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Automatic Laser Welding Machine Using PLCs

Jadhav Vaibhavi Santosh[1], Nailkar Dnyaneshwari Tanaji[2], Nevase Aaditi Mugutrav[3], Sawant Raj[4], S.I. Nipanikar[5,*]

Abstract

This paper presents the design and implementation of an automatic laser welding machine controlled by a Programmable Logic Controller (PLC) technology. Laser welding has gained significant attention in various industries due to its precision, speed, and efficiency. However, manual operation of laser welding systems can be labor-intensive and prone to errors. The proposed system aims to address these challenges by automating the welding process using PLC-based control. The system architecture consists of a PLC unit interfaced with sensors, actuators, and a high power laser source. The PLC program is developed using ladder logic programming language to control the operation of the machine. The program incorporates logic for workpiece detection, laser acivation, welding process control, and safety interlocks. Key components of the system include proximity sensors for workpiece detection, servo motors for precise positioning of the workpieces, and a high-power laser source for welding. The implementation of the system involves hardware selection, PLC programming integration of components, testing, and validation. In conclusion, the proposed automatic laser welding machine provides a reliable and efficient solution for industrial welding processes. Future work may focus on optimization of process parameters, integration with robotics systems, and exploration of advanced control strategies to further enhance the performance and capabilities of the system.

Keywords: Laser, Source, Protection, Window, Head, Collimation, Lense,

INTRODUCTION

In recent years, laser welding has emerged as a leading technology across industries due to its exceptional precision, speed, and efficiency. Compared to traditional welding methods, laser welding offers distinct advantages such as minimal heat-affected zones, reduced distortion, and the capability to weld complex geometries with unparalleled accuracy. The demand for faster, more accurate, and efficient production processes in today's competitive manufacturing environment has spurred continuous innovation in this field.

***Author for Correspondence**
S.I. Nipanikar
E-mail: Sin.rdtc@gmail.com

[1-4]Student, Department of Electronics & Telecommunication Engineering Shri. Chhatrapati Shivajiraje College of Engineering, Dhangawadi, Maharashtra, India
[5]Assistant Professor, Department of Electronics & Telecommunication Engineering Shri. Chhatrapati Shivajiraje College of Engineering, Dhangawadi, Maharashtra, India

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Automatic Laser Welding Machines, powered by Programmable Logic Controllers (PLCs), exemplify the evolution towards automation in welding technology. Manual operation of laser welding systems can be labor-intensive, time-consuming, and prone to errors, especially in high-volume production environments. To overcome these challenges, PLCs have increasingly been integrated to control and automate the laser welding process. This integration offers numerous benefits, including enhanced process control, improved productivity, and consistent weld quality.

PLCs are programmable devices capable of executing logic operations, sequence control, and

data manipulation. They provide a robust and flexible platform for implementing complex control algorithms and coordinating the operation of various components within the welding system. Additionally, PLCs offer real-time monitoring capabilities and compatibility with industrial communication protocols, making them ideally suited for industrial automation applications [5–7].

This paper aims to present the design and implementation of an automatic laser welding machine utilizing PLC-based control. The system is engineered to automate every stage of the welding process, from workpiece detection and precise positioning using proximity sensors and servo motors, to laser activation and precise control of welding parameters.

Laser welding technology has revolutionized manufacturing by enabling high-speed, high-accuracy welding across a variety of materials while minimizing thermal distortion. PLCs enhance these capabilities by providing real-time control and monitoring of critical welding parameters such as laser power, beam positioning, and welding speed [8–10].

This article explores the advantages of integrating PLCs into Automatic Laser Welding Machines, delving into design concepts and operational mechanics. PLC-driven automation ensures consistent weld quality and operational efficiency through adaptive process optimization and seamless coordination of motion control systems.

Discover how PLCs can elevate productivity and achieve operational excellence by transforming conventional welding processes into sophisticated, autonomous systems capable of meeting the rigorous demands of modern manufacturing.

LITERATURE SURVEY

The author of paper [1] presents the design and implementation of an automated laser welding system controlled by a PLC. The study focuses on the integration of PLC-based control to automate the welding process, including workpiece detection, laser activation, and parameter adjustment. Experimental results demonstrate improved efficiency, consistency, and safety compared to manual operation.

The author of paper [2] discusses the development of an automatic laser welding machine using PLC control. The study describes the system architecture, including hardware components, PLC programming, and safety features. Experimental results show increased productivity and weld quality, along with enhanced operator safety, compared to traditional manual welding methods.

The author of paper [3] provides an overview of the integration of PLC control in laser welding systems. The study examines various approaches and applications of PLC-based control in automating laser welding processes. It discusses the advantages, challenges, and future trends in the field, offering insights for researchers and practitioners.

Problem Statement

Manual operation of laser welding machines in industrial settings poses several challenges, including inefficiency, inconsistency in weld quality, and operator fatigue. These challenges can lead to decreased productivity, increased production costs, and potential safety hazards. Therefore, there is a need for an automated solution that can improve the efficiency, accuracy, and safety of laser welding processes.

The objective of this project is to design and implement an automatic laser welding machine controlled by a Programmable Logic Controller (PLC). The system aims to address the following key problems associated with manual operation:

1. Inefficiency
2. Complexity of Welding Operation

3. Operator Fatigue and Safety 4)
4. Inconsistency in Weld Quality

METHODOLOGY

1. *System Design:* Define the requirements and specifications of the automatic laser welding machine, including workpiece dimensions, welding parameters, and safety features.
2. *Component Selection:* Select appropriate hardware components, including the PLC unit, proximity sensors for workpiece detection, servo motors for precise positioning, and a high-power laser source for welding.
3. *PLC Programming:* Develop the PLC program using ladder logic, structured text, or other programming languages supported by the PLC. Define control logic for workpiece detection, positioning, laser activation, welding parameter adjustment, and sequence control.
4. *Integration:* Interface the PLC with other hardware components, including sensors, actuators, and the laser source.
5. *Safety Considerations:* Implement safety features such as emergency stop buttons, light curtains, and interlocks to prevent accidents and ensure operator safety.
6. *Testing and Debugging:* Conduct thorough testing to verify the functionality of the automatic laser welding machine. Test individual components, subsystems, and the integrated system to identify and rectify any errors or malfunctions.
7. *Optimization:* Fine-tune the PLC program and welding parameters to optimize performance, efficiency, and weld quality. Identify areas for improvement and implement iterative changes to enhance the overall performance of the system.
8. *Documentation and Training:* Document the design, wiring diagrams, PLC program, operating procedures, and safety protocols for future reference and maintenance. Provide training for operators on how to use the automatic laser welding machine safely and efficiently.
9. *Deployment and Maintenance:* install the automatic laser welding machine in its intended location and ensure proper calibration and alignment of components.

SYSTEM DESCRIPTION

Human Machine Interface (HMI)

- *Description:* Human-Machine Interface, refers to (Figure 1) the system used for interaction between a human operator and a controller. HMIs can vary in complexity, from simple control panels with buttons and indicator lights to advanced industrial PCs featuring high-resolution color graphics displays and specialized HMI software.

To improve operational control, guarantee operator safety, maximize process efficiency, and enable smooth integration with larger industrial systems, a Human Machine Interface (HMI) must be included into an Automatic Laser Welding Machine that uses PLCs. To maximize efficiency and guarantee dependable operation in industrial settings, the HMI serves as a central hub for monitoring, regulating, and optimizing the laser welding process.

- Features:
  1. Graphical User Interface
  2. Touchscreen Control
  2. Alarm Management
  3. Security

PLC-DELTA 14ss2

- *Description:* In this project, we used DVP14SS1 (Figure 2) is a model of PLC manufactured by Delta Electronics for programming purpose. It has 32-bit Processor, includes digital input/output channels, analog input/output channels and communication ports. In automatic laser welding maching, a PLC manages the overall sequencing of operations in the laser

welding process. A PLC interfaces with various peripherals devices such as sensors, motors, etc. The PLC monitors signals and parameters related to the welding process, detecting faults or errors. By combining a PLC with a separate controller in a automatic laser welding machine, manufactures can achieve comprehensive control, efficient operation, and enhanced safety, and consistency in laser welding applications.

- Features:
  1. Flexible Programming
  2. High reliability
  3. Real-time Control
  4. I/O Flexibility
  5. Networking Capabilities
  6. Safety Functions

Figure 1. HMI.

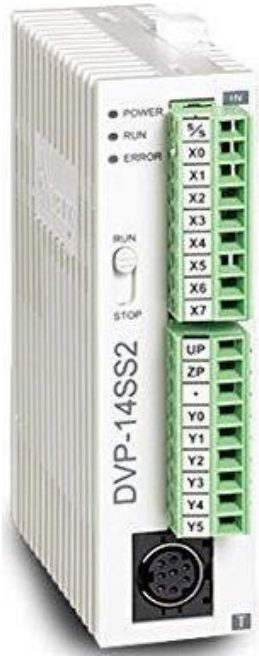

Figure 2. PLC-Delta 14ss2.

Controller

- *Description:* In this project we used RDC644 Controller (Figure 3). It provides high-speed and precise control of the laser head for cutting and engraving various materials such as wood, acrylic, leather, and metal. Controller handles the motion control and laser parameters during the welding process.

The controller communicates with the machine's motor and other hardware components to execute motion command.

- Features:
  1. High Performance
  2. Multiple Axis Controller
  3. User-friendly Interface
  4. Networking Capabilities
  5. Safety Features
  6. Wireless connectivity

Figure 3. RDC644 Controller.

RESULT

The actual implementation of the described components and functionality would involve creating rungs (sequences of logic) that integrate these components based on the specific requirements of your automatic laser welding machine. Each component (sensors, motors, lasers) would have its corresponding input and output representations in the ladder logic code. The Implementation of the PLC-controlled system is shown in Figure 4.

Figure 4. Implementation of the PLC-controlled system.

Significant improvements in manufacturing and production efficiency have resulted from the use of PLCs in autonomous laser welding equipment. The results of implementing such a system are covered in this section:

Operational Efficiency

Enhanced output: By automating tedious jobs and reducing downtime in between operations, the PLC-controlled system has greatly increased welding output.

Decreased Setup Time: Operators gain from simplified setup processes made possible by user-friendly HMI interfaces, which enable speedier program modifications and adjustments.

Consistency in Quality

Accurate Welding Parameters: PLCs guarantee accurate control over welding parameters, including laser power, beam alignment, and pulse length, leading to a constant quality of weld.

Real-time Monitoring: Through the HMI, operators can keep an eye on welding conditions in real-time, allowing for quick modifications to maintain the highest standards of quality.

Enhanced Safety Measures

Integrated Safety Protocols: The HMI has extensive safety features, like safety interlocks and emergency stop buttons, that guarantee operator safety throughout the whole operating process.

Risk Mitigation: PLCs make it easier to put safety procedures into place that reduce the dangers connected to using high-energy lasers, which improves worker safety.

Adaptability and Flexibility

Versatile Application: The system's adaptability enables it to meet a range of production needs by fitting different welding jobs and material types.

Integration Simplicity: PLCs provide easy integration with current manufacturing systems, hence boosting operational synergy and enabling overall plant automation.

Productivity and Competitiveness

Enhanced Overall Productivity: The system boosts manufacturing output and overall productivity by streamlining operational procedures and reducing manual involvement.

Competitive Advantage: In the manufacturing industry, sustaining a competitive advantage is facilitated by improved productivity, quality control, and safety protocols.

Data Analysis and Operational Insights

Data Recording and Evaluation: To support data-driven decision-making and process optimization, the system logs extensive data on welding settings, operating logs, and quality measures.

Performance Evaluation: By regularly analyzing data gathered from PLCs and HMIs, efforts for continuous improvement are made possible by insights into system performance.

Overall, the integration of PLC’s in automatic laser welding machines leads to improved operational efficiency, consistent quality, enhanced safety, and greater flexibility, ultimately contributing to higher productivity and competitiveness in manufacturing environments.

CONCLUSION

The development and implementation of an automatic laser welding machine using PLC control represent a significant advancement in industrial welding technology. Through this project, we have

successfully addressed the need for increased productivity, consistency in weld quality, operator safety, and ease of operation in laser welding processes.

Furthermore, the automatic laser welding machine has simplified and streamlined welding operations by executing predefined sequences with precision and reliability. The user-friendly interfaces and intuitive controls have facilitated ease of operation and maintenance, enabling operators to perform welding tasks efficiently and effectively.

In conclusion, the automatic laser welding machine using PLC control offers a reliable, efficient, and cost-effective solution for industrial welding applications. By achieving improvements in productivity, well quality, safety, and ease of operation, the system provides manufacturers with a competitive advantage in today's fast-paced industrial landscape. Moving forward, continued research and development in this field will further enhance the performance and capabilities of automatic laser welding machines, driving innovation and progress in industrial manufacturing.

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