JURNAL TEKNIK

Volume 23, No. 1, Juni 2025
P-ISSN : 1693-6191 E-ISSN : 2715-7660 DOI : https://doi.org/10.37031/jt.v23i1.551

# Design of Smart Iron Plate Heating Machine Using Quality Function Deployment Method

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## Abstrak

Jumlah sarung tangan yang masuk ke departemen setrika lebih banyak daripada sarung tangan yang disetrika membuat adanya banyak penumpukan sarung tangan yang belum disetrika. Berdasarkan permasalahan tersebut, maka dilakukan identifikasi permasalahan menggunakan metode IDEF0. Berdasarkan hasil diskusi yang dilakukan, solusi dari permasalahan yang ada adalah merancang mesin pemanas plat setrika menggunakan metode Quality Function Deployment (QFD) yang dapat mengurangi waktu proses menyetrika dan meningkatkan produktivitas. Setelah mesin selesai dibuat, maka dilakukan pengujian dimana hasil sarung tangan dari mesin pemanas plat setrika sudah memenuhi standar operasional prosedur. Selain itu, waktu baku penyetrikaan menurun dimana awalnya saat menggunakan setrika konvensional membutuhkan waktu penyetrikaan sebesar 47,68 detik. Sedangkan saat menggunakan mesin pemanas plat setrika membutuhkan waktu penyetrikaan sebesar 36,14 detik. Jumlah sarung tangan yang dihasilkan dalam 4 jam penggunaan mesin setrika konvensional menghasilkan 300 sarung tangan sedangkan pada mesin pemanas plat setrika menghasilkan 350 sarung tangan.
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**Kata kunci:** Mesin pemanas; Quality Function Deployment; IDEF0; Sarung tangan

## *Abstract*

*The number of gloves entering the ironing department is greater than the number of gloves that are ironed, causing a lot of accumulation of gloves that have not been ironed. Based on this problem, a problem identification was carried out using the IDEF0 method. Based on the results of the discussion, the solution to the existing problem is to design an ironing plate heating machine using the Quality Function Deployment (QFD) method which can reduce ironing process time and increase productivity. After the machine was completed, a test was carried out where the results of the gloves from the ironing plate heating machine had met the standard operating procedure. In addition, the standard ironing time decreased where initially when using a conventional iron it took 47.68 seconds to iron. While when using an ironing plate heating machine it took 36.14 seconds to iron. The number of gloves produced in 4 hours of using a conventional ironing machine produced 300 gloves while the ironing plate heating machine produced 350 gloves..*

***Keywords**: Heating machine; Quality Function Deployment; IDEF0; Gloves*

Diterima : April 2025
Disetujui : Mei 2025
Dipublikasi : Juni 2025



## Introduction

The manufacturing industry, driven by technological advancements, plays a pivotal role in bolstering a nation's economy by transforming raw materials into finished goods. Production processes within this industry, heavily reliant on machinery, are continually evolving to enhance productivity and efficiency (Nachazelova et al., 2024; Zhu et al., 2024). With rapid technological advancements, competition among manufacturing companies has become increasingly fierce, compelling them to continuously improve operational efficiency to meet the ever-evolving and complex demands of consumers (Motoyama et al., 2024). A critical aspect of the production process is the management of tools and technology employed at each stage of production. In this context, PT Adi Satria Abadi (ASA), a manufacturing company adopting a 'make-to-order' production system, encounters significant challenges in one of its production stages, namely the glove ironing process.

As a prominent golf glove manufacturer, ASA's production process encompasses several stages, including sample making, raw material preparation, material cutting, sewing preparation, sewing, inspection, ironing, packaging, and shipping (Isaksson et al., 2008). The ironing stage is particularly crucial as it prepares the gloves for the final stage and ensures quality (Kim et al., 2008). However, conventional ironing machines currently in use exhibit several drawbacks that hinder the company's productivity. Primary issues include unstable heat, inadequate plate size, and a relatively short lifespan of around three months. These issues result in limited ironing capacity and a backlog of gloves awaiting processing.

Daily, the ironing department at PT ASA receives approximately 4,500 gloves for ironing. With seven operators available, each operator can only iron an average of 600 gloves per day. This output falls short of the department's incoming glove quantity, leading to a backlog of unprocessed gloves. This accumulation has the potential to degrade product quality, including material stiffness and color fading, and often necessitates overtime work to meet delivery deadlines. This situation not only highlights the urgent need to enhance ironing capacity to meet production targets but also underscores the immediate actions required to mitigate the negative impacts of processing delays.

To overcome this challenge, the analysis was carried out using the Integration Definition for Function Modeling (IDEF0) method (Vilasdechanon & Sopadang, 2018) to map existing processes and identify problems systematically. Based on the results of the analysis, several potential solutions were proposed, including increasing the number of operators, adding more conventional ironing machines, or designing new, more efficient machines. To ensure that the machine design meets the requirements, the Quality Function Deployment (QFD) method is applied (Siwiec et al., 2023). QFD allows product design based on consumer needs and preferences—in this case, operators—resulting in machines that are not only more effective but also better suited to operational conditions (Suhartini et al., 2022; Xu et al., 2022).

This QFD-based approach provides an opportunity to create more systematic and data-driven solutions, ensuring that the designed products truly meet the specific needs of users (Nikolov et al., 2023). In this context, this research not only contributes to the development of technology in the manufacturing industry but also has the potential to influence other sectors, with a focus on improving productivity and operational efficiency. Using this method, the resulting solution can be measured and aligned with the identified needs, paving the way for wider applications in other industrial sectors, thereby demonstrating the broader impact of the proposed solution (Duru et al., 2020; Mu'Tamar et al., 2021; Ocak & Gönül Sezer, 2022).

## Method

The research methodology systematically addressed operational challenges in PT Adi Satria Abadi's ironing department through process analysis, user requirement translation, and rigorous testing. Using IDEF0 for problem analysis and QFD for designing the ironing plate heating machine, the approach ensured a reliable and effective solution.

The initial phase of this research involved problem identification through the IDEF0 method, a business process modeling tool to map workflows and identify contributing elements to inefficiencies. Direct observations were conducted at the site to understand the workflow of the glove ironing process. Observations focused on identifying inputs, outputs, mechanisms, controls, and environmental factors impacting process efficiency (Tserng et al., 2021; Vasilyev et al., 2020). An IDEF0 model was developed to visualize the existing ironing process (Bevilacqua et al., 2015). The diagram captured relationships among process elements, as illustrated in Figure 1 below:

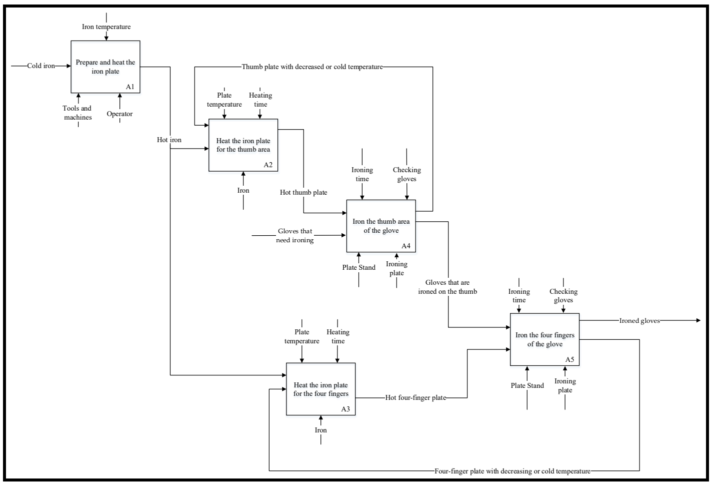



**Fig. 1.** IDEF0 Diagram of the Existing Ironing Process

This diagram illustrates inputs, such as gloves to be ironed; mechanisms, including operators and conventional ironing machines; controls in the form of SOPs;

and outputs such as ready-to-ship gloves. After mapping the existing process, a gap analysis was performed to evaluate the disparity between the current ironing capacity and daily production requirements. The analysis included cycle time assessments, product accumulation, and defects caused by delayed ironing. Based on the IDEF0 analysis, the proposed solution was the design of a more efficient ironing plate heating machine. The design process utilized the QFD method (Zhou et al., 2024), encompassing the following stages: 1) Customer voice was gathered through questionnaires distributed to ironing operators. The feedback identified desired product attributes, such as machine size, stable heating, ease of use, and safety features. 2) The HoQ matrix was used to translate product attributes into technical responses. An example of the HoQ matrix is presented in Table 1:

**Table 1.** Prioritization of Product Attributes and Technical Responses in the House of Quality (HoQ) Matrix

| Product Attributes | Weight | Technical Responses | Priority |
|---|---|---|---|
| Stable heating | 5 | Use of dual heating elements | 1 |
| Ease of use | 4 | Simple user interface design | 3 |
| Operator safety | 4 | Additional thermal insulation | 2 |

The machine was designed with key features to optimize performance and safety, including compact dimensions (40 cm × 30 cm) for worktable compatibility, dual heating elements for even heat distribution, an adjustable thermostat (70–80°C), and a durable stainless steel frame. After completing the design phase, a prototype was developed and underwent functional and safety testing. Functional tests measured ironing process time and product quality, comparing the results to conventional machines, while safety tests evaluated surface temperatures, demonstrating reduced heat exposure risks due to enhanced thermal insulation.

Following testing, revisions were made to address issues, such as relocating control components to minimize heat exposure to plastic parts. Data from the testing phase were analyzed using descriptive and inferential statistics, focusing on process times, standard deviations, and significance testing. Efficiency improvements were quantified to demonstrate the advantages of the new machine over conventional models.

$$Efficiency\ (\%) = \frac{Conventional\ Ironing\ Maching\ Time - Ironing\ Plate\ heating\ Machine\ time}{Conventional\ Ironing\ Maching\ Time}$$

## Results and Discussion

### Results

This research aimed to address inefficiencies in the ironing department of PT Adi Satria Abadi (ASA) by redesigning an ironing plate heating machine. Using the IDEF0 method, the glove ironing process was analyzed to identify bottlenecks and inefficiencies. Observations revealed that the current workflow struggles to handle the volume of gloves requiring ironing, resulting in backlogs, increased overtime, and higher operational costs. These delays also impact product quality, with issues like material stiffness and color fading arising from prolonged storage of unfinished gloves.

The IDEF0 diagrams provided a comprehensive overview of the process, highlighting the constraints of existing mechanisms. The analysis identified several limitations of conventional ironing machines, such as the absence of adjustable temperature indicators, small ironing surfaces, and short operational lifespans. These constraints force operators to rely on manual adjustments and inefficient processes, exacerbating the pile-up of gloves and increasing the risk of delivery delays. Potential solutions considered included adding operators, purchasing more conventional machines, or designing a new machine.

Given operational constraints, the company ruled out hiring additional staff and found conventional machines inadequate due to their inherent limitations. The proposed solution focused on designing a new ironing plate heating machine tailored to the company's needs. This machine is expected to address inefficiencies by reducing glove backlogs and overcoming the shortcomings of existing equipment, ultimately improving workflow efficiency, product quality, and delivery reliability.

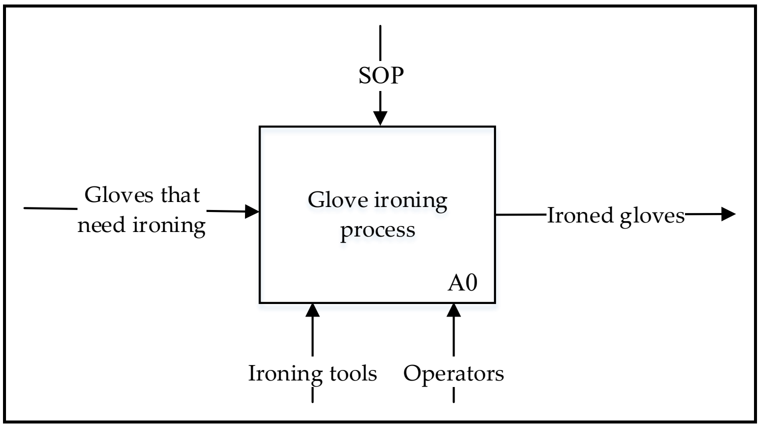
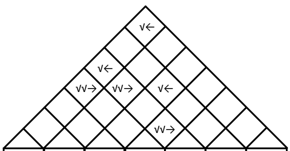



**Fig. 2.** IDEF A-0 diagram

The product design process utilized Quality Function Deployment (QFD) to ensure alignment between customer needs and technical specifications. In the product planning stage, customer feedback was collected through detailed questionnaires to identify key product attributes. These attributes, combined with technical responses, were analyzed to establish priorities using the House of Quality (HOQ) matrix. The HOQ visually represents the relationship between product attributes and technical responses, enabling designers to prioritize features effectively. The matrix, as illustrated in Figure 3, serves as the foundation for subsequent design decisions (Hwangbo et al., 2020; Moran et al., 2021).

Following the HOQ analysis, the design deployment stage focused on translating prioritized technical responses into machine specifications. The resulting design specifications guided the development of the ironing plate heating machine, ensuring it met identified customer needs and technical requirements. Figures 4 through 6 showcase the detailed designs, including the overall machine, the upper frame, and the under frame, demonstrating the integration of technical responses into practical design elements. This systematic approach ensured the machine design addressed both functional and customer-centric goals.




| Product attributes | The machine has a thermostat | Machine size 40 x 30 cm | The machine is easy to open and close and has a handle | The machine has stable and long-lasting heat | There are 2 heating elements | The distance between the top and bottom sides of the heater can be adjusted. | The machine uses electricity to power it. | IC | CSP | Goal | IR | SP | RW | NRW | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technical response | | | | | | | | | | | | | | |
| The heater size is larger than the existing iron so it can heat more than 2 plates. | | ◎ | | | O | | | 4,71 | 1,71 | 4,86 | 2,842 | 1,5 | 20,06 | 0,16 | 1 |
| Machine size is less than 100 cm x 70 cm or smaller than the size of the work table | | ◎ | | | | | | 4,71 | 3,43 | 4,57 | 1,33 | 1,2 | 7,517 | 0,06 | 7 |
| There is a temperature indicator and the temperature can be set by the operator himself | ◎ | | | | | | | 4,71 | 2,43 | 4,71 | 1,94 | 1,5 | 13,706 | 0,11 | 3 |
| The machine is easy to use and learn | | | Δ | | Δ | O | Δ | 4,71 | 3,71 | 4,71 | 1,27 | 1,5 | 8,973 | 0,07 | 6 |
| The machine must pay attention to the health and safety of the operator and be easy to clean. | O | | ◎ | | | | | 4,71 | 3,43 | 4,71 | 1,37 | 1,5 | 9,679 | 0,08 | 5 |
| The machine is started using electricity | | | | | | | ◎ | 4,71 | 3,43 | 4,71 | 1,37 | 1,2 | 7,743 | 0,06 | 7 |
| The plate is easy to remove after the heating process. | | | | | | ◎ | | 4,86 | 4 | 4,71 | 1,18 | 1,5 | 8,602 | 0,07 | 6 |
| The process of taking the smooth gloves is the same as using the previous machine. | | | | | | | | 4,86 | 3,86 | 4,86 | 1,26 | 1,5 | 9,185 | 0,07 | 6 |
| The machine heats the ironing plate faster than using the previous machine. | | | | O | O | | | 4,71 | 2 | 4,86 | 2,43 | 1,5 | 17,168 | 0,13 | 2 |
| The heat produced by the engine does not change easily so the heating time does not vary much. | O | | | ◎ | Δ | | | 4,71 | 2,57 | 4,86 | 1,89 | 1,5 | 13,353 | 0,1 | 4 |
| Machines make the ironing process better | O | O | | O | ◎ | | | 4,71 | 2,57 | 4,71 | 1,83 | 1,5 | 12,929 | 0,1 | 4 |
| *Contribution* | 1,83 | 2,28 | 0,79 | 1,2 | 1,55 | 0,86 | 0,61 | | | | | | | | |
| *Normalized contribution* | 0,20 | 0,25 | 0,08 | 0,13 | 0,17 | 0,09 | 0,07 | | | | | | | | |
| Priority | 2 | 1 | 6 | 4 | 3 | 5 | 7 | | | | | | | | |

**Fig. 3.** House of Quality (HOQ)

*3.2.1. Design Deployment (Part Deployment)*

Based on the HOQ matrix that has been created, the desired machine specifications are obtained. After obtaining the desired specifications, the next step is to determine the design for the machine being designed. The design that is designed must be able to realize the technical response obtained. The design can be seen in Figure 4.

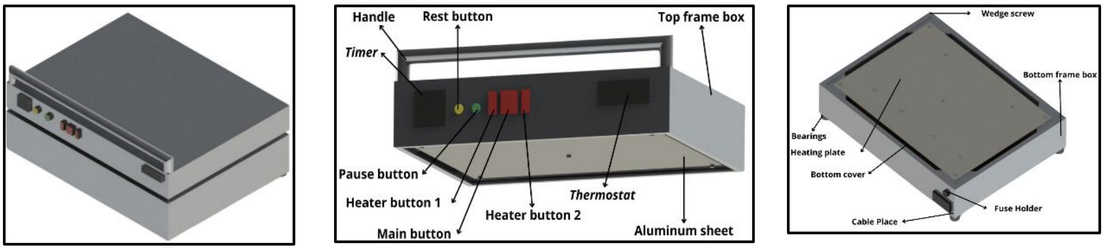



**Fig. 4.** Design and Component Details of the Ironing Plate Heating Machine: Overview, Upper Frame, and Under Frame

The manufacturing process for the designed ironing plate heating machine consists of several steps to ensure optimal performance. First, the machine's height is adjusted to create an appropriate gap between the upper and lower frames using a screwdriver to adjust the screws. Next, the machine is powered on by sequentially pressing the main button, heater button 1, and heater button 2, followed by setting the thermostat to a temperature range of 70–80°C. The machine's operational cycle is programmed to run for 4 hours with a 30-minute rest period using the built-in timer.

Once the machine is heated, the ironing plates are prepared. The heating process accommodates multiple plates, prioritizing the 4-finger plates, which require longer heating times, alongside a thumb plate. Finally, the gloves are ironed, beginning with the thumb section using the thumb plate. After completing the thumb section, the process alternates between reheating the thumb plate and ironing the 4-finger section using the designated plate, ensuring efficiency and precision in the ironing process.

The redesigned machine was tested against the conventional machines to evaluate its performance in terms of process time, productivity, and safety.

1. Process Time Improvement The new machine demonstrated a significant reduction in process time. On average, it required only 36.14 seconds to iron one glove, compared to 47.68 seconds for the conventional machine. This represents a time efficiency improvement of approximately 24.19%, as shown in Figure 5.

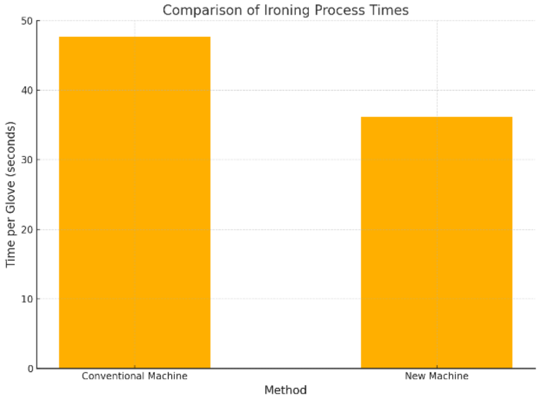



**Fig. 5.** Comparison of Ironing Process Times

2. Increased Productivity Productivity testing over a four-hour operation period revealed that the new machine could process 350 gloves, compared to 300 gloves processed by the conventional machine. This represents a 16.67% increase in productivity, as summarized in Table 2.

**Table 2.** Productivity Comparison

| Machine Type | Gloves Produced (4 Hours) |
|---|---|
| Conventional ironing machine | 300 |
| New Ironing Plate Machine | 350 |

3. Safety and Operator Comfort The redesigned machine incorporates several safety features, including thermal insulation to prevent accidental burns and a built-in fuse to mitigate electrical hazards. These features, combined with the ergonomic design, contribute to a safer and more comfortable working environment for operators.

## Discussion

The analysis using the IDEF0 method identified that the accumulation of gloves in the ironing department resulted from limited ironing capacity, leading to the design of an ironing plate heating machine. This machine aims to reduce ironing time and increase productivity. Through the QFD method, customer needs—represented by operator feedback—were analyzed, resulting in 11 product attributes and 7 technical responses. Key features include a larger heating surface for accommodating multiple plates, adjustable temperature controls, compact dimensions (40 × 30 cm), and enhanced safety measures, such as stainless steel frames and PTFE-coated handles to prevent heat and electrical hazards. A fuse was also incorporated to ensure safety in case of electrical short circuits.

Testing demonstrated that the ironing plate heating machine met company SOPs, significantly improved efficiency, and reduced defects. While conventional machines required re-ironing for 75 gloves during a 4-hour test, the new machine produced defect-free gloves. Additionally, the ironing process time dropped from 47.68 seconds with conventional machines to 36.14 seconds, resulting in increased productivity. Over 4 hours, the new machine produced 350 gloves compared to 300 gloves with the conventional machine. This improvement enabled the ironing department to exceed daily requirements, ironing 4,900 gloves versus the 4,200 achieved with conventional machines, effectively addressing the issue of glove accumulation.

However, the design has limitations, particularly the proximity of plastic components to heating elements, which restricts the maximum temperature settings to prevent melting. A proposed solution is relocating plastic components to a separate section of the machine to enhance durability. Future iterations could refine these aspects and explore scalability for larger operations or adaptability to other products, ensuring sustained productivity and efficiency improvements.

## Conclusion

Based on research on the design of an ironing plate heating machine to increase productivity, a machine measuring 30 cm × 40 cm was obtained which has a thermostat, timer, and 2 heating elements. Gloves produced from the ironing plate heating machine have a quality that meets company standards. The ironing plate heating machine can increase productivity where previously the use of a conventional ironing machine could produce 300 pcs in 4 hours. The use of an ironing plate heating machine can produce 350 pcs of gloves in 4 working hours. The standard time for ironing gloves using a conventional ironing machine is 47.68 seconds while the standard time on the ironing plate heating machine is 36.14 seconds.

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