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Enhancing Heat Flow Efficiency through Robotic Arm Assisted Soldering Iron Tip

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Abstract: *This paper introduces an innovative approach to address the intricate task of soldering electronic components by unveiling a pioneering robotic system integrated with an advanced control feedback mechanism. Through the emulation of soldering patterns, the end effector of the robotic arm intricately guides the assembly process, with a specific focus on through-hole elements on printed circuit boards (PCBs). Notably, the system implements a novel error attenuation technique to ensure precise soldering, thereby reducing errors and enhancing operational efficiency. Additionally, the heat control mechanism, guided by the arm's mimicry, carefully regulates solder iron movements, effectively addressing potential issues arising from excess solder film and safeguarding miniature heating voltages. This research marks a significant advancement in automated assembly processes, offering the promise of streamlined operations and heightened quality control in electronic manufacturing.*

Keywords: Heat , Efficiency, Robotic Arm, Soldering Iron.

Introduction

A "robot" is a mechanism capable of functioning to exhibit human behaviors, meaning it's a system capable of making decisions and completing assigned tasks independently, without requiring external interference. Soldering is a process of joining two or more metal components by melting a filler metal (solder). The solder could be inform of a wire or paste when heated it becomes liquid and then flows to fill a gap between the components to be joined. This research investigates the fusion of robotic arm technology with soldering techniques to enhance heat flow efficiency, a critical aspect in electronic (Abdurakhmonov, 2021.) device manufacturing. Traditional soldering methods often struggle to achieve consistent heat distribution and precise control over the soldering iron tip's movements, resulting in inferior solder joints and potential reliability issues. In response, a novel approach leveraging (Baby, 2017.) robotic arm assistance has emerged, aiming to revolutionize soldering practices by improving precision, repeatability, and overall solder joint quality. Integrating robotic technology with the soldering iron offers promise for enhancing heat flow efficiency during soldering processes. This study delves into the effectiveness of robotic arm-assisted soldering iron tips in optimizing heat flow, utilizing (Patel, 2020.) a combination of theoretical modelling, empirical validation, and performance assessment. The primary objective is to develop (Shavkat, 2022.) an induction heating soldering iron suitable for both small electronics stores and continuous industrial use, while maintaining cost-effectiveness.

To achieve this, force (Santiago et al., 2019.) sensors are strategically placed at the gripper to detect the applied force on the object. Additionally, a graphical user interface (GUI), integrated using Processing software, facilitates user inputs and coordinates joint movements during soldering. Utilizing Java script, the GUI ensures (Begum, 2015.) efficient programming and coordination of degrees of freedom.

The main focus of this research is to develop an induction (Jing, 2020.) heating soldering iron that is economically viable for large-scale reproduction in industrial settings.

Materials And Methods

The components utilized include thermocouples, circuit boards, a robotic arm, electronic parts, lead-free solder wire, solder flux, and metal alloys. Initially, a correlational study was conducted to investigate the relationship between different types of solder commonly used like tin-silver-copper (Sn-Ag-Cu) and tin-copper (Sn-Cu). Based on variations in their thermal conductivity ranging from 20 W/m·K to over 100 W/m·K in soldering joints. Various Printed Circuit Boards (PCBs), including Ceramic PCBs used as an independent variable designed for high-power and high-frequency application. Heat transfer from the soldering iron tip to the joint relies on thermal conduction and resistivity alongside coefficient of forced convection through direct metal-to-metal contact. Soldering iron tips come in various shapes and sizes to maximize contact area, ensuring efficient (Thandapral, 2021.) heat transfer for proper solder melting and flow contact area. Solder joints are meticulously prepared using stencil printing with a stencil thickness of 245 µm. To prevent short circuits during soldering, the stencil aperture is reduced by 50% over the thermal pad.

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Soldering procedures are carried out using different soldering ovens, including batch and convection reflow ovens. The robotic arm (Yin, 2017.) underwent calibration with a self-conditioning timing drop of solder at 5 seconds to ensure precise motion at the twisting angle.

Figure 1: Adjustable temperature soldering

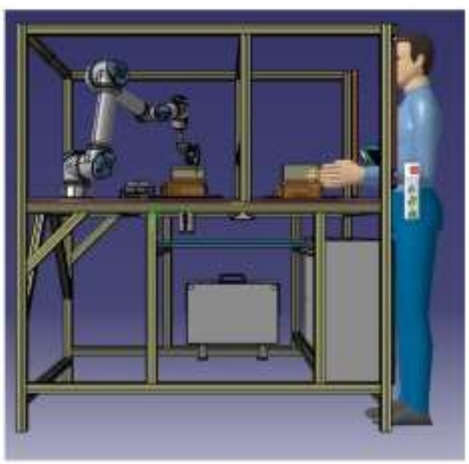

Figure 2: Figure 2: Five link robotic Arm Using Prismatic movement soldering
Source: New Product Development of a Robotic Soldering Cell Using Lean Manufacturing Methodology, Emanuela etal., 2022.

Results and Discussion

It is observed from the experimental results in table 1 below demonstrate the significant role of speed in soldering operations. Higher speeds of the robotic arm may lead to shorter soldering times. Yet they could potentially disrupt heat distribution and compromise solder joint quality. Conversely, lower speeds offer more precise control and better heat regulation, albeit at the expense of prolonging the overall soldering duration

Table 1: Optimization parameter for soldering Geometry

Dwell Time (seconds)	Speed (m/s)
5.07	3.20
8.11	1.30
12.33	1.80
18.61	2.22
21.70	7.00
27.01	0.60

Conclusion

The research concludes that the emphasis on the pick-and-place capability of the robotic arm highlights its significance in addressing ergonomic challenges such as bending of neck, strain in hand wrist and waist strain during soldering, which often lead to significant errors in the soldering process. Integrating the robotic arm with an interface, heat sensors, and proximity pressure detection can mitigate issues such as solder splatter affecting the heating element during the assembly of electronic components, enhancing the efficiency and accuracy of the soldering process.

Recommendation

Using a robotic arm system to supervise and control heat distribution offers significant benefits, such as increased productivity, lower error rates, and the possibility of reducing labor costs. This advancement in technology ensures accurate soldering by tackling issues such as overheating and the formation of cold joints, ultimately improving the efficiency of heat transfer from the soldering iron tip to the joint."

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