BULLETIN OF ENGINEERING SCIENCE, TECHNOLOGY AND INDUSTRY
(BESTI Journal) | ISSN (e): 3025-5821
Website : https://bestijournal.org/index.php/go/index | Volumes 4 No. 2 (2026)

DESIGN AND MODIFICATION OF A MULTI-STATION JIG FOR IMPROVING PRODUCTION CAPACITY IN A PAD PRINTING MACHINE

Egy Gunawan Manurung[1], Prasaja Wikanta[2*]
Department of Electrical Engineering, Manufacturing Electronics Engineering Program,
Batam State Polytechnic, Batam, Indonesia.
E-mail: egymanurung25@gmail.com [1], antok@polibatam.ac.id [2*]

Received: 07/07/2026 | **Revised:** 15/07/2026 | **Accepted:** 27/07/2026 | **Published:** 20/08/2026

Abstract

Pad printing is an essential manufacturing process widely deployed across the electronics industry to transfer logos, serial numbers, and identification marks onto product surfaces with high precision. The performance of this process heavily relies on the architectural design of its work-holding jig system, which ensures accurate part alignment and structural stability during high-pressure ink transfer. At PT RPS Precision Engineering, the pad printing machine uses a multi-station jig system. However, the existing jig suffers from constrained dimensions, leading to restricted workpiece placement, slow manual loading/unloading operations, and degraded throughput. This study re-architects and modifies the dimensions of the multi-station jig to maximize production capacity while maintaining total compatibility with the existing printing infrastructure. The applied engineering design framework integrates field observation, CAD-based design optimization, electro-pneumatic integration via Programmable Logic Controller (PLC) synchronization, and a comparative performance evaluation. The re-engineered multi-station jig expands the available workpiece loading area, optimizes operator handling motions, and significantly elevates part positioning accuracy. Empirically, the system achieved a cycle time reduction from 28.45 seconds to 18.00 seconds per unit in initial trials, boosting production output to 1,600 pieces per shift. Machine idle time is minimized, enabling a highly efficient, automated throughput workflow without requiring fundamental modifications to the core pad printing machine. These findings demonstrate that dimensionally optimizing multi-station work-holding systems is an exceptionally practical and cost-effective approach to improving industrial manufacturing productivity.

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

INTRODUCTION

The electronics manufacturing sector demands high productivity, strict operational efficiency, and uncompromised product consistency to maintain competitiveness in global supply chains. Within this context, pad printing serves as a critical surface-finishing process used to apply high-resolution logos, tracking serial numbers, date codes, and technical identification marks to complex, uneven, or flat component surfaces. To achieve high repeatability and print crispness, the target workpiece must be localized accurately and held rigidly throughout the printing stroke. Consequently, the work-holding jig and fixture configuration directly governs the operational precision and cycle efficiency of the printing system. At PT RPS Precision Engineering, component marking relies on a multi-station pad printing setup. Although the baseline machinery supports continuous production cycles, the original jig infrastructure possesses highly restrictive dimensions. This structural limitation limits the workspace envelope, causing operators to face high physical handling constraints during loading and unloading tasks. These constraints prolong non-productive handling times, induce high machine idle rates, and bottleneck the machine from hitting its true throughput potential. To resolve this, structural modifications to the jig mechanism are required without introducing expensive re-engineering to the primary pad printing machine assembly.

Modern manufacturing literature establishes that re-engineering jigs and fixtures is one of the most cost-efficient methods to eliminate non-value-added time, reduce human handling errors, and enhance part positioning accuracy (Fiedler et al., 2024). In specialized surface-marking applications like pad printing, transitioning toward flexible, optimized fixation matrix components enables small-to-medium manufacturing setups to scale up production capacity without incurring massive capital expenditures on new machinery (Ramírez et al., 2023). Within the Indonesian manufacturing ecosystem, optimized geometric placement and structural customization of parts nested on local workholding matrices have proven pivotal in lowering machining latencies (Diratama, 2023). Furthermore, shifting from high-fatigue manual alignment baselines towards localized stop-pins and rigid structural nesting drastically cuts down indexing alignment errors (Tjiptady et al., 2021). This study addresses these production challenges by redesigning and fabricating a reconfigured multi-station jig system. The engineering objective focuses on expanding the workpiece pocket layout, optimizing the clamping envelope, and integrating an automated PLC control mechanism. The performance of the reconfigured design is thoroughly validated using a comprehensive before-and-after operational comparison framework, measuring improvements across processing cycle times, operational ergonomics, and shift-based volumetric output.

METHOD

2.1 Engineering Design Framework

This research utilizes a structured Engineering Design Method to plan, fabricate, and validate the structural modification of the pad printing machine's multi-station jig system. The engineering workflow spans six sequential phases: (1) Problem Diagnosis via field observations of production line bottlenecks; (2) Data Acquisition through precise dimensional measurement of the machine's rotary indexing table; (3) CAD Redesign of the jig plates using Computer-Aided Design software; (4) Fabrication & Assembly of the physical components; (5) PLC Integration via customized control logic; and (6) Empirical Validation running comparative time-studies.

2.2 System Architecture & Process Workflow

The production machine used in this study is an industrial pad printing machine located at PT RPS Precision Engineering. It prints identification marks on electronic components using a high-deformation silicone pad. As shown in figure 1, the machine consists of a pad printing head, pneumatic cylinder, rotary indexing table, and multi-station jig. The production sequence begins with loading the workpiece onto the jig, indexing to the printing station, ink transfer by the pad, printing onto the product, and indexing to the next station.

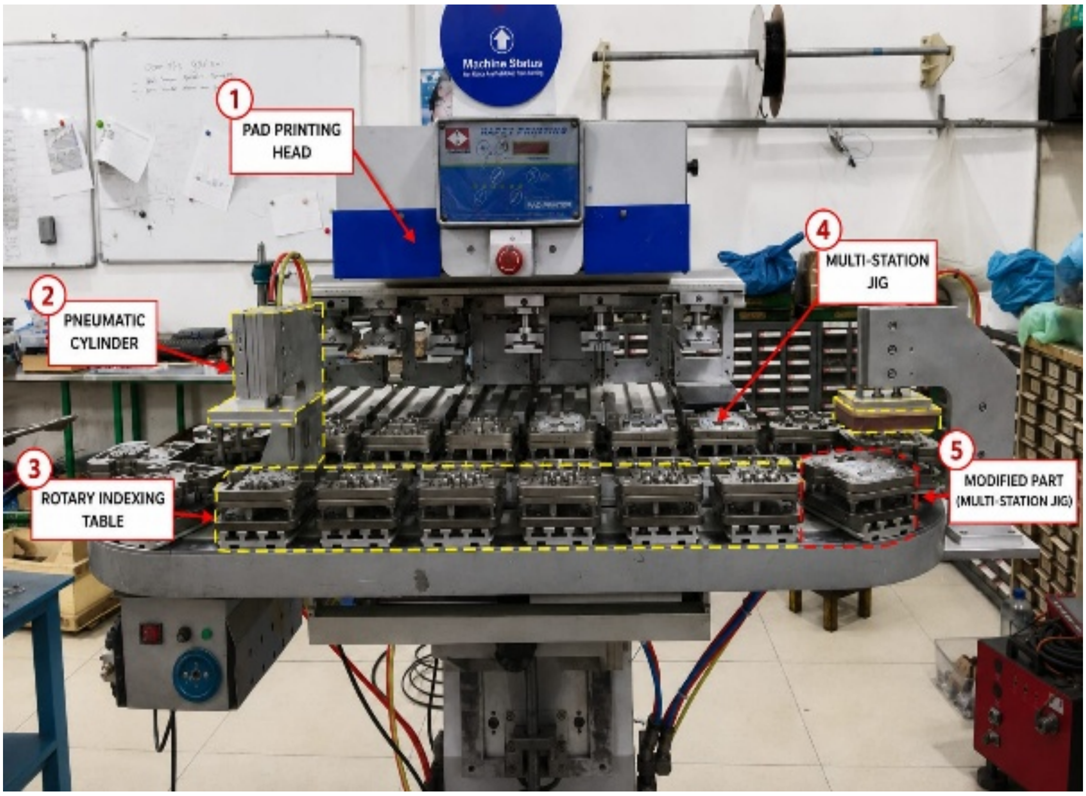

Figure 1: Configuration of the industrial pad printing machine setup at PT RPS Precision Engineering.

2.3 Structural Jig Re-Engineering

The pad printing machine uses a multi-station jig to accurately position the workpieces during the printing process. The modified jig consists of the Product Pocket, Workpiece Clamp, Jig Base Plate, Alignment Pin, Transparent Cover Plate, and Locator Pin as shown in figure 2. The modification was carried out because the dimensions of the existing multi-station jig were relatively small, limiting the workpiece area and reducing production efficiency. Therefore, the jig dimensions were optimized to provide a larger workpiece area, improve loading and unloading operations, and increase production efficiency without changing the main mechanism of the pad printing machine.

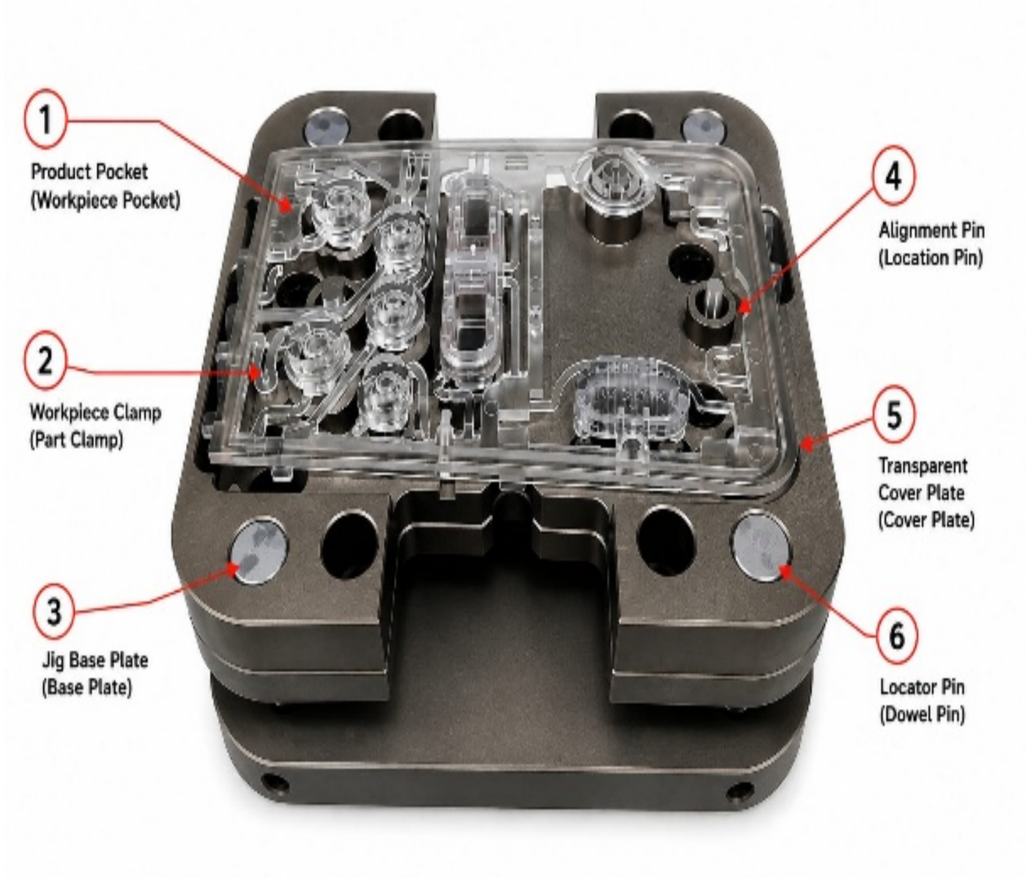

Figure 2: The physical configuration of the modified multi-station jig section on the pad printing machine.

To achieve greater capacity without causing physical interference with the surrounding printing head or sensors, the jig's structural dimensions were expanded up to a maximum outer width boundary of 61.00 mm per symmetrical wing (total width of 122.00 mm) and a depth layout detailed by key fastening distances ranging from 28.00 mm to 55.00 mm. As illustrated in figure 3, the engineering design schematics, the physical dimensions of the jig were strategically optimized to provide a significantly larger workpiece nest footprint while maintaining absolute mechanical compatibility with the existing pad printing machine interface. A series of high-precision boring procedures established mounting holes at diameters of Ø 4.13 mm, Ø 5.50 mm, Ø 10.00 mm, Ø 12.00 mm, and Ø 13.50 mm to accommodate the updated pneumatic rod attachments and locator pins, mirroring reliable multi-plate prototyping strategies deployed in high-speed alignment environments (Purbaningrum et al., 2023).

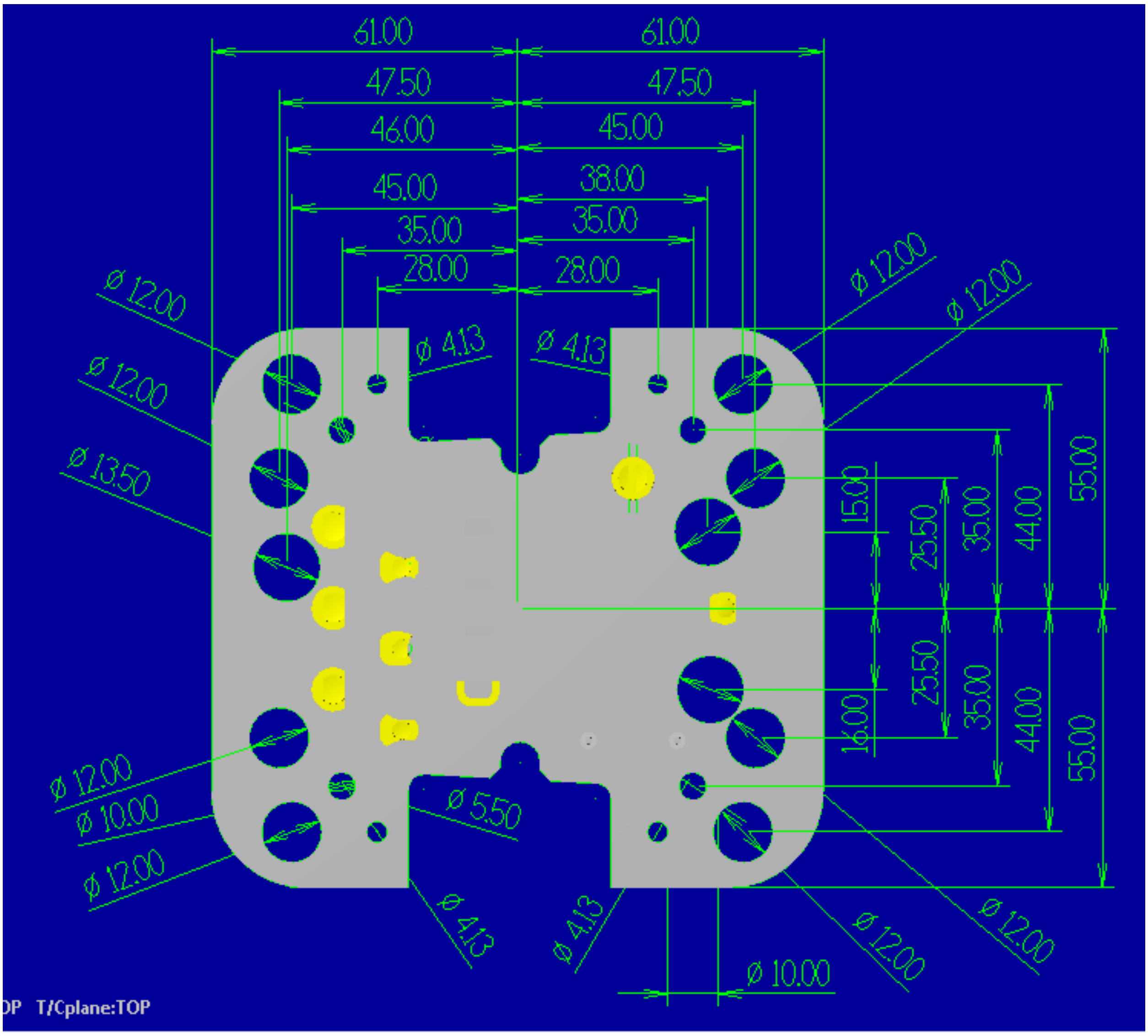

Figure 3: Detailed CAD engineering design and dimensions of the multi-station jig after modification.

2.4 Electrical Architecture and Control Logic

The manual and semi-automatic operations of the legacy setup were upgraded to a fully automated system driven by a centralized Programmable Logic Controller (PLC) processor operating on a stable 24VDC power supply architecture. Inputs consist of industrial proximity sensors that monitor the real-time position of the rotary indexing table, alongside a hardwired Emergency Stop safety loop. The PLC output channels interface with a centralized Solenoid Valve Manifold, which routes compressed air lines to the double-acting pneumatic clamping and printing cylinders. The schematic diagram can be seen in figure 4.

Figure 5 shown algorithm of ladder diagram for PLC. The process starts with system initialization, followed by checking the start conditions. Once all conditions are satisfied, the workpiece is clamped, and the pad printing process begins. The PLC controls the pad movement, ink transfer, and rotary indexing table sequentially. After each printing cycle, the system checks whether all stations have been completed. If not, the rotary table indexes to the next station and the process repeats. When all stations are finished, the workpiece is released, the cycle is completed, and the system waits for the next start command or stops when the stop or emergency button is activated.

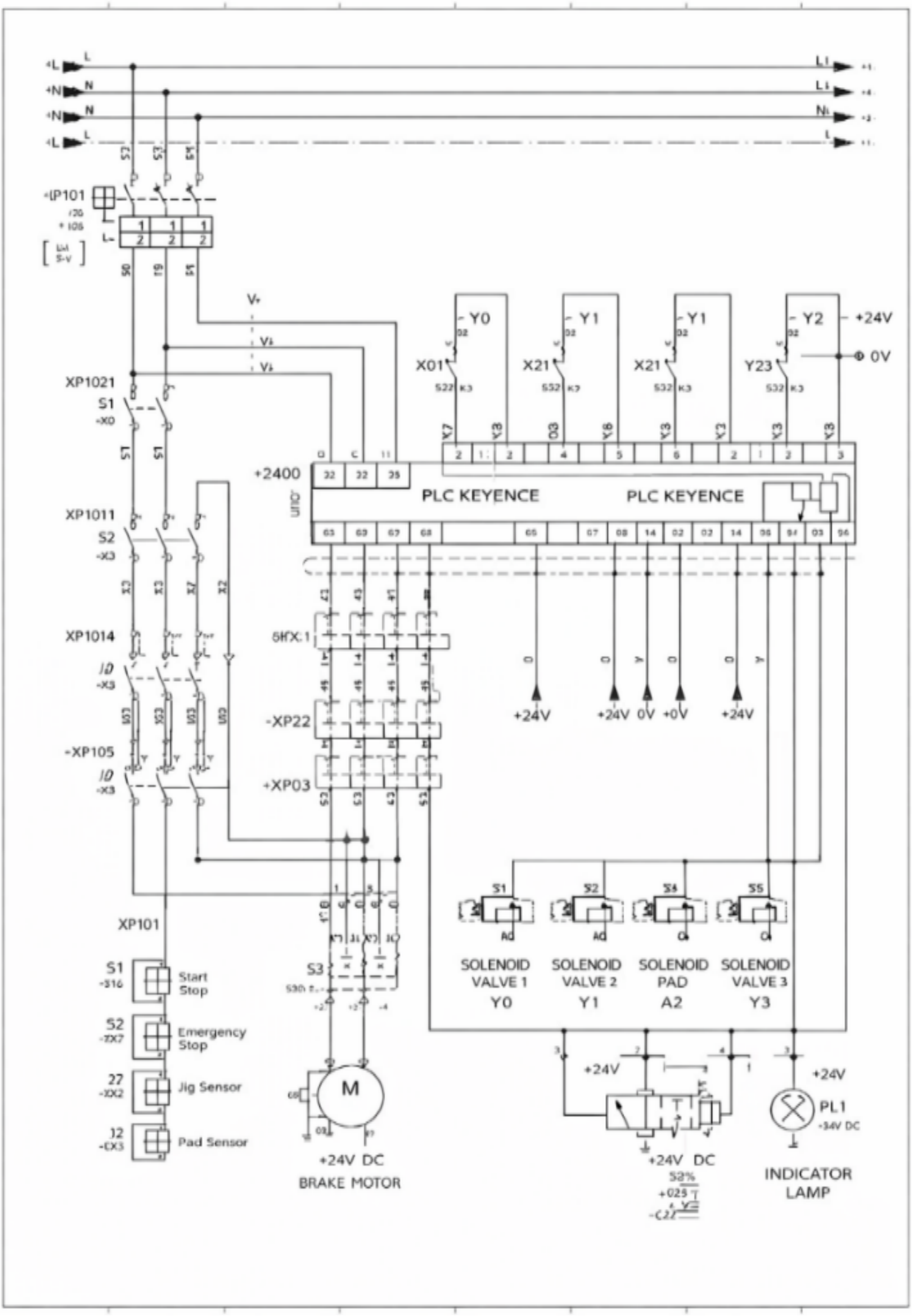
PLC KEYENCE
PLC KEYENCE
XP1021
S1
XP1011
S2
XP1014
-XP105
-XP22
+XP03
XP101
S1
Start
Stop
S2
Emergency
Stop
Jig Sensor
Pad Sensor
S3
M
+24V DC
BRAKE MOTOR
SOLENOID
VALVE 1
Y0
SOLENOID
VALVE 2
Y1
SOLENOID
PAD
A2
SOLENOID
VALVE 3
Y3
+24V
0V
+24V DC
PL1
INDICATOR
LAMP
+2400

Figure 4: Complete electrical circuit schematic diagram for the automated PLC control integration.

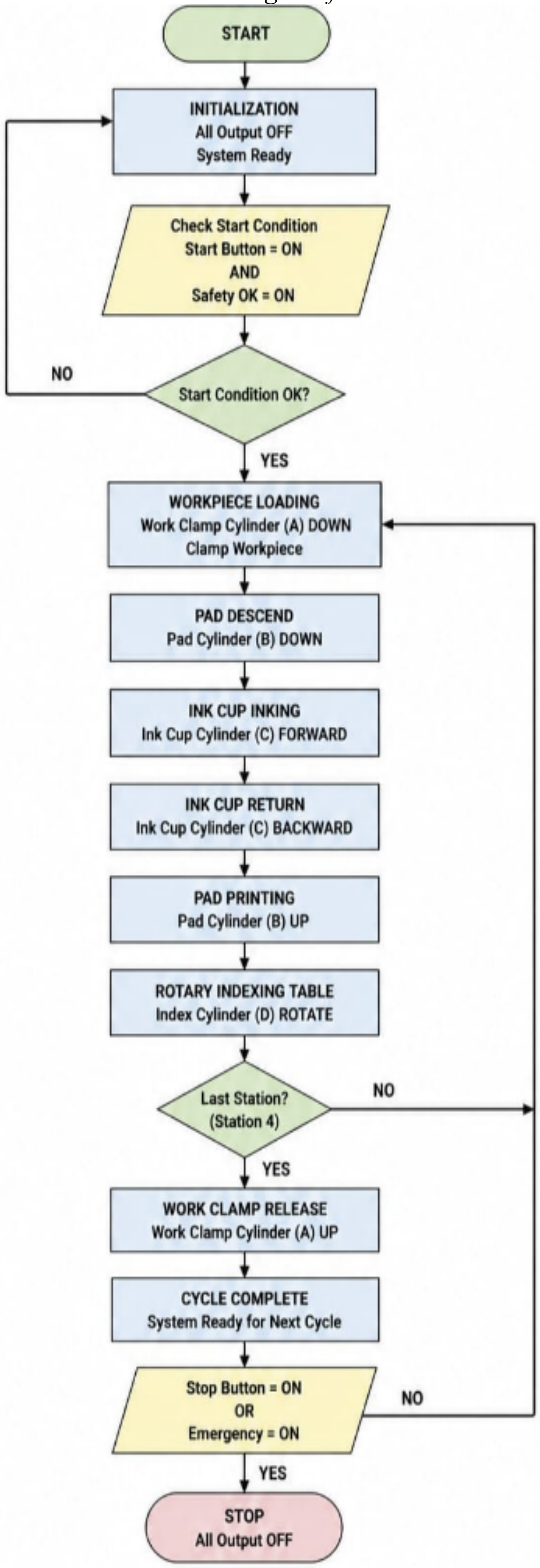

Figure 5: Flowchart PLC.

3.3 Results and Discussion
3.1 Structural and Operational Comparison

Empirical data collected before and after the engineering intervention demonstrates substantial improvements across all operational parameters. Table 1 compiles the qualitative and structural changes observed between the legacy and modified systems.

Parameter	Existing Multi-Station Jig	Modified Multi-Station Jig
Jig Dimensions	Relatively small / restricted	Optimized and significantly larger
Workpiece Area	Limited loading envelope	Expanded workpiece placement area
Loading Process	Less efficient / high manual latency	Highly streamlined and ergonomic
Unloading Process	Obstructed / low handling speed	Rapid part extraction
Workpiece Positioning	Adequate / prone to slight shifting	Highly stable and accurate alignment
Operator Accessibility	Confined physical clearance	Excellent operational clearance
Production Efficiency	Lower operational yield	High automated performance
Machine Compatibility	Base machine standard	100% compatible with existing hardware

Table 1: Structural and operational metrics comparison of the multi-station jigs.

3.2 Production Throughput and Cycle Time Analysis

To fully validate the real-world manufacturing performance of the reconfigured system, data was analyzed across sustained standard run production trials.

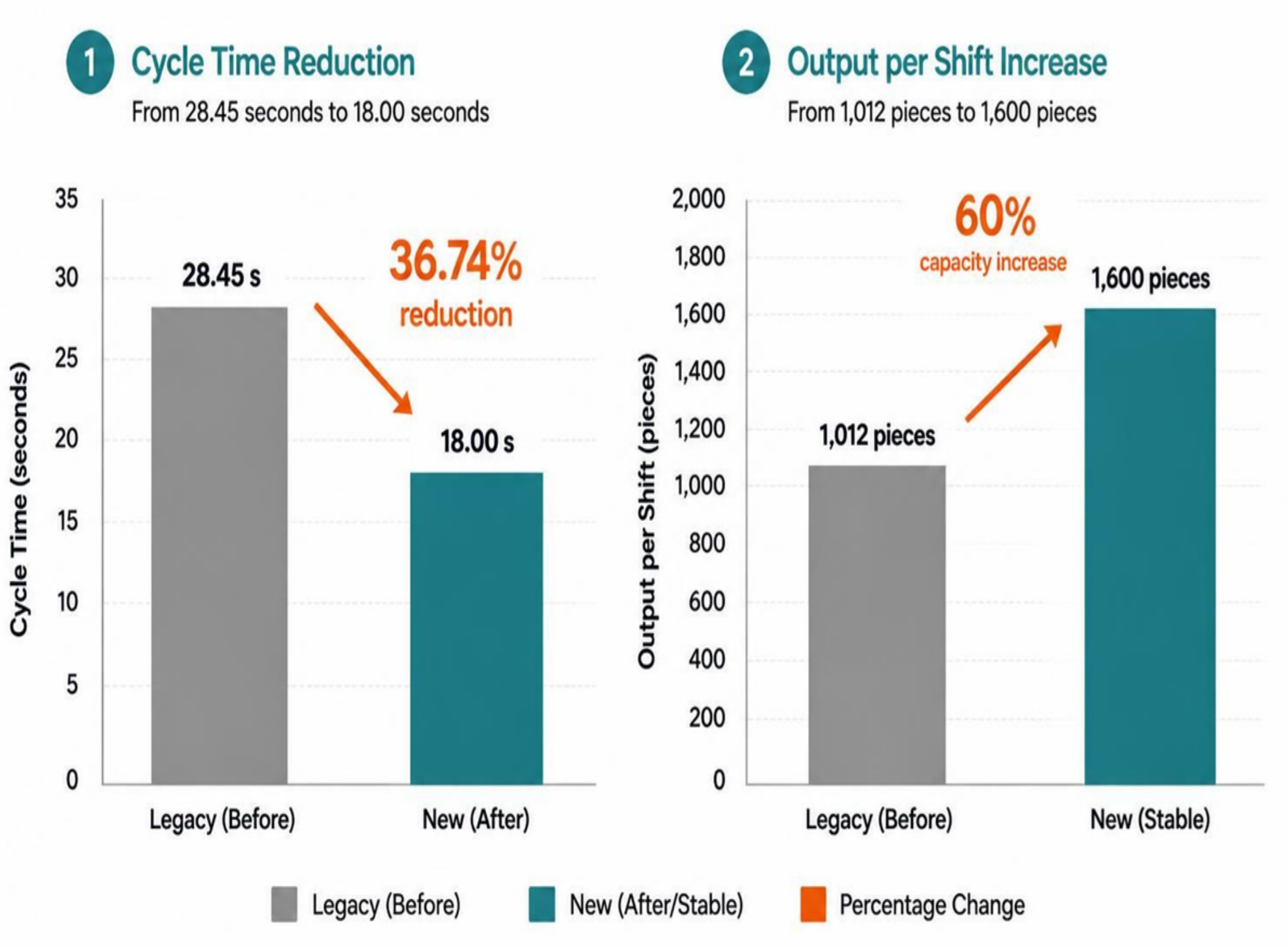

Figure 6: Comparison of Cycle time Time and Production Capacity Before and After Modification

As shown in figure 6, long-term performance testing under standard factory operating conditions verified the high stability of the automated PLC logic. The standard legacy operational cycle time of 28.45 seconds (inclusive of manual load delays and physical operator fatigue) was cut down to a stable 18.00 seconds per finished unit. This represents an approximate 36.74% reduction in total processing time. Total output scaled up from a historical baseline of 1,012 pieces per shift to a highly stable output of 1,600 pieces per shift, marking a 60% capacity increase relative to legacy production runs.

By automating the clamping-to-printing synchronization loop via the PLC, the system completely eliminated machine idle intervals during parts handling. The custom workpiece pockets provide highly rigid part localization, which prevents micro-shifting under the compression stroke of the silicone pad. This directly aligns with data from comparable automated setups where replacing human alignment interventions with customized pneumatic fixtures results in a significant reduction in structural defect ratios and defects-per-million-opportunities (Supriyanto et al., 2024). Furthermore, establishing stable localized alignment ensures that ink-layer micro-registration remains uniform throughout extended running cycles, avoiding variations common in high-volume stamp-based imprint systems (Guan & Sun, 2020). This matches state-of-the-art implementations where integrating automated sensors and pneumatic clamping loops into automated workstations yields massive cycle time savings and stabilizes parts positioning (Wei et al., 2024).

CONCLUSION AND SUGGESTIONS

4.1 Conclusion

This study successfully redesigned, fabricated, and deployed an optimized multi-station jig system coupled with an automated PLC control upgrade for an industrial pad printing machine at PT RPS Precision Engineering. The legacy manual work-holder has been successfully re-engineered into an automated, dimensionally optimized multi-station electro-pneumatic jig system. Integrating a centralized PLC architecture significantly maximizes production line efficiency by running the clamping, indexing, and printing strokes in a flawless, automatic sequence. The modified system delivers exceptional consistency, reducing processing cycle times by up to 36.74% (from 28.45 seconds down to 18.00 seconds) and driving shift capacity upward by 60% (from 1012 pieces to 1,600 pieces per shift).

4.2 Suggestions

To further expand the performance and technological capability of this manufacturing system, the following future developments are recommended: (1) Deploy a localized Human-Machine Interface (HMI) panel to give production technicians real-time visual control over cycle time configurations; (2) Incorporate an Internet-of-Things (IoT) telemetry module to enable remote machine monitoring; and (3) Establish a strict, calendar-based maintenance protocol for the pneumatic cylinder seals and proximity sensors to eliminate down-time from component wear.

REFERENCES

Diratama, M. Y. (2023). Perancangan Jig and fixture Untuk Pembuatan Ragum Tipe 125. ROTASI, 25(1), 1-8. https://doi.org/10.14710/rotasi.25.1.1-8

Fiedler, F., Ehrenstein, J., Höltgen, C., Blondrath, A., Schäper, L., Göppert, A., & Schmitt, R. (2024). Jigs and Fixtures in Production: A Systematic Literature Review. Journal of Manufacturing Systems, 72, 373-405. https://doi.org/10.1016/j.jmsy.2023.10.006

Guan, Y., & Sun, B. (2020). Detection and extraction of heavy metal ions using paper-based analytical devices fabricated via atom stamp printing. Microsystems & Nanoengineering, 6, Article 71. https://doi.org/10.1038/s41378-019-0123-9

Herdiana, B., Setiawan, E. B., & Sartoyo, U. (2024). Tinjauan Komprehensif Evolusi, Aplikasi, dan Tren Masa Depan Programmable Logic Controllers. Telekontran : Jurnal Ilmiah Telekomunikasi, Kendali dan Elektronika Terapan, 11(2), 173-193. https://doi.org/10.34010/telekontran.v11i2.12896

Indrawan, R., Purnomo, D. A., Bisono, F., Karuniawan, B. W., & Fajardini, R. A. (2024). Design and Fabrication of Jig and Fixture for Milling Operations in the Manufacturing Sector. Rotasi, 26(4), 54–59. https://doi.org/10.14710/rotasi.26.4.54-59

Petruzella, F. D. (2020). Programmable Logic Controllers: Industrial Automation. McGraw-Hill.

Purbaningrum, S. P., Johannes, J., Imansuri, F., Salati, D., & Solih, E. S. (2023). Implementasi Jig Welding Untuk Meningkatkan Efisiensi Pengelasan Frame Base. Journal of Community Services in Sustainability, 2(1), 55-64. https://doi.org/10.52330/jocss.v2i1.277

Ramírez, J. A. F., Hernández-Uribe, Ó., Cárdenas-Robledo, L. A., & Luna, A. C. (2023). Universal fixation system for pad printing of plastic parts. Mathematical Biosciences and Engineering, 20*(12), 21032-21048. https://doi.org/10.3934/mbe.2023930

Supriyanto, H., Reyfasha, M. L., & Supriyanto, M. F. R. (2024). Increasing the Sigma Level and Customer Value in the Manufacturing Industry: A Case Study of Cover Components. International Journal of Mechanical Engineering and Robotics Research, 13(1), 26-34. https://doi.org/10.18178/ijmerr.13.1.26-34

Tjiptady, B. C., Rahman, R. Z., Meditama, R. F., & Widayana, G. (2021). Jig and Fixture Redesign for Making Reamer on Head Cylinder. Jurnal Pendidikan Teknik Mesin Undiksha, 9(1), 32-41. https://doi.org/10.23887/jptm.v9i1.32597

Wei, F., Wang, D., & Zhang, X. (2024). Development and Design of an Online Quality Inspection System for Electric Car Seats. Sensors, 24(21), 7085. https://doi.org/10.3390/s24217085