OPTIMISATION OF PRODUCT MARKING ACCURACY THROUGH THE IMPLEMENTATION OF A QR CODE SCANNER SYSTEM BASED ON RASPBERRY PI SBC IN THE AUTOMOTIVE MANUFACTURING INDUSTRY

Heru Suprapto, Mochamad Nur Fadhilah Irfan, Syahril Ardi*, M Hidayat
Program Studi Mekatronika, Politeknik Astra, Bekasi, 17530, Indonesia
E-mail: syahril.ardi@polytechnic.astra.ac.id*

***Abstract* -- In automotive manufacturing, accurate product marking is essential for traceability and safety. One interior component requires laser marking of the label "AIR BAG" and the attachment of a QR code. However, production data revealed recurring defects due to missing QR code labels or skipped marking processes, which were caused by the lack of a verification system. This study aims to design and implement an automated QR code verification system using a Raspberry Pi 4, a single-board computer (SBC) of this type. The novelty of this approach lies in its cost-effective integration of hardware and image processing software (OpenCV) to detect QR codes in real time. The system is designed to scan for a QR code before the laser marking process begins. If a QR code is detected, a signal is sent to the laser machine to proceed with marking. It ensures that each product is verified correctly and marked. The method involved prototyping, software development, hardware integration, and implementation on a real production line. Results showed a significant reduction in marking-related defects and an improvement in process reliability. This solution minimizes operator error, enhances production efficiency, and supports quality assurance. Future work will focus on integrating the system with PLC-based controls and exploring machine learning techniques to enhance detection accuracy and facilitate predictive maintenance.**

Keywords: Laser marking machine, QR code scanner, Raspberry Pi, product quality, production automation

Abstrak -- Dalam industri manufaktur otomotif, ketepatan penandaan produk merupakan aspek krusial untuk mendukung ketertelusuran dan keselamatan. Salah satu komponen interior kendaraan memerlukan proses penandaan laser dengan label "AIR BAG" serta pemasangan label kode QR. Namun, data produksi menunjukkan adanya cacat berulang akibat label kode QR yang hilang atau proses penandaan yang terlewat. Permasalahan ini disebabkan oleh tidak adanya sistem verifikasi yang memastikan kehadiran kode QR sebelum proses penandaan dilakukan. Penelitian ini bertujuan untuk merancang dan mengimplementasikan sistem verifikasi kode QR otomatis menggunakan Raspberry Pi 4, yaitu komputer papan tunggal (single-board computer/SBC) yang berbiaya rendah namun andal. Keunggulan utama dari pendekatan ini terletak pada integrasi perangkat keras dan perangkat lunak pemrosesan citra secara efisien menggunakan pustaka OpenCV, yang memungkinkan deteksi kode QR secara real-time. Sistem dirancang untuk melakukan pemindaian terhadap keberadaan kode QR sebelum mesin laser memulai proses penandaan. Jika kode QR terdeteksi, sinyal akan dikirim ke mesin laser sebagai izin untuk melanjutkan proses penandaan. Dengan demikian, sistem memastikan bahwa setiap produk telah diverifikasi dan ditandai dengan benar. Metodologi penelitian mencakup pembuatan prototipe, pengembangan perangkat lunak, integrasi perangkat keras, dan implementasi langsung pada lini produksi. Hasil pengujian menunjukkan penurunan signifikan pada jumlah cacat terkait penandaan serta peningkatan reliabilitas proses secara keseluruhan. Solusi ini juga terbukti mengurangi kesalahan operator, meningkatkan efisiensi produksi, dan mendukung upaya penjaminan mutu. Pengembangan lanjutan dari sistem ini akan difokuskan pada integrasi dengan sistem kontrol berbasis PLC serta eksplorasi teknik pembelajaran mesin (machine learning) guna meningkatkan akurasi deteksi dan mendukung pemeliharaan prediktif.

Kata Kunci: Mesin penanda laser, pemindai kode QR, Raspberry Pi, kualitas produk, otomatisasi produksi

I. INTRODUCTION

The automotive manufacturing industry is facing increasingly complex challenges in maintaining product quality, consistency, and production efficiency. One critical aspect of this process is the accuracy of product marking, which is directly related to vehicle identification and safety. Interior components, such as the Garnish Centre Pillar, require a marking process using laser machines and the attachment of QR code labels as part of the product identification system. It is the focus of innovation in the present study.

Based on production data from the past two months, 35 defective products were recorded due to operator negligence, such as missing QR code labels or skipped marking processes. These findings highlight the weaknesses of a verification system that still relies on manual control. To address this issue, an automated system is needed to verify the presence of QR codes in real-time before the marking process begins.

Single-board computers (SBCs) such as the Raspberry Pi have proven effective in various industrial applications due to their flexibility, compact size, and relatively low cost [1]. Although other studies have utilized PLC-based control systems for communication in industrial machines, in this case, the Raspberry Pi can be combined with image processing software, such as OpenCV, to detect QR codes accurately [2]. This technology has already been successfully implemented in warehouse management systems [3], intelligent parking systems [4], and inventory tracking applications [5].

Furthermore, utilizing the Raspberry Pi for real-time QR code detection has been shown to enhance process efficiency and minimize errors resulting from human intervention [6]. Therefore, integrating this system into laser marking machines is expected to strengthen marking accuracy, reduce product defects, and accelerate the production cycle.

Based on this background, the objective of this study is to design and implement a QR code verification system using Raspberry Pi 4, integrated with a laser marking machine, to enhance the effectiveness and efficiency of the marking process on an automotive manufacturing production line.

This research was conducted at an automotive manufacturing company that produces injection-moulded plastic components for four-wheeled vehicles. The production process is divided into three main stages: Plastic Injection (PI), Assembly (ASSY), and Painting. The Plastic Injection stage involves melting plastic materials, injecting them into moulds, and cooling them to form solid products [7]. In the Assembly stage, several components from the injection process are assembled into a complete product. Meanwhile, the Painting stage involves applying colour according to customer specifications, using an oven-drying process at a temperature of 80°C.

The company produces a variety of automotive components, including exterior parts (such as bumpers, front fenders, and hoods), engine compartment parts (such as grilles and battery trays), AC components (such as ducts and casings), and vehicle interior components. One of these interior components is the Garnish Centre Pillar (Garn CTR Pillar), a structural element in the vehicle's interior.

The production process of the Garn CTR Pillar involves several stages, including injection moulding, runner cleaning, pad and adjuster installation, manual QR code labelling, and laser marking. According to production data, defects often occur due to missing QR code labels or skipped marking processes [8].

To resolve this issue, this study proposes the implementation of an automated verification system based on Raspberry Pi 4. The system is designed to scan and verify the presence of QR code labels before the marking process begins, thereby minimizing errors caused by operator negligence. Additionally, the system features a mechanism for directly transmitting scanning data to the laser marking machine, ensuring that the marking process is carried out automatically, accurately, and efficiently.

II. RESEARCH METHODOLOGY

The Garnish Centre Pillar (Garn CTR Pillar) is an interior vehicle component located between the front and rear doors. This component functions as a seatbelt support and plays an essential role in the safety and comfort of passengers. Before being delivered to customers, the Garn CTR Pillar product must undergo a series of post-production processes, which include: Adjuster installation, QR code label installation, and Marking process using a laser marking machine.

This research focuses on the product marking process and efforts to reduce defects caused by missing QR code labels or unperformed marking processes. Figure 1 presents a visualization of the QR code installed on the product as part of the identification and tracking system [9, 10].

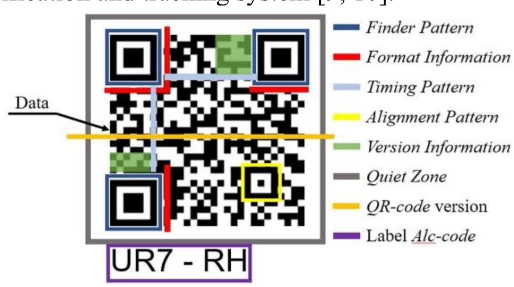

Figure 1. The product QR-Code

Therefore, in this stage, a QR code verification system based on the Raspberry Pi 4 will be developed and implemented to scan the presence of the label before the laser marking process is automatically carried out.

The methodological steps used in this research include:

- Identification of issues in the Garn CTR Pillar production line,
- Design of a QR code verification system using the Single Board Computer (SBC) Raspberry Pi 4,
- Integration of the system with the laser marking machine,
- Testing the functionality of the system in an actual production environment and

- Analysing the implementation results regarding defect rate reduction and production efficiency improvement.

Based on the flow chart of the Garnish Centre Pillar (Garn CTR Pillar) production process, the product manufacturing process starts with the injection moulding stage using an injection moulding machine. After the product comes out of the machine, the ABB robot arm picks it up and places it onto a conveyor. The conveyor then moves the product to the production line, where two operators perform further processes.

The first operator will cut the runner and visually inspect the moulded product. If the product is deemed defective, it will be placed in the NG (Not Good) box. However, if the product is deemed good, the process continues with the removal of the runner. Next, the operator installs the pad, which serves as the base for the adjuster installation. The product is then handed over to the second operator for the adjuster installation process.

The adjuster will be installed on the Garn CTR Pillar product, which has previously undergone visual inspection, runner cutting, and pad installation by the production operator. The adjuster component adjusts the height of the seatbelt so that it can be tailored to the user's height. After the adjuster installation, the second operator will perform additional checks and install the QR code label and ALC code on the product.

The QR code is installed after the adjuster installation process is completed on the Garn CTR Pillar product. The QR code and ALC code labels are placed on the back of the product, specifically around the adjuster area. The primary function of the QR code is to store and provide critical product information, such as the customer number, installation position, manufacturing date, and production location. In this way, the QR code serves as a digital identity for the product, facilitating tracking and quality control [11, 12].

2.1 Use of QR-Code on Products

The QR code on the Garn CTR Pillar product is used as a traceability system, which records the production history. This QR code is very helpful in the identification process in case of Not Good (NG) products or other issues, as the information stored within allows us to determine when, by whom, and where the product was made [13, 14, 15].

The data embedded in the QR code includes various important details related to the production process, such as:

- Part Number Auto Plastik Indonesia: Identifies the product according to the company's internal system.
- Part Number Customer: Identifies the product according to the customer's system.
- ALC-Code: The ALC code that indicates the product classification.
- Production Location: Information about the place where the product was manufactured.
- Quantity Packaging: The number of products in a single package.
- NPK: Employee Identification Number of the person who produced the product.
- Production Date: Includes the day, month, and year the product was made.
- Production Time: Information about the time the product was processed.

After applying the QR code, the next step is marking using a laser marking machine. The first step begins when the second operator places the product on the jig provided on the laser marking machine table. Then, the operator presses a lever to move the table to the marking position. Once the table reaches the correct position, the operator automatically presses the activation button to begin the marking process. Figure 2 shows the "AIRBAG" marking.

The marking text is "AIRBAG," indicating that the product is part of the vehicle's safety system and includes an airbag. After the marking process, the operator returns the lever to its original position to move the laser marking machine table back to the home position. Finally, the operator retrieves the product from the table and places it in the storage box for finished goods.

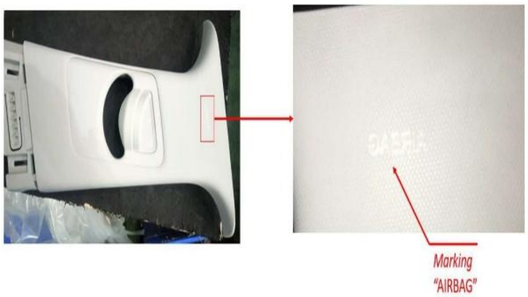

Figure 2. Marking “AIRBAG”

Figure 3 shows the laser marking machine used in the product marking process. The machine has several key components, including buttons, a jig, a table position lever, and a laser marking device. The button sends a signal to the laser marking machine to initiate the marking process, while the table position lever adjusts the table's position during marking operations.

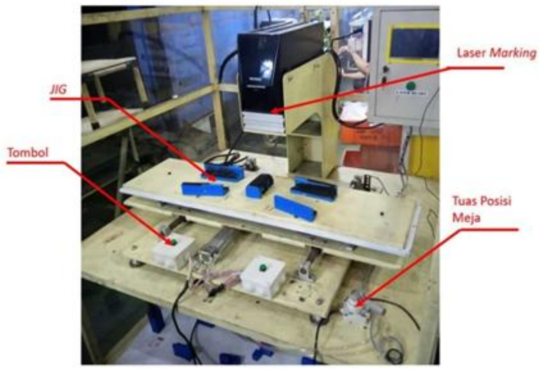

Figure 3. Laser Marking Machine

2.2 Problem Summary and Improvement Design

Based on NG (Not Good) data from May to June 2022, several defects were found in the Garn CTR Pillar product supplied to Hyundai. The issues included black spots from material contamination, missing springs due to operator oversight, missing or incorrect QR-code labels, and absent laser markings. Most of these defects were caused by operator negligence during inspection and verification processes.

To address these issues, a verification system has been designed for the final stage of production, specifically on the laser marking machine. This system includes a QR-code scanner to ensure each production step is completed correctly and to verify the product type before marking [16, 17, 18].

System flow: Once a product is confirmed as "Good," the operator presses a button to activate a solenoid and initiate the laser marking process. A proximity sensor ensures the marking table is correctly positioned, and timers control the marking duration. After marking is complete, the table returns to its initial position, and the Raspberry Pi records the product as finished. The operator then inspects the marked product and places it into the finished goods stock box.

2.3 Laser Marking Machine Control System Design

The block diagram of the control system implemented for the laser marking machine is shown in Figure 4. This system incorporates several key components that function as inputs, processing units, and outputs, all working in coordination to ensure the machine operates accurately and efficiently [19, 20, 21, 22, 23].

a. Scanner (Input). *Function:* Reads the QR code on the product and sends data to the Raspberry Pi. *Description:* Acts as the input device to verify product identity and trigger the laser marking process.
b. Raspberry Pi (Processing Unit). *Function:* Central processor and system controller. *Description:* Validates QR code data, manages the countdown timer for marking duration, and directs signal flow to other components.
c. Relay Module (Input/Output). *Function:* Interface between Raspberry Pi and system hardware. *Description:* Transfers control signals from the Raspberry Pi to the 24VDC relay, enabling coordination with the machine's physical components.
d. 24VDC Relay (Output). *Function:* Controls output to the timer and position controller. *Description:* Activates the laser table's movement and machine power based on signals from the Raspberry Pi via the relay module.

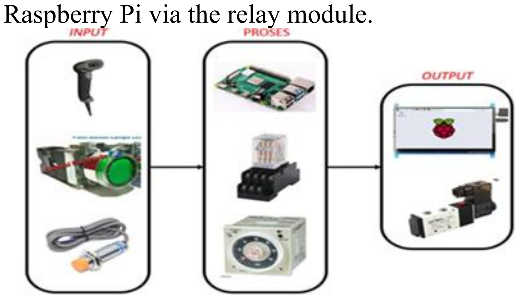

Figure 4. The block diagram of the control system design

2.4 Programming Flow Using Raspberry Pi

This system utilizes a Raspberry Pi to manage QR code validation and control the laser marking process. The workflow is as follows:

a. First QR-Code Scan: The operator scans the product's QR code, Raspberry Pi checks the code against the database, if not found, the operator is prompted to rescan with the correct product.
b. Second QR-Code Scan (Opposite Side): The operator scans the opposite side of the product, If the scan fails or returns NG (Not Good), the system requests a rescan.
c. Verification: If both scans are OK, the product is approved for marking, If NG, scanning must be repeated until verified.
d. Marking Process: Verified products proceed to laser marking, A signal from the first timer confirms the completion of the marking.
e. Data Logging and Counting: After marking, the system updates the product count, it ensures accurate tracking of finished goods and packaging quantities.

III. DESIGN, TESTING, AND ANALYSIS

3.1 Laser Marking System Programming Design

The programming design of the laser marking system aims to integrate various hardware and software components to enable the machine to perform marking automatically, accurately, and efficiently. This system is designed to read data from a QR code, process the information through a control unit, and operate the laser to carry out the marking process. Below is a breakdown of each component in the system:

a. QR Code

The QR code serves as a unique identification medium for each product. Each QR code contains essential information such as serial numbers, production dates, or other specific data that will be marked on the product. The programming design defines how data from the QR code is captured and processed for marking purposes.

b. Scanner

The scanner (usually a camera-based scanner or barcode reader) functions to read the QR code attached to the product. Programming tasks include integrating the scanner with the Raspberry Pi system, extracting data from the QR code, and transmitting the data to the control system for further processing.

c. Raspberry Pi

The Raspberry Pi acts as the brain of the system — the main controller. The programming design for the Raspberry Pi includes:

- Processing input from the scanner (QR code data)
- Connecting to and communicating with the database for data validation or retrieving additional information
- Managing the system logic and workflow
- Controlling actuators or triggering the laser marking process

The Raspberry Pi runs scripts written in programming languages such as Python or C++, and functions as a bridge between all connected devices.

d. Database

The database stores data related to the products, such as valid QR code entries, marking history, and tracking information. The programming involves connecting the Raspberry Pi to the database (using tools like phpMyAdmin) to:

- Validate QR codes
- Store the results of the marking process
- Log and track data for production or quality control purposes

e. Laser

The laser is the main execution component that physically marks the product. Programming controls when and how the laser operates based on the processed data. Key functions include:

- Selecting the pattern or text to be marked
- Adjusting the marking position
- Setting the laser duration and intensity as needed

3.2 Circuit Development

Figure 5 illustrates the wiring for transmitting digital signals from the Raspberry Pi to the laser marking machine. When the Raspberry Pi activates an output relay, it turns on an LED on the front panel to signal that marking can begin.

The operator then presses two push buttons, triggering a second relay that activates a timer and the solenoid to move the laser marking table into position. A proximity sensor confirms the table's position and activates a second timer to ensure proper alignment.

Once alignment is confirmed, the second timer initiates the laser marking process. After marking, the first timer sends a signal to return the table to its home position and notifies the Raspberry Pi, which then updates the packaging quantity.

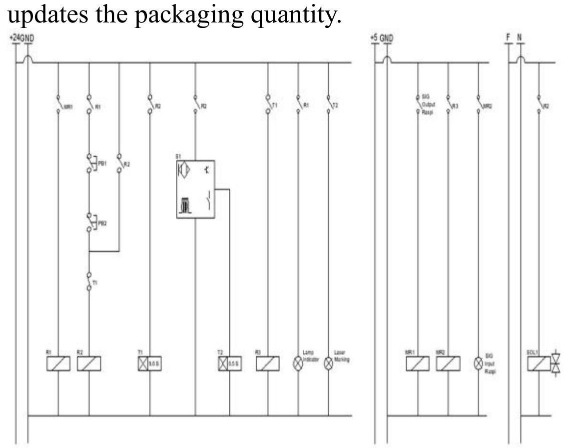

Figure 5. Wiring Diagram

3.3 Testing

After the program development and circuit assembly were completed, the developed program was tested by integrating it with the web-based interface. This testing phase aims to verify whether the program functions as intended and whether it can operate seamlessly alongside the website system.

During the testing, several functional aspects were evaluated, including the program's ability to operate with two cavities or one cavity and whether the website could correctly display alerts indicating whether the scanned product is "Good" or "Not Good."

A webpage interface is displayed to select the product cavity. This cavity selection feature determines whether the marking process will be executed for two or one product.

Once the operator selects the cavity type, the webpage displays several pieces of information, including Cavity mode, Part name, ALCCODE, Part number, Packaging quantity, and Countdown timer.

This data is retrieved from the Raspberry Pi during the scanning process and from the database.

Additionally, an alert message is shown to the operator. This alert notifies the operator whether the scanned QR code matches the expected product and, if so, confirms that the process can proceed to the next stage.

3.4 Result Analysis

a. QR-Code Scanner

Implementing a QR-code scanner in the laser marking machine allows the system to verify whether the product being processed matches the expected data. Additionally, it helps prevent errors related to incorrect or duplicate QR codes. Figure 6 shows the result when the scanned QR code matches the correct product. The display screen on the front panel will show a notification that reads "OK," indicating the QR code is valid. Figure 7 shows the result when the scanned QR code does not match the product. In this case, the screen will display a notification that reads "NG" (Not Good), indicating a mismatch or invalid QR code.

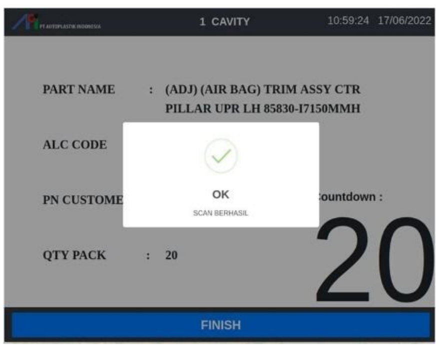

Figure 6. The result Scan QR-Code OK

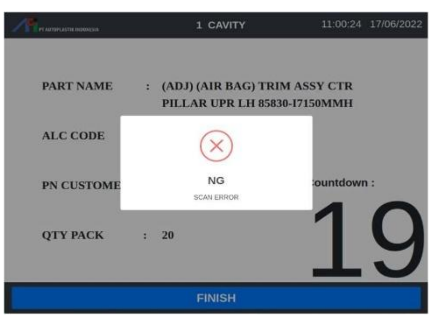

Figure 7. The result Scan QR-Code NG

b. Database

The addition of a data recording system to the database allows users to access information about the laser marking process. The database stores details related to the products that have undergone the marking process. Table 1 shows the product results.

Table 1. The product result

id	qr_code	npk	status	created_at
10	85840I7150MMH_2200007831_UR7_API1_20_0000_040222_0935	0000	1	6/17/2022
9	85830I7100MMH_2200000354_UL5_API1_20_0000_110122_1931	0000	0	6/17/2022
8	85840I7150MMH_2200007830_UR7_API1_20_0000_040222_0933	0000	1	6/17/2022
7	85830I7150MMH_2200009077_UL7_API1_20_0000_080222_1855	0000	1	6/17/2022
6	85830I7150MMH_2200009076_UL7_API1_20_0000_080222_1855	0000	1	6/17/2022
5	85830I7150MMH_2200009074_UL7_API1_20_0000_080222_1855	0000	1	6/17/2022
4	85830I7100MMH_2200000352_UL5_API1_20_0000_110122_1928	0000	0	6/17/2022
3	85830I7150MMH_2200009071_UL7_API1_20_0000_080222_1855	0000	1	6/17/2022
2	85840I7150MMH_2200007828_UR7_API1_20_0000_040222_0933	0000	1	6/17/2022
1	85840I7150MMH_2200007828_UR7_API1_20_0000_040222_0933	0000	1	6/17/2022

The database system enables users to access detailed information on each product that has undergone the marking process, including processing time, product type, and QR code scan results. This data supports production tracking, quality evaluation, and further analysis in case of discrepancies.

A *status* column in the database indicates the QR-code scan result:

- Status 1: The product is "good" — the QR code is valid and meets the standards.
- Status 0: Product is "not good" — there is an error or mismatch in the QR code.

In an initial trial, 2 out of 10 products showed a status of 0. However, this data is still assumed and used for simulation purposes as the system is under development.

The integration of the QR-code scanner with the database in this laser marking machine is designed to enhance efficiency, accuracy, and traceability. It helps detect product errors early, reducing the risk of defects and improving quality control. Further development is needed to ensure the system's reliability before full-scale implementation.

IV. CONCLUSION

Based on the research findings, the QR code scanning system for a laser marking machine, developed using a Raspberry Pi, successfully met the predefined objectives. The system is capable of effectively identifying which products require marking, thereby reducing the risk of errors during the marking process. Additionally, a data recording system has been successfully integrated into a database. Out of the 10 products tested, two were identified as defective. It indicates that the system can prevent faulty products from proceeding to the marking stage, ultimately contributing to improved overall product quality. For further development, it is recommended that the system be enhanced by enabling the Raspberry Pi to send signals directly to the laser marking machine. It would allow the marking output to be controlled automatically and with greater precision, resulting in a more efficient and accurate production process. Furthermore, it is advisable to add a rescanning step after the marking process to ensure that the QR code has been correctly registered in the database. This re-scan could also serve as a prerequisite for initiating the next production cycle.

V. ACKNOWLEDGMENT

The authors would like to express their deepest gratitude to researchers in the automotive manufacturing industry for their support during the implementation of this research. Support in the form of research facilities and industrial funding. Appreciation is also given to Polytechnic Astra for their continued support and collaboration during this project.

VI. REFERENCES

[1] Circuit Digest, “QR code scanner using Raspberry Pi and OpenCV,” 2022. [Online]. Available: https://circuitdigest.com/microcontroller-projects/qr-code-scanner-using-raspberry-pi-and-opencv

[2] Kostikar, “QR Code Scanning for Warehouse using Raspberry Pi,” GitHub, 2020. [Online]. Available: https://github.com/kostikar/QR-Code-Scanning-for-Warehouse-using-Raspberry-Pi

[3] Qengineering, “QR scanner Raspberry Pi,” GitHub, 2021. [Online]. Available: https://github.com/Qengineering/QR_scanner_Raspberry_Pi

[4] P. Coles, “Scan QR Codes with Raspberry Pi Pico,” Hackster.io, 2021. [Online]. Available: https://www.hackster.io/pete-coles/scan-qr-codes-with-raspberry-pi-pico-0b9596

[5] Core Electronics, “Real time scanning and storing QR codes with Raspberry Pi and OpenCV,” 2023. [Online]. Available: https://core-electronics.com.au/guides/QR-codes-raspberry-pi

[6] Instructables, “Raspberry Pi Laser Scanner,” 2019. [Online]. Available: https://www.instructables.com/Raspberry-Pi-Laser-Scanner

[7] Kalpakjian, S., & Schmid, S. R. (2014). Manufacturing Engineering and Technology (7th ed.). Pearson Education.

[8] Groover, M. P. (2016). Automation, Production Systems, and Computer-Integrated Manufacturing (4th ed.). Pearson.

[9] Hadiyan Sabri Wibowo. 2021. Modifikasi Desain Gripper Dan Pembuatan Sistem Interlock Untuk Mengurangi Reject Pada Produksi Shroudfan Di Mesin 1060-5 PT Autoplastik Indonesia. Laporan Tugas Akhir Politeknik. Politeknik Manufaktur Astra.

[10] Robyanzah, Rizal. 2018. Implementasi NFC (Near Field Comunnication) dan Led Touch Screen untuk Mengontrol Absensi Karyawan Berbasis Web. Universitas Muhammadiyah Malang.

[11] Indra Setiawan. 2021. Pembuatan Sistem Traceability Product Dengan QR-Code Berbasis Aplikasi Web yang Terintegrasi Dengan Radio Frequency Identification Di PT Autoplastik Indonesia. Politeknik Manufaktur Astra.

[12] Dewi Kartika Ajeng. 2018. Pembuatan Sistem Kontrol Pengemasan Sekunder Produk Detergen Kemasan Otomatis Pada Mesin Automation Cartoning di PT Astra Otoparts Divisi Winteq. LTA, Politeknik Manufaktur Astra.

[13] Liu, Y., Zhang, X., & Wang, H. (2020). Application of QR Code Technology in Manufacturing Traceability Systems. International Journal of Production Research, 58(15), 4600-4612.

[14] Chen, J., & Lin, C. (2019). QR Code-Based Traceability System for Quality Control in Plastic Injection Molding. Journal of Manufacturing Systems, 51, 123-134.

[15] Zhao, X., & Wang, F. (2018). Design and Implementation of a QR Code Marking and Recognition System for Industrial Products. Journal of Industrial Information Integration, 12, 45-52.

[16] Arif, M. S., Supomo, H., Alifia, W. U., & Wahidi, S. I. (2022). *Ship production process monitoring application using QR-code technology.* *IOP Conference Series: Earth and Environmental Science, 972(1), 012016.*

[17] Petcharat, W., Sutthirak, T., Poolphol, T., Janwichian, K., Atitang, P., & Kanjanaklod, W. (2024). *The Development of Information System for The Management of Materials via QR Code and Line Notify With MVC Framework. Journal of Applied Informatics and Technology, 6(1), 113–131.*

[18] Anggara, B., Anshor, A. H., & Hadikristanto, W. (2024). *Implementation Web-Based QR-Code Information System Design in Warehouse Inventory Management System Using Rapid Application Development (RAD) Method at PT Dharma Precision Parts. Formosa Journal of Computer and Information Science, 3(2), 81–90.*

[19] Arya, F., & Siregar, R. R. (2020). Komunikasi sistem pembaca 2D dengan mesin laser marking berbasis PLC. *Jurnal Aplikasi Elektro dan*

Elektronika (JAEE), *2*(1), 30–35. https://jurnal.polibatam.ac.id/index.php/JAEE/article/view/1079

[20] Liu, Y., Guo, J., Liu, Z., & Huang, Y. (2014). An embedded laser marking controller based on ARM and FPGA processors. *Sensors*, *14*(3), 4265–4279. https://doi.org/10.3390/s140304265

[21] Li, Z., Liu, Y., & Wang, Q. (2020). Design and implementation of laser marking machine control system. *IOP Conference Series: Materials Science and Engineering*, *769*, 012026. https://doi.org/10.1088/1757-899X/769/1/012026

[22] Ren, X. (2013). Laser marking machine application research based on fuzzy control system. *Advanced Materials Research*, *816–817*, 1045–1048.

[23] Damanik, R. H., & Manurung, A. H. (2021). Rancang bangun prototipe mesin gravir laser dengan mikrokontroler Arduino. *Jurnal Teknologi Mesin Indonesia*, *1*(2), 86–92. https://www.jurnal.bkstm.org/index.php/jtmi/article/view/104