



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 4, April 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

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# CNC Spot Welding Machine for Li-ion Battery Pack

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**ABSTRACT:** The design and execution of an Arduino-based Automatic Spot Welding Machine for the assembly of lithium-ion battery packs and related applications are presented in this project. The system includes safety features to avoid accidental welds, a pushbutton to start welding, and a potentiometer to vary the welding time. An LCD display for visual feedback on welding parameters and an indication LED to indicate readiness are included in the user interface. The welding process is managed by the Arduino microcontroller, which guarantees accuracy and dependability. The spot welding machine contributes to higher productivity and quality in production processes by demonstrating effective automation, improved consistency, and increased safety in battery pack assembly.

**KEYWORDS:** CNC Spot Welding, Li-ion Battery Pack Assembly, Welding Automation, Battery Manufacturing, Electrical Spot Welding.

## I. INTRODUCTION

Spot welding is an essential step in the production of lithium-ion battery packs, which are utilized in a variety of applications such as consumer electronics, renewable energy storage systems, and electric cars. The labor-intensive, time-consuming, and inconsistent nature of traditional manual spot welding techniques leads to variances in the dependability and quality of the weld. Automation solutions are being used more frequently to increase battery pack assembly efficiency, consistency, and safety in response to these issues.

In this project, an automatic spot welding machine based on Arduino is presented. Its purpose is to automate the spot welding procedure used in the assembly of lithium-ion battery packs. The system's objectives are to offer exact control over welding parameters, such as tunable welding time, and to include safety elements to guard against accidental welds and guarantee operator security.

We will give a summary of the project goals in this introduction, go over the main parts and features of the spot welding machine, and talk about the importance of automation in battery pack assembly. We will also discuss the advantages of controlling the welding process with Arduino technology and lay out the format for the other portions of the project report. We hope that this introduction will provide readers a thorough grasp of the significance and use of the Arduino-based Automatic Spot Welding Machine.

## II. RELATED WORK

When researching related work for your paper on CNC spot welding machines in Li-ion battery pack production, consider exploring existing literature and studies on the following topics:

**Automation in Battery Manufacturing:** Investigate how CNC spot welding machines fit into the broader landscape of automation in the production of Li-ion battery packs.

**Spot Welding Techniques for Battery Assembly:** Review studies that discuss various spot welding techniques and their applications specifically in battery pack assembly.

**Optimization of Welding Parameters:** Look into research focusing on the optimization of welding parameters such as current, voltage, and pulse duration for achieving high-quality welds in Li-ion battery packs.

**Robotic Welding Systems:** Explore literature on robotic welding systems and their utilization in battery pack manufacturing, including the integration of CNC control for precise spot welding operations

**Quality Control and Assurance:** Investigate studies that discuss quality control methods and assurance techniques implemented in CNC spot welding processes to ensure the reliability and safety of Li-ion battery packs.

Energy Efficiency and Environmental Impact: Consider research examining the energy efficiency and environmental impact of CNC spot welding machines compared to traditional welding methods in battery pack production.

Case Studies and Industrial Applications: Look for case studies or reports detailing the implementation of CNC spot welding machines in real-world manufacturing environments for Li-ion battery pack production

Materials Science and Welding Metallurgy: Explore studies focusing on the metallurgical aspects of welding in battery pack assembly, including material selection, weld joint design, and thermal management.

Process Monitoring and Control: Investigate research on real-time process monitoring and control systems integrated into CNC spot welding machines to ensure consistency and reliability in weld quality.

Future Trends and Emerging Technologies: Consider exploring literature discussing upcoming trends and emerging technologies in CNC spot welding for Li-ion battery pack production, such as advancements in robotics, artificial intelligence, and additive manufacturing.

By examining these areas of research, you can provide a comprehensive overview of the current state-of-the-art in CNC spot welding machines used in the production of Li-ion battery packs and identify potential gaps or areas for further investigation in your paper

### III. PROBLEM STATEMENT

There are various difficulties with the conventional manual spot welding method for putting together lithium-ion battery packs, such as:

1. Inefficiency: Manual spot welding requires a lot of time and work, which raises manufacturing costs and lowers productivity.
2. Inconsistency: Differences in operator technique and environmental factors might lead to inconsistent weld quality, which can cause problems with battery pack reliability.
3. Safety Concerns: Manual spot welding exposes operators to dangers due to the handling of strong currents and possibly dangerous equipment.
4. Lack of Control: Weld quality and dependability can be impacted by a lack of control over welding parameters like current, duration, and An automated system that can:

Improve Efficiency: Automate the spot welding process to boost production throughput and lower labor costs is required to overcome these difficulties

Guarantee Consistency: To guarantee uniform weld quality throughout all battery packs, give exact control over the welding settings.

Improve Safety: Provide a safe working environment for operators by incorporating safety measures and precautions to reduce dangers related to high currents and welding operations.

Provide Flexibility: To meet various battery pack configurations and production needs, provide welding parameters that may be adjusted. In order to overcome these obstacles and offer a reliable, dependable, and secure method of constructing lithium-ion battery packs, the problem statement centers on the creation of an Arduino-based Automatic Spot Welding Machine.

### IV.MOTIVATION

The following are the main reasons for which an Arduino based Automatic Spot Welding Machine was developed:

1. Efficiency Improvement: Manual spot welding procedures are frequently labor- and time-intensive, which causes inefficiencies in the construction of battery packs. The welding process can be automated using Arduino technology, which will increase production and lower manufacturing costs.
2. Consistency Improvement: Differences in operator technique and environmental factors can lead to inconsistent weld quality, which compromises battery pack performance and dependability. Precise control over welding settings can be attained by automating the spot welding process, guaranteeing uniform weld quality throughout all battery packs.
3. Safety Enhancement: Handling strong currents and possibly dangerous equipment while manual spot welding puts operators' safety at risk. Operators can operate in a safer environment by automating the welding process and incorporating the precautions.
4. Technological necessary safety measures and Advancement: Because Arduino technology is inexpensive, flexible, and easy to use, it provides a flexible foundation for creating automation solutions. It is possible to create an Automatic Spot Welding Machine with cutting-edge features and functionalities to satisfy the changing requirements of battery pack assembly by utilizing Arduino's capabilities
5. Industry Demand: As lithium-ion battery technology becomes more widely used in a variety of industries, including consumer electronics, electric vehicles, and renewable energy storage, there is an increasing need for battery pack



assembly solutions that are dependable and efficient. This need is met by an Arduino-based Automatic Spot Welding Machine, which offers a creative and affordable spot welding solution. In conclusion, the goal of creating an Arduino-based Automatic Spot Welding Machine is to satisfy the changing demands of the business by utilizing technological improvements to improve battery pack assembly operations efficiency, consistency, and safety.

## V. LITERATURE SURVEY

Applying heat to unite comparable metals is the technique known as welding. One can apply pressure during the welding process or not. Metal parts' edges are either melted or made plastic during the welding process. Filler materials can be added during the welding process or left out. The process of welding creates permanent joints. Car bodies, airplane frames, railroad wagons, machine frames, structural work, furniture, tanks, boilers, general repair work, and ship building are among the industries that use it. Most metalworking businesses employ welding at some point. We are building a portable spot welding machine for this project that will be useful in a variety of fields and be simple to transport.

For several decades, current and time governed the spot welding process, which produces millions of automobiles annually. The nugget volume and, thus, the weld's outcome were determined by the predetermined welding time and current level. Adhesives and the ever expanding variety of high-strength steels are creating new beginning circumstances for the assembly to be welded, which makes achieving good welding results more difficult. The output was now mostly determined by the welding voltage rather than only current and time. The process resistance, which varies spot-by-spot, is determined by the actual welding current and the voltage that must be measured directly between the electrode tips.

There was no known way to measure the precise welding voltage and, consequently, the momentary process resistance due to the loss of measuring cables that were only contacting sites between the electrode tips and the material to be welded.



Fig..1 spark between two electrodes

However, the energy input is determined by current, process resistance, and time over the course of the entire process, and is contingent upon the nugget diameter, volume, and technological parameters. The long-known physical background of this is as follows: When current and resistance are time variant parameters that change with time, energy is produced by the integral of current in square multiplied by the impedance over time ( $e = \int i(t)^2 * r(t) * dt$ , where  $e$  = energy,  $i$  = current,  $r$  = resistance, and  $t$  = time). A trustworthy assertion regarding the energy input must be false as long as the variable resistance is neither measured nor utilized by the weld controller. One of the earliest methods of joining two or more metal sheets together without the need of filler material is spot welding, a type of resistance welding. Study of research paper.

A review was conducted by Shruti Naik, Dr. M. Aruna Devi, and Dr. C.P.S. Prakash on the optimization of resistance spot welding of aluminum components. Utilized in the Automotive Sector, per his research, One popular welding technique for sheet joining, particularly in the automotive and aerospace industries, is resistance spot welding (RSW). It is employed in many different sectors, most notably in the assembly of car bodywork made of sheet steel. This kind of resistance welding involves making spot welds on overlapping metal sheets at regular intervals. Spot welding is mostly utilized to join components that are typically up to 3 mm thick. Weld-bead geometry, mechanical qualities, and other characteristics can be used to describe the joint quality

The goal of the study is to identify the ideal set of factors that contribute to higher joint quality. To acquire the best weld quality, the complex behavior of the process must be examined in order to determine the ideal settings. The FEA

simulation of the RSW process is also presented in this study. It was noted in the review that the spot welding pressure, current, and weld duration are the common input parameters influencing the strength of many spot-welded joints. Spot welds are far more resilient to shearing forces than conventional forces. There are two ways in which the spot weld can break. Interfacial failure happens in weaker joints and nugget pullout failure happens in stronger joints. The survey unequivocally demonstrates that spot welding in automobile applications greatly favors aluminum material. Because of these characteristics, spot welding aluminum takes one-third the time to weld steel but requires substantially higher tip pressures and welding current. The development of next-generation resistance spot welding technologies was completed by Taniguchi Koichi, Okta Yasuaki, and Ikeda Rinsei. In his paper, Improving the Weld Properties of Advanced High Strength Steel Sheets, In order to achieve the high crash safety of automobile bodies, innovative resistance spot welding technologies are important. These technologies have been employed extensively in the production of vehicle bodies. High strength steel sheets can have their weld joint strength increased by using Pulse Spot™ welding, which makes use of a brief, high-current post-heating process.

The limitations of the three-sheet lap welding, which is increasingly commonly done with greater use of high strength steels, can be mitigated by using Intelligent Spot™ welding, which modifies the force and welding current during the welding process. Application of high functionality, high-strength steel sheets to auto bodywork requires both excellent performance in terms of steel sheet material quality and the development of manufacturing techniques such as press technologies and welding technologies. Two innovative spot-welding technologies that achieve increased joint strength and weld ability were demonstrated in these publications. By increasing the uses of high strength steel sheets, the authors hope to improve crashworthiness and environmental performance by promoting the actual application of these welding technologies. They also hope to reduce the weight of automobiles.

However, the energy input is determined by current, process resistance, and time over the course of the entire process, and is contingent upon the nugget diameter, volume, and technological parameters. The long-known physical background of this is as follows: When current and resistance are time variant parameters that change with time, energy is produced by the integral of current in square multiplied by the impedance over time ( $e = \int i(t)^2 * r(t) * dt$ , where  $e$  = energy,  $i$  = current,  $r$  = resistance, and  $t$  = time). A trustworthy assertion regarding the energy input must be false as long as the variable resistance is neither measured nor utilized by the weld controller.

Researchers have already discovered the potential of calculating weld quality using a variety of techniques and analyzing the nugget growth mechanism. The most popular technique for assessing spot weld quality was the destructive test method, which was also frequently used for mechanical characteristic testing and macro- or microstructure inspection [1-3]. The use of non-destructive testing is essential during the manufacturing process due to its low efficiency and tendency to render the product invalid. Engineers have created a number of non-destructive test techniques, including ultrasonic testing [4, 5] and ultrasonic C-scan detection [6], to assess the integrity of spot welds. These are all offline test techniques that continue to have issues with test efficiency. Weld quality tests based on online technologies are now being proposed, which can serve as a foundation for the technological advancement of non-destructive testing. An further factor that significantly affects the quality of the weld is electrode heating. One aims for a long electrode life when producing electrode materials and using them. The number of welds produced, or the electrode life, is determined by a number of parameters that impact the behavior of the electrode material under non stabilized temperature conditions, including ongoing recrystallization and ageing.

The chemical makeup of the alloy used in the electrode and the thermomechanical treatment that affects the alloy's hardness, structure, softening temperature, and electric conductivity are the most significant elements impacting electrode life. 2. Depending on the kind, grade, and thickness of the material being welded, the settings for the welding parameters (pressure force, value, and time of welding current), 3. An electrode's form and working diameter, the working area's heating temperature, the electrode cooling medium's flow rate, and the welding rate. Numerous studies have examined the effect of the aforementioned parameters on electrode life [2, 4–11]. Therefore, one of the more crucial components of a welding process is the electrodes; study has been done on the effect that an electrode's form has on the welding process [12,13]. The temperature distribution in the welding region has been the primary subject of many studies [15, 16]. Researchers found that in creating novel welding technologies, using numerical computational models could save money and time [14, 17]. The size of the weld nugget and the residual stresses from the welding process are two further crucial factors that affect how the spot weld joints behave mechanically.

Structures may become less fatigued and fracture resistant due to residual stresses in welded portions. This suggests that the necessary nugget sizes and minimal welding residual stresses could be obtained by using the right parameters

[18]. Electrode force impacts not only the electrical resistance but also the residual stresses, welding time and current, electrode diameter, materials, pre-heating, and post-heating. It also applies pressure to the weld zone during heating and cooling. Other useful criteria are work piece thickness and cycle [19 20]. Additionally, a methodical approach was taken from a safety perspective in accordance with the research investigations conducted by Irfan et al. [21]. One of the earliest methods of joining two or more metal sheets together without the need of filler material is spot welding, a type of resistance welding

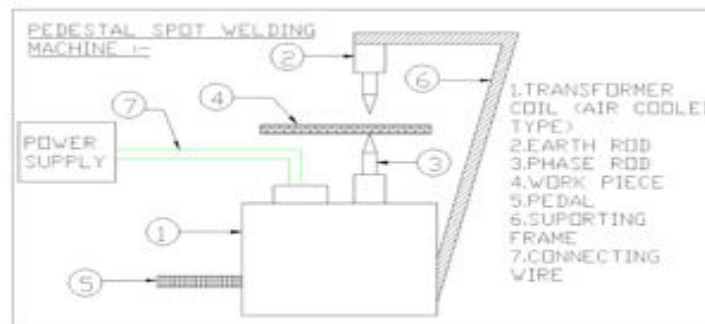


Fig..2 constructional arrangement

Through the use of shaped alloy copper electrodes that pass an electrical current through the weld pieces, pressure and heat are applied to the weld area during the process. Once the material melts and fuses the components together, the electrode pressure is maintained, the current is cut off, and the molten "nugget" solidifies to form the joint.

## VI. METHODOLOGY

### A. Block Diagram :

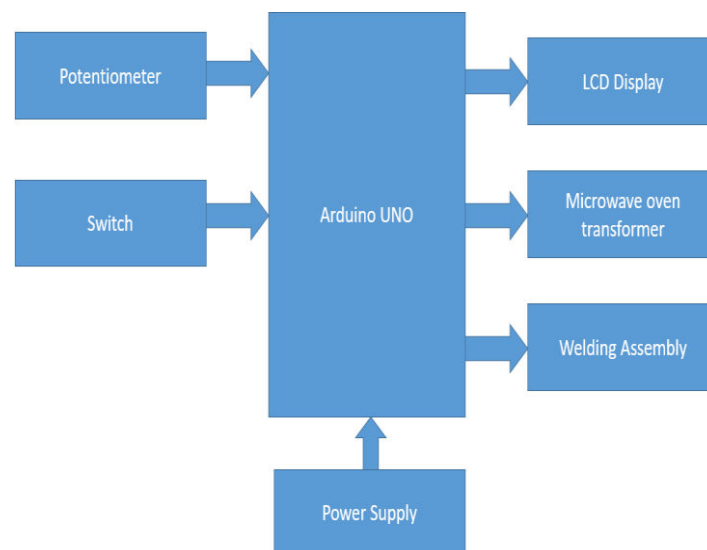


Fig1: Block Diagram of Proposed System

### B. Working Principle:

This block diagram shows the parts and connections of the automatic spot welding machine that runs on Arduino:

- Potentiometer (Analog Input): This device lets the user modify the welding time, which regulates the transformer's ON time.

- Arduino Microcontroller: This device processes input signals, regulates output devices, and operates the spot welding machine.
- Pushbutton (Digital Input): When the user presses this button, the welding process starts.
- Relay (Digital Output): Manages the transformer's power supply and turns on and off the welding operation.
- Ready LED (Digital Output): Shows whether the welding machine is prepared to work. When the machine is prepared to begin welding, it illuminates.
- LCD Display (I2C): Gives the user feedback regarding the welding parameters by showing the set welding time in milliseconds.

The automatic spot welding machine's component relationships are depicted in this block diagram, which also demonstrates how these relationships work together to speed up the welding process.

### C. Hardware Specification:

Arduino Uno:

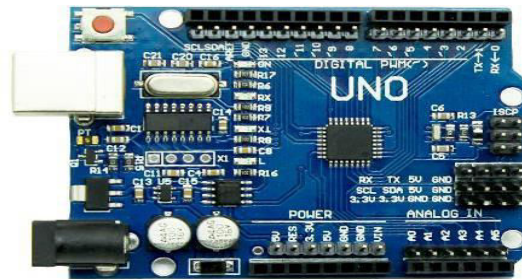


Fig3 Arduino UNO

The less expensive variant of the well-known Uno R3 Arduino is the Uno R3 CH340G ATmega328p Development Board. Rather than utilizing an Atmega16U2 processor, the CH340 USB to Serial converter chip is used in its assembly. Many of these inexpensive Arduino boards with CH340 chips have been utilized by us, and we have found them to function flawlessly. The CH340 chip is only utilized when programming or utilizing the USB port's serial output. This board functions exactly the same as the more costly model without the CH340 chip under typical circumstances. This microcontroller board, which is based on the Atmega328, was created by Arduino.cc. In comparison to its predecessors, which took up more room, were more expensive, and could only accomplish a limited number of tasks, electronic gadgets are now becoming more affordable, versatile, and small while also being able to accomplish more tasks. Automation experts are constantly trying to innovate new systems that involve less work and produce more. The electronics industry introduced the microcontroller to ease our tasks associated with even a remote connection with automation in any form. Microcontrollers are commonly utilized in embedded systems, enabling items to function in accordance with our specifications. Controllers like the 8051, Atmega16, Atmega328, and PIC16F877 have already been covered. The Arduino Uno, which has an Atmega328 microcontroller, 14 digital I/O pins, 6 analog pins, and a USB interface, is a very useful addition to the world of electronics. Using the Tx and Rx pins, serial communication is also supported. You ought to look into this UNO for novices as well. The Arduino Uno and Arduino Mega are the most widely used Arduino boards, while there have been many other versions released onto the market, including Arduino Due, Arduino Leonardo, and Arduino Mega. Using an Arduino Uno would be the best, easiest, and most affordable choice if you were planning to construct a project involving digital electronics, embedded systems, robotics, or the Internet of Things.

LCD Display:



Fig 4 LCD Display

16\*2 LCD Display

- Operating Voltage: 4.7V to 5.3V
- Operating Current 1mA (without backlight)
- Can display (16x2) 32 Alphanumeric Characters
- Custom Characters Support
- Works in both 8-bit and 4-bit mode

Rechargeable Battery:



Fig 5 Rechargeable Battery

INVENTO 12V 4.5Ah 4500mah Rechargeable Sealed Lead Acid Battery

- Maintenance free lead acid battery with Strong ABS Body. Recharge after every use.
- Voltage: 12V - 4.5AH (4500mah); Initial Current: Less than 1.35A.
- Cycle Use: 14.4V - 15V; Standby Use: 13.5V 13.8V.
- Battery Size: 90 x 70 x 101 mm (L x W x H).



Relay:



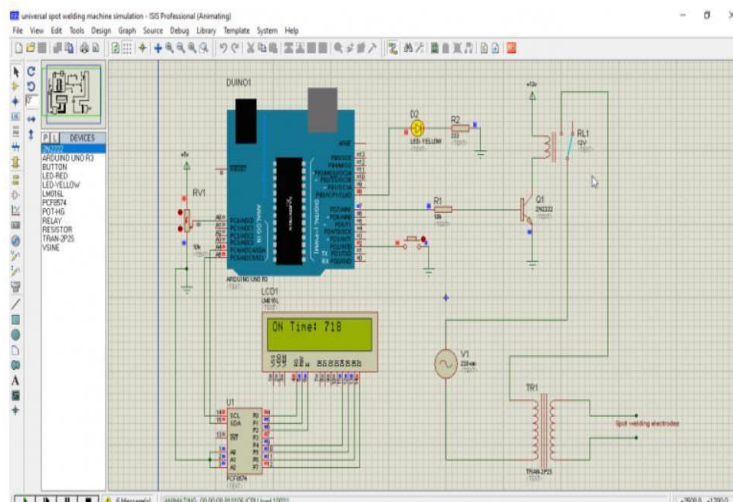
Fig 6 Relay

This interface board, which is compatible with Arduino, AVR, PIC, ARM, and other platforms, is a 5-volt, 1-channel relay module. This module has a high current capability of up to DC30V 10A or AC250V 10A. Using the digital outputs from controllers and processors, it manages larger loads and devices like DC motors, AC motors, and other AC and DC devices. Since it is a 1-channel relay module, any 1 device can be controlled by it. A supply of 5 volts and 15-20mA driving current are required for each relay or channel in a single channel relay module.

Product Specifications:

- Dimensions: 75 x 55 x 19.3 mm; Product Type: 1-Channel Relay Module
- Color of relay: Blue
- Blue is the PCB color.
- Relay maximum output: DC30V 10A and AC250V 10A
- Compatible with Arduino, AVR, PIC, ARM, Raspberry Pi, and other platforms
- Number of Relays: 1
- Control signal type: TTL level
- Input voltage: 5 volts
- Package includes: 1 piece of 1 channel relay module

## VII. RESULT DISCUSSION



## VIII. CONCLUSION

In this conclusion, the creation of an Automatic Spot Welding Machine driven by Arduino presents a viable resolution to the difficulties encountered during the assembly process of lithium-ion battery packs. This research solves important problems like inefficiency, inconsistent results, and safety hazards related to hand welding techniques by automating the spot welding process. Precise control over the welding conditions is made possible by the incorporation of Arduino technology, allowing for consistent weld quality and dependability across all battery packs. By reducing the dangers related to welding operations and strong currents, safety measures guarantee operator safety.

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