle-free and highly efficient. Assembly is accomplished through welding, binding with adhesives, riveting, and threading. Fasteners, or even additional bends in the form of a crimped seam. Structural Steel and sheet metal are the typical starting materials for fabrication, plus the welding wire, flux and fasteners that will connect the cut pieces. As are others, Human labour and automation are widely utilized in manufacturing processes.

A product that is the result of fabrication can be referred to as a fabrication. Since the final products of other usual forms of metalworking like machining, metal stamping, forging, and casting can be of the same shape and purpose, but those processes are not categorized as fabrication.

II. OVERVIEW OF FIXTURE DESIGN PROCESS

In the industrial business, fixtures are primarily used to hold and support a specific work piece. A fixtures primary purpose is to precisely position and precisely position the work piece that is being held in order to carry out numerous manufacturing operations with total accuracy and uniformity.

III. OBJECTIVE OF PROJECT

Automated welding has important benefits, such as reduced cycle times, improved throughput, and greater overall productivity. Because no two welds are ever the same, even experienced welders struggle with fatigue, sickness, poor ergonomics, challenging materials, or complicated part shapes. Automation may replace some tasks, but more frequently it changes the job of human employees. Rather than cutting jobs, it transitions welders and operators into jobs that include monitoring and optimizing computerized systems, maintaining quality control, and learning new manufacturing techniques.

IV. LITERATURE REVIEW

It is important to research some of the previous studies conducted in this subject to have an understanding of the research domain. A perusal of the literature indicates that several researchers and subject-matter specialists in machine condition monitoring have written about various machine monitoring-related issues. This study endeavours to address issues regarding machine health problems and challenges with their isolated causes.

V. SYSTEM DESIGN

The system to be proposed includes:

- Fixture Design: A specially designed fixture that firmly clamps the work piece, avoiding movement during welding.
- Rotational Mechanism: A servo/stepper motor-driven rotary system providing accurate angular motion.
- Sensor Integration: Position sensors and feedback systems to ensure 0.1 mm accuracy.
- Welding Unit: An automated welding head in synchronization with fixture rotation.
- Control System: A PLC-based automation system to synchronize welding and rotation.
- User Interface: A Human-Machine Interface (HMI) for monitoring and manual operation.
- Emergency Safety Mechanism: Protection against overload, emergency stop, and temperature protection to guarantee operation safety.

A. *Fixture and Mechanical Design*

1) Material Selection: The fixture is designed using hardened steel and heat-resistant alloys to withstand welding conditions.
2) Rotary Mechanism: A high-precision servo motor controls the rotation, allowing stepwise movement for precise welding alignment.
3) Clamping System: A pneumatic/electromechanical clamping system ensures rigid work piece fixation, minimizing vibration.

B. *Sensor-Based Automation*

1) Proximity Sensors: Detect the exact position of the work piece before initiating welding.
2) Rotational Sensors: Ensure precise angular control for uniform welding.
3) Temperature Sensors: Monitor welding heat to prevent overheating and defects.
4) Auto-Shutdown Feature: The welding system automatically turns off upon process completion, improving energy efficiency.

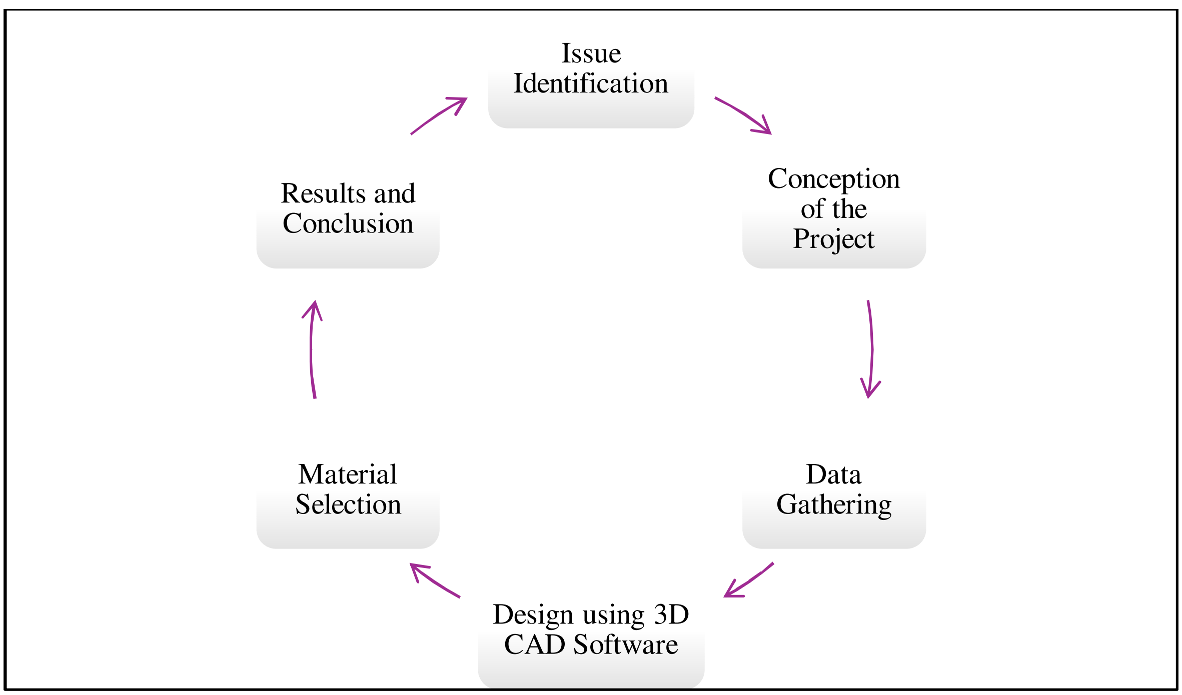
C. *Controls and Synchronization*

The system is coded by a Programmable Logic Controller (PLC), which:

1) Syncs welding speed and rotation for smooth functioning.
2) Adapts to varying material thicknesses by welding parameter adjustment.
3) Allows real-time monitoring and correction of errors with sensor feedback.

VI. METHODOLOGY

1) Issue identification: Recognising the main issues with conventional welding procedures, such as uneven weld quality, extended cycle times, higher operating expenses, and employee fatigue, is the first step. The need for automation is justified by evaluating factors such as human error, ergonomic concerns, and material complexity.
2) Conception of the Project: The next stage is to create a conceptual framework for an automated welding system after the problems have been identified. Determining the goals, extent, and anticipated advantages of automation is part of this. The goal is to create a system that increases overall production, decreases the need for human involvement, and improves precision.
3) Data Gathering: Extensive research is carried out to gather pertinent information on current welding technologies, automation methods, material characteristics, and industrial needs. Industry reports, case studies, scholarly publications, and expert consultations are the sources of the information. This stage makes that the suggested solution satisfies realistic manufacturing requirements.
4) Design using 3D CAD Software: Utilising CAD software, a comprehensive 3D model of the automated welding system is created utilising the data gathered. In this process, crucial parts such the rotary mechanism, welding fixture, control systems, and material handling units are designed. To maximise design efficiency and identify possible defects prior to production, the CAD model enables virtual simulations.
5) Material Selection:Selecting the appropriate materials is essential to guaranteeing cost-effectiveness, durability, and heat resistance. The right metals and supporting materials are chosen for the fixture and robotic components based on welding needs, taking into account characteristics like strength, conductivity, and heat tolerance.
6) Result and Conclusion: Analysing the system's performance in terms of production output, operational effectiveness, and weld accuracy is the last phase. Testing is done to evaluate gains in cycle time, defect reduction, and cost savings by contrasting automated and hand welding outcomes. The inferences made from these findings confirm that automation can improve welding procedures and redefine the function of human labour in industrial environments.



VII. RESULTS AND FUTURE SCOPE

The following outcomes were noted during the prototype's industrial testing:

- Weld Accuracy: 0.1 mm tolerance was attained, as opposed to 0.5 mm for manual welding.
- Process Time Reduction: 35% less time was spent on welding cycles.
- Energy Savings: The auto-shutdown feature reduced power consumption by 15%.
- Minimisation of Defects: Defect rates were lowered from 8% for manual systems to 2% for automated ones.
- Operational Efficiency: 40% less setup time and better work piece handling.

A. *Comparative Study*

Parameter	Manual Welding	Automated Welding Fixture
Accuracy (mm)	0.5 mm	0.1 mm
Cycle Time Reduction	-	35% improvement
Energy Consumption	High	15% lower
Defect Rate (%)	8%	2%
Automation Level	None	Semi-automated

B. *Future Scope*

1) Increased productivity: Because robots can do multiple complex welds simultaneously, they can complete operations fast and well. As a result, production is expedited, and the return on investment is significant over time.
2) Consistent, high-quality welds: Robots are less likely to get fatigued than human workers. They can continuously generate high-quality welds and have exceptional precision.
3) Less waste: Robotic welding produces more efficient and less wasteful operations by using fewer production processes and resources.
4) Safety: People may be exposed to hazardous situations and toxic gases when welding. These threats to humans are eliminated by robotics welding.

VIII. CONCLUSION

An automated rotary welding system with a special-purpose fixture that improves accuracy, efficiency, and cost-effectiveness is successfully demonstrated in this study. The technology offers a flexible and scalable solution for industrial applications by preserving accuracy in large production without depending on robotic automation. Welding fixture activities enhance alignment procedures and expand knowledge of automated fixture mechanisms, while sensor-guided control and rotational synchronisation are combined to guarantee constant weld quality. Additionally, the fixture improves accuracy, boosts productivity, and shortens cycle time by reducing errors brought on by inadequate labour skills, making it an essential part of contemporary automated welding systems.

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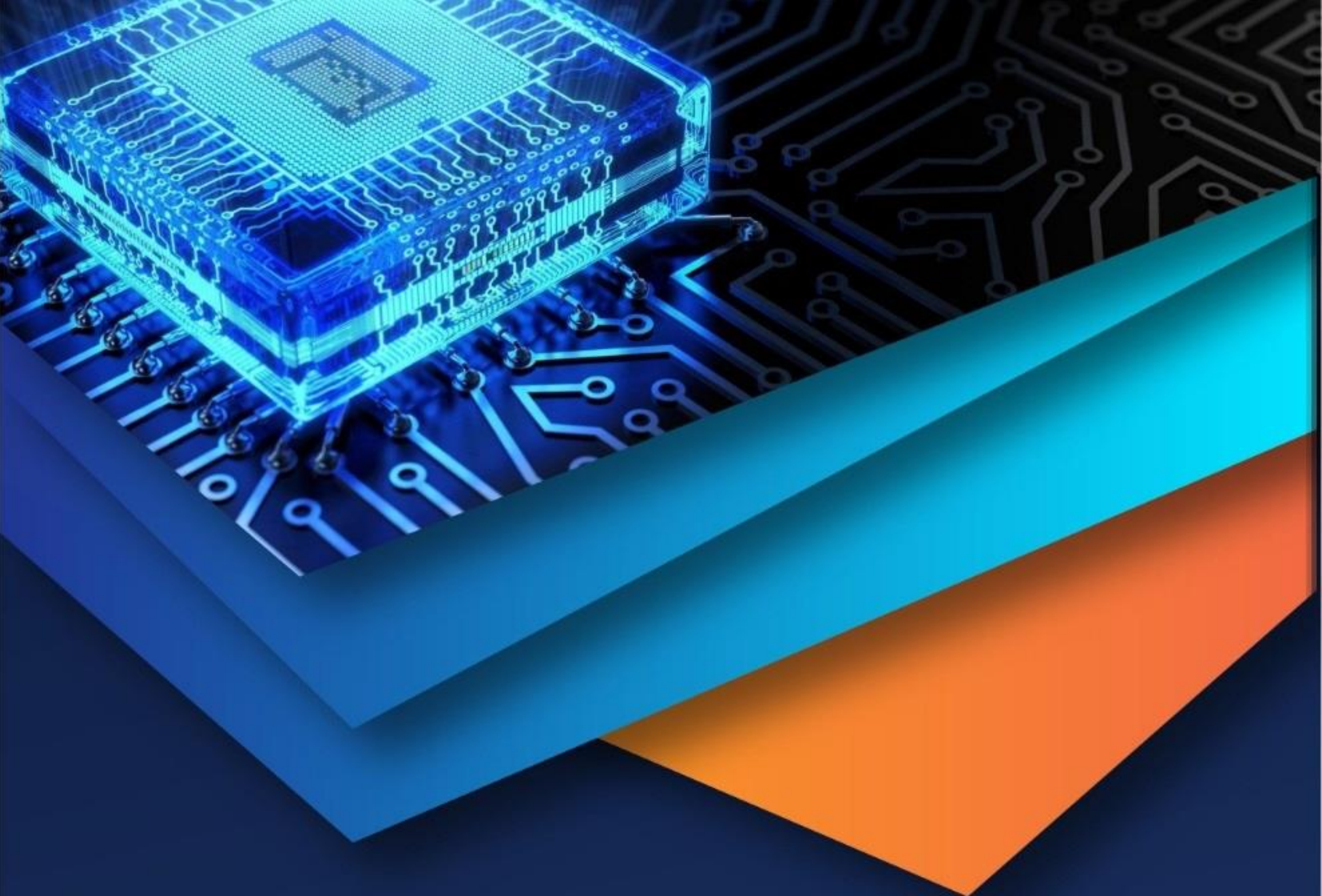

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