Design And Modification Of A Multi-Station Jig For Improving Production Capacity In Pad Printing Machine

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Received on dd-mm-yyyy | Revised on dd-mm-yyyy | Accepted on dd-mm-yyyy

***Abstract*— Pad printing is a crucial process in electronics manufacturing used to transfer product information onto components with high precision. However, the use of a conventional single-station jig system often results in long cycle time, high machine idle time, and low production output due to manual handling and repositioning. This study aims to design and modify a multi-station jig system to improve production capacity on a pad printing machine. The research method uses an engineering approach, including observation of the existing system, problem identification, CAD-based design, implementation, and performance evaluation using a before-after comparison method. The results show that the implementation of the multi-station jig system successfully reduces cycle time from 28.45 seconds to 18.0 seconds per unit and increases production output up to 1,600 pieces per shift. In addition, machine idle time and handling time are significantly reduced, while jig stability improves, resulting in better alignment and consistency of printing quality. These improvements indicate that the multi-station jig system effectively enhances productivity, operational efficiency, and process reliability in the pad printing workstation without requiring major machine modifications.**

Keywords: multi-station jig, pad printing, productivity, cycle time, manufacturing efficiency

I . INTRODUCTION

In the electronics manufacturing industry, productivity, operational efficiency, and product quality are essential factors in maintaining competitiveness. One of the important processes in this industry is pad printing, which is used to transfer product information such as logos, serial numbers, and identification marks onto component surfaces with high precision. As production demand continues to increase, optimizing each workstation becomes crucial to prevent delays and improve overall system performance.

At PT RPS Precision Engineering, the pad printing process still utilizes aConventional single-station jig system. This condition leads to inefficiencies because component handling and repositioning are still performed manually, resulting in longer cycle time and higher machine idle time. As a consequence, the production output does not meet the expected target, especially during peak production periods.

Previous studies have shown that improvements in jig and fixture design can significantly enhance productivity by reducing handling time, minimizing operator movement, and improving positioningaccuracy. A multi-station jigsystem enables multiple components to be processed within a single cycle, allowing parallel activities such as loading and unloading while the machine continues operating. This approach aligns with lean manufacturing principles by eliminating non-value-added activities.

Based on these issues, this study aims to design and modify a multi-station jig system to improve the efficiency and production capacity of the pad printing machine. Theimplementation is expected to reduce cycle time, increase production output, and improve process reliability.

1. Literature Review

1.1 Pad Printing Process

Figure 1. Pad Printing & Tampo Machine

Pad printing is a widely used process in the electronics manufacturing industry for transferring ink onto component surfaces with high precision. This process utilizes a silicone pad to transfer ink from an engraved plate to the target surface, making it suitable for printing on small, curved, or irregular objects. The flexibility of the silicone pad allows consistent ink transfer even on complex geometries. However, the effectiveness of this process is highly dependent on the jig system used to position the components during printing.
Poor jig design can lead to misalignment,printing defects,and reduced productivity.

1.2 Multi-Station Jig Concept

A jig is a tool used to hold and position a workpiece accurately during he manufacturing process. In conventional systems, single-station jigs are commonly used, where only one component is processed in each cycle.This approach often results in inefficiencies due torepeated manual handling and increased cycle time. multi-stationjig system is designed to accommodate multiple components within a single fixture, allowing parallel operations such as loading and unloading while the machine is running. This configuration helps reduce machine idle time, improve workflow continuity, and enhance overall production efficiency.

1.3 Production Capacity and Cycle Time

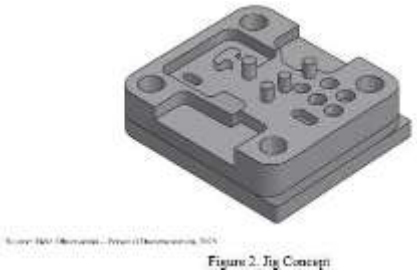

Figure 2. Jig Concept

Production capacity is closely related to cycle time, which is defined as the time required to complete one unit of production. A shorter cycle time leads to higher production output within a given period. In many manufacturing processes, non-value-addedactivities such as excessive handling, waiting time, and manual repositioning contribute to longer cycle time. Therefore, reducing these inefficiencies is essential to improve productivity. The implementation o a multi-station jig system can significantly reduce cycle time by minimizing manual operations and enabling continuous production flow, resulting in increased output and better machine utilization.

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II . METHOD

1.3 Research Method

This study applies an engineering research approach to design and modify a multi-station jig system for improving production capacity on a pad printingmachine. The research method includes observation, problem identification,design and modeling, implementation, and performance evaluation. The evaluation is conducted using a before-and-after comparison method with parameters such as cycle time, handling time, machine idle time, and production output.

1.4 Existing System Condition

Table 1. Existing System Condition Before and After Modification

No	Work	Before Modification	After Modification
1	Product Placment	One product per jig	Some product in a multi-station jig
2	Position Settings	Manual Operator	Automatic by design jig
3	Printing Process	One by One per jig	Sequential on several stations

The existing system uses a multi-station jig, whereonly one component is processed in each cycle. Most of the operations areperformed manually by the operator, including loading, positioning, and unloading. This condition results in longer cycle time, higher machine idle time, and limited production output.

2.3 *System Design*

The proposed system introduces a multi-station jig configuration that allows multiple components to be processed within a single cycle. The jig is designed using CAD software to ensure compatibility with the existing pad printing machine. The design also considers positioning accuracy, ergonomic factors, and ease of operation to improve overall performance.

2.4 *Tools and Materials*

Category	Description
Pad Printing Machine	Primary machine used for product marking
Current jig system	Baselines reference for improvement
CAD Software (SolidWorks)	Modeling and specification adjustment
Prototype fixture materials (Aluminum/Steel)	Jig fabrication material
Measuring tools (Caliper, ruler)	Dimensional evaluation
Stopwatch	Time study for productivity validation
Pneumatic Cylinder	For the pressing and simplifying jig
Regulator	Regulate air pressure and quality
Flow control valve	Adjust air speeds
Selenoid valve	Control air direction
Acrilyc	Mount of component electrical
Pad printing ink	Main materials on printing machines
PLC Keyence	For the controls machines and process automatically

The tools and materials used in this study include a pad printing machine, existing jig system, CAD software for design modeling, measuring instruments such as calipers and rulers, and supporting components such as pneumatic cylinders, solenoid valves, and PLC for system control.

2.5 *Comparison of Cycle Time and Production Capacity Before and After Jig Modification*

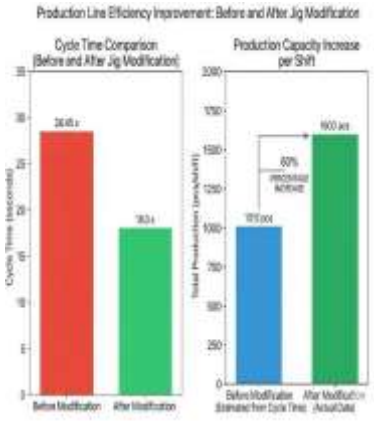


Figure 4. grafik Cycle Time and Production Capacity Before and After Jig Modification

2.6 *PLC Control Algorithm for Multi-Station Jig Pad Printing Machine*

```
BEGIN
// ======================
// INITIALIZATION
// ====================== SET RUN = OFF
SET STEP = 0
RESET COUNTER C1  SET ALL_OUTPUT = OFF

// ======================
// START SYSTEM
// ======================
    IF PB_START  =  ON  AND
EMERGENCY = OFF THEN
```

```
   RUN = ON STEP = 1
   ENDIF

   // ====================
   // SYSTEM RUNNING
   //    ====================     WHILE
   RUN = ON DO


   //                                                  ------------
   // STEP 1 : CHECK JIG
   //                                                  ------------
   IF STEP = 1 THEN
IF SENSOR_JIG = ON THEN STEP = 2
      ENDIF ENDIF


   // ------------------
   // STEP 2 : CLAMP ON
   // ------------------IF STEP = 2 THEN
   CLAMP_CYLINDER = ON STEP = 3
   ENDIF
   //
   // STEP 3 : CHECK PAD                            ------------
   //                                               ------------
   IF STEP = 3 THEN
IF PAD_READY = ON THEN STEP = 4
      ENDIF ENDIF


   3// -------------------------
   // STEP 4 : PRINT PROCESS
   // -------------------------IF STEP = 4 THENPRINT_EXTEND = ON
   DELAY T1 (2 SEC) PRINT_EXTEND = OFF STEP = 5
   ENDIF

   // -------------------------
   // STEP 5 : RETRACT CYLINDER
              ----//------------
IF STEP = 5 THEN PRINT_RETRACT = ON DELAY T2 (1 SEC)
   PRINT_RETRACT = OFF STEP = 6
   ENDIF
   //
    // STEP 6 : RELEASE JIG ----
   //          -----------------
IF STEP = 6 THEN CLAMP_CYLINDER = OFF COUNTER C1 = C1
   +1 STEP = 1
   ENDIF


   // -----------------
   // EMERGENCY STOP
   //          ------------
IF EMERGENCY = ON THEN RUN = OFF  ALL_OUTPUT = OFF
      ENDIF ENDWHILE

      END
```

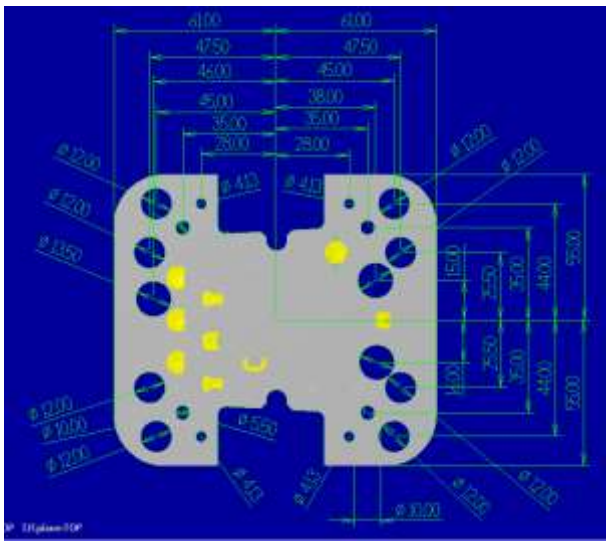
III. RESULT AND DISCUSSION

3.1 Initial Condition (Before Modification)

The initial condition of the pad printing process utilizes a single-station jig system, where only one component is processed in each cycle. In this system, most of the operations such as loading, positioning, and unloading are performed manually by the operator. This condition results in inefficient workflow, longer cycle time, and increased machine idle time.

Based on the observation, the average cycle time of the system before modification is 28.45 seconds per unit. The handling time is relativelyhigh due to manual repositioning, and the machine often experiences idle time while waiting for the operator to load the next component. As a result, the production output is below the expected target, and the overall system performance is not optimal.

3.2 Multi-Station Jig Dimensions Before Modification



The image below shows jig dimensions before modification, the hole diameter in the jig was still relatively small,resulting in limited clearance between the pad and the

hole. This condition causes the pad to feel cramped when entering the print area, potencially causing demage, innacurate print posisitioning, and slowing the production process. Therefore, adjusting the hole diameter is necessary to smoother pad movement, improve printing accuary, and reduce the risk of product defects and component wear.

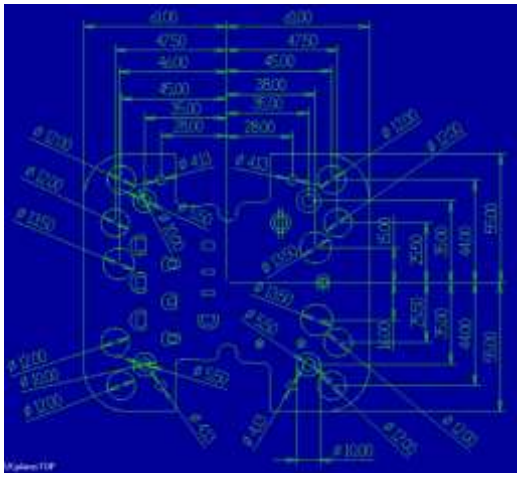
3.3 Improved Condition (After Modification)

Figure 5. Improved Condition (After Modification)

After implementing the multi-station jig system, significant improvements are observed in the productionprocess. The modified jig allows multiple components to be processed within a single cycle, enabling parallel operations such as loadingand unloading while the machine is still running.

The results show that the cycle time is reduced to 18.0 seconds per unit. The production output increases significantly up to 1,600 pieces per shift. In addition, machine idle time is minimized, and handling time is reduced due to improved jig design and better workflow. The stability of the jig also improves, resulting in more accurate positioning and better printing consistency.

3.2 Multi-Station Dimensions Jig (After Modification)

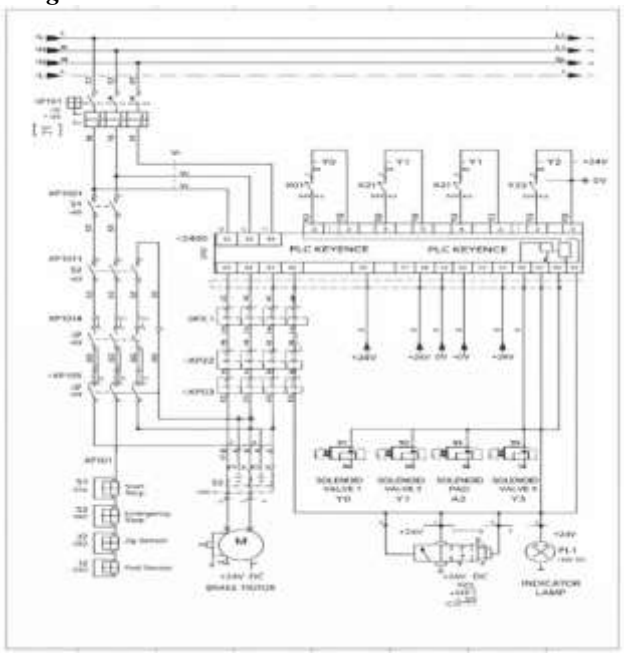


The jig design after modification underwent significant changes from a single-station system to a multi-station system (4 stations) arranged in a circle on a rotary table.

The addition of the width and length dimensions of the jig was adjusted to the work area of the pad printing machine to prevent mechanical collisions. The overall diameter of the jig unit was designed in such a way as to accommodate four components at once with precise distances between stations, to ensure the pad can reach every print area without obstruction.

In addition, the dimensions of the product holder hole (pocket) were increased in accuracy with tight tolerance values to ensure product stability during the printing process at high speeds.

3.4 Design Electrical

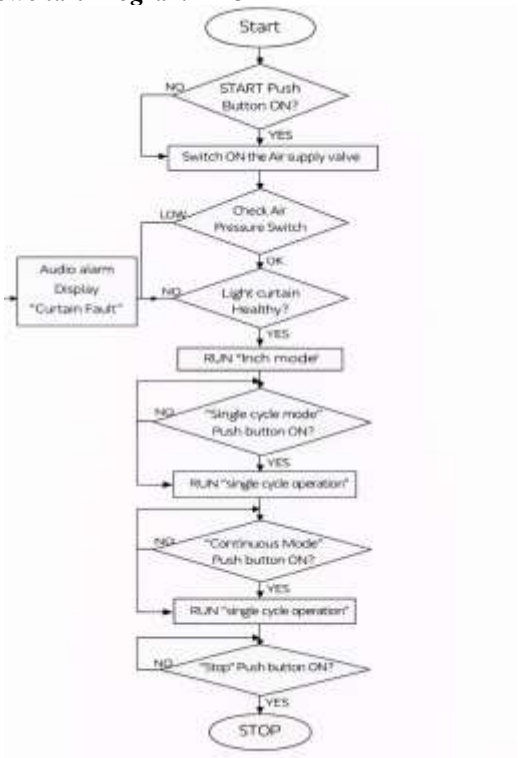


The electrical design of this pad printing machine modification focuses on the integration of a Keyence PLC-based automatic control system to replace manual operations. The electrical architecture is arranged in a control panel that uses an acrylic board as the main foundation, which functions as an electrical insulator while providing ease in visual monitoring of components.

The main components in this design include a 24VDC Power Supply as a stable power source for the control system, as well as a PLC unit that functions to execute the logic of the ladder program. In the input section, this design connects a proximity sensor to detect the position of the indexing rotary table and an emergency stop button to ensure work safety.

While in the output section, the signal from the PLC is forwarded to the Solenoid Valve Manifold which is responsible for distributing air pressure from the compressor to the pneumatic cylinder. All wiring is planned to use cable duct to ensure neatness and prevent signal interference (noise) between components, so that the jig movement and printing processes can run synchronously and precisely.

3.5 *Flowchart Program PLC*



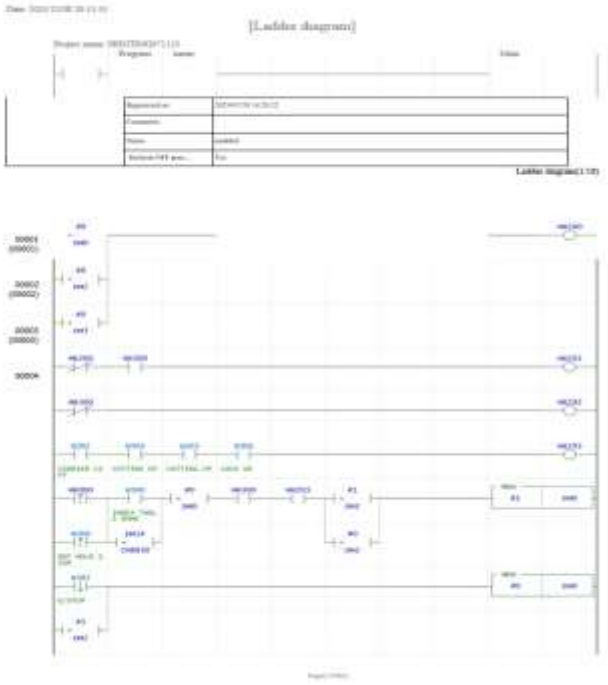
This electrical flowchart illustrates the working sequence of a PLC-based tampo printing machine control system. The process begins when the system is powered, and the PLC initializes by resetting all outputs and the production counter. The system then performs a safety check via an emergency stop; if the emergency stop is activated, the entire system stops. If the conditions are safe, the PLC waits for a command from the start push button.

After the start button is pressed, the PLC checks the jig position sensor to ensure the jig is in the ready position. Next, the jig rotary motor is activated to move the jig to the next station until the specified position is reached.

Once the jig is in the correct position, the system activates a pneumatic clamp to hold the product during the process. Each completed cycle increments the production counter, and the PLC then compares the production quantity with the predetermined target. If the target is not reached, the system automatically repeats the work cycle. If the target is reached or an emergency occurs, the system stops to maintain safety and operational stability.

3.5 Program PLC

A ladder diagram in a PLC serves as the primary control logic for managing each process stage on a multi-station tampo printing machine. Each rung represents a sequence of operations, from homing, rotary table positioning, pneumatic cylinder actuation, ink pickup by the pad, to ink transfer to the product. This ladder ensures that all machine movements are automated, coordinated, and safe, according to the designed sequence.



4 Discussion

The implementation of the multi-station jig system demonstrates a significant improvement in production fficiency. The reduction in cycle time indicates that non-value-added activities such as manual handling and waiting time have been successfully minimized. The ability to process multiple components simultaneously allows continuous machine operation, reducing idle time and increasing productivity.

Furthermore, the improved jig design enhances positioning accuracy and reduces operator movement, contributing to better ergonomics and consistency in the printing process. These improvements not only increase production output but also improve processreliability and product quality.

Overall, the results confirm that the multi-station jig system is an effective solution for overcoming the limitations of the single-station jig. The proposed design successfully enhances production capacity and supports more efficient

manufacturing operations without requiring major modifications to the existing machine.

IV. CONCLUSIONS

4.1 Conclusion

Based on the results of the study, it can be concluded that the use of a single-station jig system in the pad printingProcess leads to inefficiencies, particularly in terms of long cycle time, high machine idle time, and low production output. The manual handling and repositioning of components significantly affect the overall system performance.

The implementation of the multi-station jig system successfully improves the production process by enabling multiple components to be processed within a single cycle. This improvement reduces the cycle time from 28.45 seconds to 18.0 seconds per unit and increases the production output up to 1,600 significantly reduced, while jig stability and positioning accuracy are improved pieces per shift. In addition, Machine idle time and handling time are.

Therefore, it can be concluded that the proposed multi-station jig system is an effective solution to enhance productivity, operational efficiency, and process reliability in the pad printing workstation without requiring major modifications to the existing machine.

4.2 *Suggestion*

To further improve the system performance, several suggestions are proposed. First, regular maintenance and inspection of the jigsystem should be conducted to ensure long-term stability and accuracy. Second, future development can focus on integrating automatic indexing systems to further reduce operator involvement and eliminate remaining idle time. Finally, the implementation of data monitoring systems is recommended to enable real-time performance analysis and support continuous improvement in the manufacturing process.

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