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DESIGN AND DEVELOPMENT OF AUTOMATIC PCB SOLDERING MACHINE USING CARTESIAN ROBOT

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ABSTRACT

The rapid evolution of electronics manufacturing demands advanced and efficient solutions for Printed Circuit Board (PCB) assembly. This paper introduces an innovative approach to PCB soldering through the implementation of an Automated Soldering System utilizing a Cartesian Robot. The proposed system aims to enhance the precision, repeatability, and overall efficiency of the soldering process in electronic manufacturing.

The Cartesian Robot, a versatile and programmable robotic system, is employed to handle soldering tasks with a high degree of accuracy. The system is designed to accommodate various PCB sizes and component configurations, making it adaptable to diverse manufacturing requirements. A user-friendly interface facilitates easy programming and customization of soldering paths, enabling quick setup for different PCB designs.

Key features of the Automated PCB Soldering System include a vision system for real-time monitoring and correction of soldering positions, ensuring the quality and reliability of solder joints. The system also incorporates a temperature control mechanism to regulate soldering iron temperature, optimizing the soldering process for different components and PCB materials.

Keywords: Cartesian Robot, Printed Circuit Board (PCB), Soldering Pot, Workstation, Stepper Motor.

I. INTRODUCTION

The automatic robot based soldering process can be used in many industries for wide variety of applications. Applications can be optimally joined at specified soldering points in a short period of time with the high strengths of alloys. The robot soldering is a process done when a robot joins different elements /parts/ components by employing molten metal and placing it at the exact point to achieve fusion. This machine utilizes a Cartesian robot, a mechanical system with three linear axes (X, Y, and Z), to precisely position and control the soldering tool. The goal is to enhance the speed, accuracy, and repeatability of the soldering process compared to manual soldering.

II. LITERATURE REVIEW

Pavan et al., investigated the design and implementation of a gantry robot for pick and place operations, addressing the inefficiencies of manual handling in production line industries. The study emphasizes the decreased productivity, slow pace, and inflexibility associated with manual mechanisms. To counter these issues, a 3-axis rectangular plane gantry robot, functioning on Cartesian coordinates, was developed. This robot not only executes pick and place tasks but also detects obstacles obstructing its path. Integrated with a conveyor system, the gantry robot is entirely controlled by a programmable logic controller (PLC), ensuring efficient system operation. Key considerations during the design process included accuracy, object weight, metal and non-metal detection, obstacle avoidance, and overall system cost.

Ji-Hyoung et al., explored the integration of factory automation into the shipbuilding industry by developing a multi-axis gantry-type welding robot system for the automated fabrication of subassemblies. Consisting of a 4-axis gantry-type robot with two welding robots attached, the system was controlled by a PC-based controller (PC-RC) for the gantry robot and individual controllers (RCs) for the welding robots. The gantry robot, guided by the PC-RC, moved to specified points on the workpiece while the welding robots simultaneously conducted welding on both sides. Synchronization between the PC-RC and RCs was achieved through digital input-output signals. Job programs for both the gantry and welding robots were generated using an Off-Line Programming (OLP) system, with the PC-RC facilitating communication between the OLP system and the RCs. Successful performance of the system was demonstrated through field testing in a test shop.

G.S. Sharath et. al., the paper focuses on the design and analysis of a gantry robot specifically for a pick and place mechanism. The core components of the system include an Arduino Mega 2560 microcontroller for hardware control and a Python programming environment for data processing.

We learn about the in-depth examination of the design procedure associated with the gantry robot. This includes considerations such as the mechanical structure, components, and overall architecture necessary for effective pick and place operations and the most important things that we get were the selection of materials for the framework of the whole system.

Peter M et al., conducted an investigation focused on enhancing the quality of a complex wave soldering process utilized in the production of printed circuit boards (PCBs). The study outlines the implementation of an experimental design featuring a mixed-level fractional factorial structure within a high-volume production setting during regular operational hours. Weighted observed ordered-categorical data from the bottom-side joints of PCBs were utilized to derive performance measurements, including average solder quality and uniformity, accounting for spatial correlation within the same types of components. Various polynomial regression models, incorporating potential higher-order interactions among controllable variables, were fitted to these statistics. Dispersions effects were analysed and modelled based on repetitions of average and uniformity measurements. Key factors such as topside soldering quality, pre-soldering board temperature, and dispersion effects were employed to establish constraints for optimizing both average and uniformity soldering quality simultaneously. A nonlinear programming approach to constrained optimization was employed to identify the optimal settings for continuous and discrete process variables. Analysis of results from a small confirmatory experiment demonstrated a significantly improved soldering quality, with a 32.85% increase in mean scores observed when comparing samples of 20 PCBs taken before and after optimization.

Shripad J. et al. conducted a study aimed at investigating the development of an XY Scanning stage. The primary goal was to enable the translation of motion along the X and Y axes of the gantry, with the resulting motion serving as output for a microcontroller capable of modifying the commanded position of the stepper motor based on input data. The study addressed the inherent complexities and increased system integration costs associated with implementing such a methodology, particularly focusing on the development of a closed-loop control system. The research paper provides detailed insights into the electrical setup and wiring involved, featuring components such as a NEMA 17 stepper motor, an Easy Driver motor controller board, and an Arduino microcontroller. Operationally, the motor is controlled by the Arduino through wired connections, with the Arduino program dictating the number of pulses required for the stepper motor and managing the voltage level supplied to the motor through the Easy Driver circuit. This investigation highlights the coordinated efforts among the microcontroller, motor controller, and stepper motor to achieve precise control in terms of pulse generation and voltage regulation within the XY Scanning stage.

III. DESIGN CALCULATION

1. Payload Calculations

- Calculate Torque:

The torque (T) generated by each stepper motor is given by the formula:

$$T = K_t \times I$$

where Kt is the torque constant, and I applied is the applied current.

$$K_t = \frac{T_{holding}}{(I)}$$

- **Calculate Payload Capacity:**

The payload capacity (P) of the robot is determined by the torque and the dimensions of the robot. Assuming a square robot, we use the formula:

$$P = dT$$

Finally, since there are three motors on the robot, the total payload capacity (P_{Total}) is:

$$P_t = 3 \times P$$

2. Motor Calculations:

For NEMA 17 Stepper motor

Total micro steps given for the motor are 16.

Total motor steps are 200.

The stepper angle for the motor is 1.80.

One revolution of motor is given as:

1 rev = 3.5cm

Hence after converting cm to mm we eventually get:

35mm

Now,

Total steps = total micro steps x total micro steps

IV. SYSTEM HARDWARE DESIGN ON CAD / MECHANICAL DESIGN

Developing an automatic PCB (Printed Circuit Board) soldering system using a Cartesian robot involves integrating various hardware and software components to achieve precise and efficient soldering. Here's a general guide to help you understand the key steps and components involved in the system development:

Consider the situation and demand of soldering machine which is cost efficient. Unlike regular soldering machine this model is design in such a way that a cartesian robot will solder a PCB with the help of a unique technique of soldering known as soldering wave pot. Aluminium extrusion pipes are chosen because it has strength, cartesian robot X, Y, Z axis is made of this material.

We have built / design the cartesian robot with the help of Fusion 360 modelling software as shown in Figure 1.

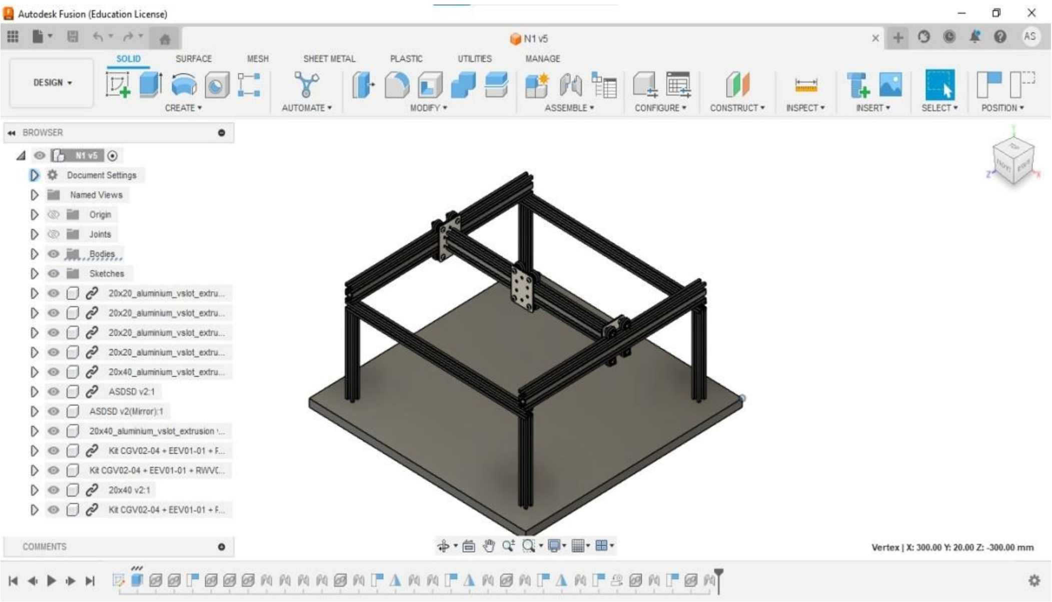

Figure 1: CAD Model Design

V. PROGRAM FOR ROBOT MOTION

Code	Description
G21 G91 G1 Z10 F600	Switch to metric units, relative positioning, move Z-axis upward by 10 units at a feed rate of 600 mm/min.
G21 G91 G1 X14 F600	Move X-axis rightward by 14 units at a feed rate of 600 mm/min, using relative positioning.
G21 G91 G1 Z-20 F600	Move Z-axis downward by 20 units at a feed rate of 600 mm/min, using relative positioning.

G21 G91 G1 Z30 F600	Move Z-axis upward by 30 units at a feed rate of 600 mm/min, using relative positioning.
G21 G91 G1 Y-23 F600	Move Y-axis leftward by 23 units at a feed rate of 600 mm/min, using relative positioning.
G21 G91 G1 Z-18 F600	Move Z-axis downward by 18 units at a feed rate of 600 mm/min, using relative positioning.
G21 G91 G1 Z18 F600	Move Z-axis upward by 18 units at a feed rate of 600 mm/min, using relative positioning.
G21 G91 G1 X-14 F600	Move X-axis leftward by 14 units at a feed rate of 600 mm/min, using relative positioning.
G21 G91 G1 Z-16 F600	Move Z-axis downward by 16 units at a feed rate of 600 mm/min, using relative positioning.
G21 G90 G0 Z5	Switch to metric units, absolute positioning, rapid move to Z-coordinate 5.
G90 G0 X0 Y0	Rapid move to X-coordinate 0 and Y-coordinate 0, using absolute positioning.
G90 G0 Z0	Rapid move to Z-coordinate 0, using absolute positioning.

VI. CONCLUSION

An automatic soldering machine, combining a Cartesian robot and a soldering pot, offers significant advantages in electronic manufacturing. The precision of the Cartesian robot ensures consistent and accurate soldering, crucial for reliable solder joints in electronic devices. Its versatility allows for intricate soldering patterns and handling of diverse components, with programmability ensuring repeatability and high product quality. The soldering pot provides controlled heat, essential for optimal soldering results and minimizing thermal damage to components. This automation reduces manual labour dependency, enhancing efficiency, reducing errors, and meeting demands for precision and reliability. Overall, this automated solution sets a benchmark for consistency, precision, and efficiency in electronic manufacturing, ensuring high-quality production in a rapidly evolving technological landscape.

VII. FUTURE SCOPE

In automated PCB soldering machines, integrating advanced vision systems with Cartesian robots is paramount for precise component recognition, alignment, and inspection. By employing high-resolution cameras and machine vision algorithms, these systems can accurately detect component orientation, verify solder joint quality, and ensure precise placement, thereby bolstering overall process reliability. Additionally, leveraging AI and machine learning capabilities allows soldering machines to learn from past experiences and autonomously make decisions. Through analysis of data from previous soldering jobs, these machines can discern optimal soldering techniques tailored to different PCBs and components. AI algorithms can continuously optimize soldering parameters such as temperature, solder flow, and dwell time based on real-time feedback, ensuring consistent soldering quality and minimal defects. Moreover, efforts to minimize human-machine interference in automatic PCB soldering machines, facilitated by Cartesian robots, aim to foster safe and effective collaboration between people and machines. Enhanced sensors, clear safety standards, user training, ergonomic design, and collaboration between experts all contribute to achieving this objective, ensuring seamless interaction and operational efficiency.

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