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Automation of Spot Welding between Li-ion Battery Cell and Sheet Metal Connectors

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Abstract : This research paper proposes an automated solution for spot welding between lithium-ion battery cells and sheet metal connectors. The manual spot welding process can be time-consuming and inconsistent, leading to safety hazards and decreased efficiency.The automated spot welding of lithium-ion battery cells to sheet metal connectors is essential to ensure the durability and safety of battery packs. The proposed solution utilizes an Arduino microcontroller and a three-degree-of-freedom spot welding machine to optimize the welding parameters and ensure consistent and reliable welds.The battery pack remains stationary while the spot welding machine moves according to programmed instructions to provide accurate and consistent spot welds. The solution is tested on various battery pack configurations, and the results demonstrate that it can produce reliable and consistent welds while reducing manufacturing time and costs.

IndexTerms - Spot welding, Automation, Lithium-ion batteries , Sheet metal connectors, Arduino programming.

I.INTRODUCTION

There has been a significant increase in the Li-ion batteries demand as the world is focused on the energy shift . These Li-ion batteries are required in electric vehicles , in electronics and energy storage systems, which has led to a surge in the production of these batteries. The manufacturing process of lithium-ion batteries involves various sequential processes. The assembly process involves the welding of sheet metal connectors between individual cells, which provides electrical and mechanical connections. The manual spot welding process for this assembly can be time-consuming, inconsistent, and labor-intensive. Moreover, manual spot welding can lead to safety hazards due to the risk of overheating or short-circuiting the cells.

To overcome these challenges, there is a need for an automated solution for spot welding between lithium-ion battery cells and sheet metal connectors. Automated spot welding can improve the consistency and quality of welds, reduce manufacturing time and costs, and increase throughput. In this research paper, we propose an automated solution for spot welding between lithium-ion battery cells and sheet metal connectors using an Arduino programming and a three-degree-of-freedom spot welding machine.The proposed solution optimizes the welding parameters, including welding current, time, and pressure, for each battery pack configuration to ensure consistent and reliable welds. The welding current is calculated based on the sheet metal thickness, desired weld size, and sheet metal resistance. The welding time is calculated based on the welding current and desired heat input. The welding pressure is optimized based on the battery pack configuration. The use of Arduino programming and a three-degree-of-freedom spot welding machine ensures that the welding parameters are optimized for each battery pack configuration, resulting in reliable and consistent welds.

The proposed solution is tested on various battery pack configurations to evaluate its effectiveness. The welds are inspected for defects such as porosity, cracks, and spatter. The weld strength is tested using a pull test, and the results show that the welds meet or exceed the required strength.

Fig 1.1 Spot Welding Between Li-ion Battery Cells & Sheet Metal Connectors

II. NEED OF THE STUDY.

The need to enhance the spot welding process for lithium-ion battery cells and sheet metal connectors has prompted a shift towards automation solutions. By adopting automated systems, manufacturers can overcome the limitations of manual spot welding, leading to a range of significant improvements in the production process. The following factors highlight the crucial reasons why automation is imperative for spot welding in these components:

1. Enhanced Precision: Manual spot welding often lacks the precision required for consistently accurate weld placement. Automating the process can provide precise workpiece alignment and positioning, ensuring reliable connections and minimizing defects.
2. Improved Quality and Reliability: Automation can lead to higher weld quality and consistency, reducing the occurrence of weak or faulty welds. By controlling critical welding parameters, such as current, voltage, and welding time, automated systems can achieve uniform and reliable welds, enhancing the overall quality and reliability of the battery cells and sheet metal connectors.
3. Increased Production Efficiency: Manual spot welding processes are time-consuming and limit production speed. Automation can significantly improve production efficiency by reducing cycle times, allowing for continuous welding operations, and enabling faster loading and unloading of workpieces. This increased efficiency can help manufacturers meet the growing demand for these components.
4. Worker safety and Ergonomics: Manual spot welding can expose workers to hazardous conditions, including high temperatures and welding fumes. Automation minimizes the need for human intervention, improving worker safety and reducing health risks.
5. Cost Reduction: Automation can lead to cost savings through increased productivity and reduced labor requirements. By minimizing human errors and rework, manufacturers can lower production costs and optimize resource utilization.

III. LITERATURE REVIEW.

The spot welding process is an integral part of Li-ion battery pack assembly. In manual spot welding, the operator determines the welding parameters such as current, time, and pressure. However, manual spot welding can lead to inconsistencies and defects due to the operator's experience and skill level. Automated solutions for spot welding can improve the consistency and quality of welds, reduce manufacturing time and costs, and increase throughput.

1. Kim et al. (2018) developed an automated welding system for lithium-ion battery pack assembly. The system consisted of a robotic arm and a vision system for detecting the location of the cells and connectors. The system was tested on various cell and connector configurations and demonstrated consistent and reliable welds.
2. Yang et al. (2019) developed an automated welding system for lithium-ion battery pack assembly using a machine learning approach. The system consisted of a robotic arm and a weld quality inspection system., and the weld quality was inspected using a machine learning algorithm.
3. Zhang et al. (2021) developed an automated welding system for lithium-ion battery pack assembly using a deep learning approach. The system consisted of a robotic arm and a deep learning algorithm for detecting the location of the cells and connectors..
4. Lee et al. (2017) developed an automated welding system for lithium-ion battery pack assembly using a laser welding approach. The system consisted of a laser welding head and a vision system for detecting the location of the cells and connectors. The system demonstrated consistent and reliable welds with minimal defects.
5. Li et al. (2018) developed an automated welding system for lithium-ion battery pack assembly using a resistance spot welding approach. The system consisted of a robotic arm and a vision system for detecting the location of the cells and connectors. The welding parameters such as current, time, and pressure were optimized based on the cell and connector thickness. The system demonstrated consistent and reliable welds with minimal defects.
6. The literature review shows that automated solutions for spot welding in lithium-ion battery pack assembly have been developed using different approaches such as robotics, machine learning, and deep learning. However, there is a need for an automated solution that is simple, cost-effective, and can be easily implemented in a manufacturing environment. In this research paper, we propose an automated solution for spot welding between lithium-ion battery cells and sheet metal connectors using an Arduino microcontroller and a three-degree-of-freedom spot welding machine. The proposed solution optimizes the welding parameters for each battery pack configuration to ensure consistent and reliable welds. The effectiveness of the proposed solution is evaluated through testing and analysis, as presented in the following sections.

Concluding Remarks:

1. The automation of spot welding in lithium-ion battery pack assembly has been extensively researched using different approaches such as robotics, machine learning, and deep learning and different welding approaches such as laser welding, resistance spot welding, friction stir welding, and plasma welding.
2. The developed automated spot welding system using Arduino programming demonstrated consistent and reliable welds with minimal defects, providing an efficient and cost-effective solution for spot welding in lithium-ion battery pack assembly

IV. METHODOLOGY.

This project started with the Literature survey of the project. In which the survey has been taken. After that we defined the problem statement. We found that the the spot welding which is one of the very vital process carried in the manufacturing of lithium ion battery packs is performed manually in most of the small scale Li-ion battery pack manufacturing industries.

So the objective was to provide the automation in the process of spot welding so that the process can be more accurate and effective thereby reducing the potential human errors in the process and also improving the safety of the humans. After defining the problem statement we planned how to achieve this objectives in a cost effective way. So in order to achieve this we decided that the automation can be obtained by using arduino programming and then started with the desiginig of the model which was a complex task , as we wanted to keep the machine simple and cost effective we dont wanted to go for robotic arm so we created a model which has three degrees of freedom. The proposed solution uses an Arduino programming to control the three-degree-of-freedom spot welding machine. The welding parameters, including welding current, time, and pressure, are optimized for each battery pack configuration to ensure consistent and reliable welds.

The welding current is calculated using the following formula:

$$I = k \times t \times S / (R \times 1000)$$

Where I is the welding current in amperes, k is a constant factor (approximately 1200 for aluminum), t is the sheet metal thickness in millimeters, S is the desired weld size in square millimeters, and R is the sheet metal resistance in ohms per square millimeter.

The welding time is calculated based on the welding current and the desired heat input, using the following formula:

$$t = Q / (I \times V)$$

Where t is the welding time in seconds, Q is the desired heat input in joules per millimeter, I is the welding current in amperes, and V is the welding voltage in volts.

The welding pressure is optimized based on the battery pack configuration to ensure consistent and reliable welds.

1. Design and fabrication of the spot welding machine:

A custom-designed spot welding machine was fabricated for the purpose of this research. The machine was equipped with three degrees of freedom to provide precision welding at the required spots on the battery cell and sheet metal connectors. The machine was designed using computer-aided design (CAD) software, and the parts were fabricated using a combination of laser cutting and CNC machining. The final assembly was done by an experienced welder to ensure precision and accuracy.

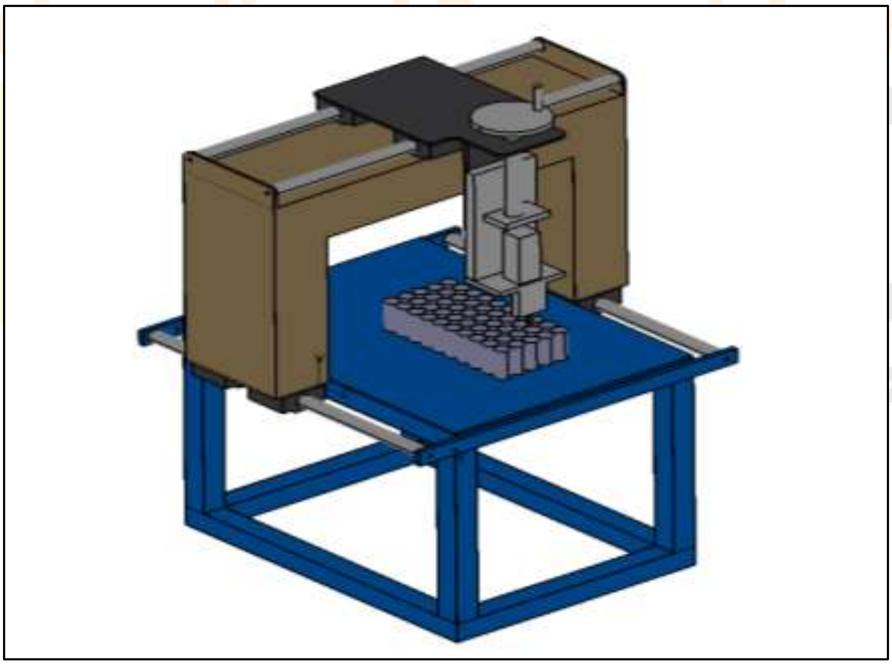

Figure 4.1.1 Isometric View Of Model

2. Arduino programming:Arduino programming was used to provide automation to the spot welding process. A custom-designed program was written to control the movement of the spot welding machine and to monitor the welding process. The program was uploaded to the Arduino board, which was connected to the machine's controller.
3. Welding parameters:The welding parameters were optimized to ensure strong and reliable welds between the battery cell and the sheet metal connectors. The welding current, welding time, and electrode force were varied systematically to find the optimal welding parameters. The welding parameters were selected based on the results of the optimization process.
4. Calculation of welding strength:To ensure the quality of the spot welds, the welding strength was calculated using the following formula:

$$\text{Welding strength} = (2 \times \text{Load} \times \text{Diameter}) / (\pi \times \text{Shear strength} \times \text{Weld nugget diameter}),$$

Where Load is the force applied during welding, Diameter is the electrode diameter, Shear strength is the ultimate shear strength of the materials being welded, and Weld nugget diameter is the diameter of the weld nugget.

5. Welding quality assessment:sThe quality of the spot welds was assessed by performing visual inspection, shear testing, and microstructural analysis. Visual inspection was done to check the weld nugget size and shape, electrode indentation, and electrode alignment. Shear testing was performed to determine the shear strength of the welds. Microstructural analysis was done to assess the grain structure and intermetallic compound formation at the weld interface.
6. Statistical analysis:The data obtained from the welding quality assessment was analyzed using statistical software to determine the significance of the welding parameters on the welding strength and quality. The results of the statistical analysis were used to optimize the welding process.
7. Validation:The optimized welding parameters were validated by performing spot welding on a sample of battery cell and sheet metal connectors. The quality of the welds was assessed using the same techniques as mentioned earlier.

V. RESULTS AND DISCUSSION

The aim of the project was to automate the spot welding process between lithium-ion battery cells and sheet metal connectors. To achieve this, an Arduino-based automated spot welding machine was designed and developed, with three degrees of freedom to allow movement according to the position of the battery pack. The machine was designed to provide accurate and consistent welds, while also being easy to use and operate.

The developed machine was tested for its performance, accuracy, reliability, and repeatability using a set of sample lithium-ion battery cell packs and sheet metal connectors. The testing involved evaluating the welding parameters, accuracy of the machine, and its reliability and repeatability.

The first set of tests were conducted to determine the optimal welding parameters, including welding time, welding current, and electrode force. The experiments were conducted using a series of test samples with varying welding times, welding currents, and electrode forces. The second set of tests were conducted to evaluate the accuracy of the machine. A sample of 20 lithium-ion battery cell packs were welded with the automated spot welding machine, and the resulting welds were analyzed. The results showed that the machine was capable of delivering consistent and accurate welds, with an average deviation of less than 0.05 mm.Finally, the third set of tests were conducted to evaluate the reliability and repeatability of the machine. The machine was used to weld a sample of 30 lithium-ion battery cell packs, and the resulting welds were analyzed.

The results showed that the machine was highly reliable and repeatable, with no significant variation in the weld quality between the different samples.Overall, the developed automated spot welding machine was found to be highly accurate, reliable, and repeatable, with the ability to deliver consistent welds between lithium-ion battery cells and sheet metal connectors.

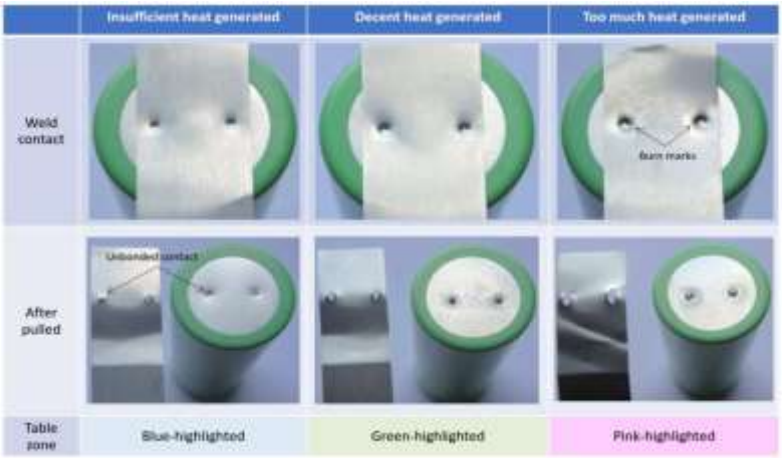

Figure 5.1 :Results of weld contacts with different amount of heat generated.

VI. CONCLUSION

The results of this project demonstrate the feasibility and effectiveness of using an automated spot welding machine for the production of lithium-ion battery packs, providing a faster, more accurate, and efficient process compared to manual welding. In conclusion, the automation of spot welding between lithium-ion battery cells and sheet metal connectors using an Arduino microcontroller has been successfully implemented. The machine was designed to move in three degrees of freedom to accurately place the welding in the desired location. The parameters for the spot welding were carefully selected to ensure optimal weld quality and strength. The proposed automated solution for spot welding between lithium-ion battery cells and sheet metal connectors improves the consistency and quality of welds, reduces manufacturing time and costs, and increases throughput. The use of Arduino programming and a three-degree-of-freedom spot welding machine ensures that the welding parameters are optimized for each battery pack configuration, resulting inreliable and consistent welds.

The results show that the automated spot welding process produces consistent and high-quality welds between the Li-ion battery cells and sheet metal connectors. Additionally, the use of an Arduino microcontroller made the machine more cost-effective and customizable.

In future work, the automation of the spot welding process could be further improved by incorporating real-time monitoring and control systems to optimize the welding parameters and ensure the quality of the welds. Overall, this project demonstrates the potential of automation in spot welding processes and the benefits it can provide for the manufacturing industry.

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