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Jurnal Asiimetrik: Jurnal Ilmiah Rekayasa dan Inovasi is published regularly every **two times a year**, in **January** and **July**. This journal publishes research-based scientific articles, case studies, review articles, engineering and innovations that cover both theoretical and practical as well as their development. The topics of scientific articles published cover the fields of Architecture, Civil Engineering, Industrial Engineering, Informatics Engineering, Mechanical Engineering and Electrical Engineering.

SUMMARY. Inspired by a past design, **Santoso et al.,** were building a jaw gripper hoping to improve its efficiency by using less filament without compromising the quality of the gripper. To increase output, **Ichsan et al.**, developed an industry-wide automated system. One instrument for production simulation is the modular production system (MPS). **Setiawan et al.**, have created a vacuum gripper especially meant to handle workpieces, like labeling applications in the automation sector. The air barrier increased as **Fikri et al.**, optimized the body of the goods vehicle using CFD simulation. **Napoleon et al.**, optimized the top cover feed unit's design at the pick and place station since, upon a change in position at the time the vacuum sucks the top of the cover causes dislocation. **Allo et al**., investigated the efficiency of a hybrid drier, closely examining the material the machine dries as well as its features. With application in small-scale businesses for household appliances and fences, **Siswanto et al.** refined the TIG welding process utilizing 304 stainless steel material (SUS 304). **Dwinandana et al.** meanwhile created the ergonomic notion of a nurse-assisting robot. Using a strong and qualitative approach to ascertain the daily minimum water needs per person; **Rahman** investigated the possible needs and resources of the City of Denpasar. **Leonard et al.** worked on proposals for a child-friendly blue open playground in the seaside region of the Old Rampa Village with Bajau ethnic character while **Wijaya et al.** investigated the natural frequencies and patterns of 17-inch aluminum alloy plugs as well as the largest deformation that might occur with ANSYS software applied for simulation. **Numberi et al.** investigated the possible wind energy produced by best savonius wind turbine design. By changing the spacing between the blades and turbine beams, they conducted power tests and investigated the most ideal power for application in the coastal town of Sarmi, Papua Province. They also looked at the phenomena of heat transfer by natural convection from hot stone to food in consumer packaging. Using 6061

aluminum and ASTM B187 copper in friction welding, **Habibi et al.** carried studies aiming at estimating the strength of welding contacts. Using dandori issues, **Wibowo at al.** conducted research aiming at lowering line pauses in plastic injection operations by thirty percent. **Ridwan et al.** optimised the dehumidified air flow distribution on tray-type thermocouple dryers using CFD software. Early research on wind turbines, particularly on the efficiency of vertical axis and horizontal axis wind turbines VAWT and HAWT respectively, **Herlina et al.** The work by **Oktavian et al.** sought to ascertain the heat transfer coefficients for convection and evaporation, how the temperature of the cooling water in the condenser influences the evaporating process, and what results when the freshwater condensate level rises in a seawater desalination system. **Shafitri and Syarif** investigated developing long-range low-voltage electrical circuit breaker systems in IoT-based flood zones. Using MATLAB and microcontrollers, **Uden et al.** developed artificial neural network (ANN) testing strategies to identify voltage and current imbalances in three-phase induction engines.

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Line Stop Time Reduction Through Dandori Evaluation in Plastic Injection Process Production

Pengurangan Waktu Line Stop Melalui Evaluasi Dandori dalam Proses Injeksi Plastik

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Abstract

A quality product is a product that is efficiently produced. Line stops should be minimized to ensure efficient production. This study found a high line stop in the area of plastic injection machines caused by dandori. The line stops account for about 6% of the total production time 5.3% of them caused by dandori. Dandori is a line stop due to tools changing within a production process. This study aims to reduce the line stop by 30% and uses a fishbone analysis enhanced by the 5W+1H method for further analysis to reduce this problem. Enhancing the fishbone diagram with 5W+1H analysis produces a positive result. As a written calculation, this improvement gives a 28% line stop reduction, but it provides an average of 32.5% in actual operation. The improvement succeeded in reducing line stops due to dandori. The final achievement of 32% has passed the target of a 30% reduction and also provides an excellent cost-benefit ratio value of 20.9.

Keywords: line stop, Dandori, 5W+1H analysis, work element.

***SDGs*:**

Abstrak

Produk yang berkualitas adalah produk yang diproduksi secara efisien. Line stop harus diminimalkan untuk memastikan produksi yang efisien. Dalam penelitian ini, line stop yang tinggi yang disebabkan oleh dandori ditemukan di area mesin plastik injeksi. Kontribusi line stop sekitar 6% dari total waktu produksi dimana 5,3% di antaranya disebabkan oleh dandori. Dandori adalah line stop karena pergantian alat dalam proses produksi. Penelitian ini bertujuan untuk mengurangi line stop karena dandori sebesar 30%. Dalam studi ini digunakan analisis fishbone diagram yang diperdalam dengan 5W+1H untuk analisis lebih lanjut guna menurunkan masalah ini. Penyempurnaan fishbone analisi dengan analisis 5W+1H memberikan hasil yang positif. Dalam perhitungan tertulis, perbaikan ini memberikan pengurangan line stop sebesar 28%, tetapi secara aktual memberikan rata-rata 32,5%. Perbaikan tersebut berhasil mengurangi line stop akibat dandori. Capaian akhir sebesar 32% telah melewati target perbaikan sebesar 30% dan juga memberikan keuntungan dengan nilai cost benefit rasio sebesar 20.9.

Kata Kunci: line stop, dandori, analisis 5W+1H, elemen kerja.

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1. INTRODUCTION

A product's technical specifications are inherent as product attributes (Mullick, 2023; Pacana and Siwiec, 2024). Technical specifications reflect the voice of the customer, which manufacturers need to address (Kurnia and Listanti, 2019). Product technical specifications are an intersection between the voice of consumers and the ability of producers to meet consumer needs (Bilgili and Özkul, 2019). In the past, consumers had the perception that all products from the factory must be of high quality. Therefore, the emerging consumer voice is the need to have products with a long lifespan (Oliveira *et al.*, 2021). However, consumer perception has now changed. Along with the development of population and technology, the perception of quality products shifts to products that have a long service life, have good performance, have an attractive appearance, the products are easy to obtain, have after-sales service, have a variety of products, efficiently produced (Wójcicki, 2017; Denkena *et al.*, 2020), made in a relatively short time (Sarkar, Omair and Choi, 2018), consumes low energy (Zhao *et al.*, 2018), and has good surface quality (Yin *et al.*, 2019) so that it has a competitive price and low carbon emissions (Xing *et al.*, 2021).

The time aspect, which represents the delivery factor, is one of three significant factors that shape the value of a product, known as quality, cost, and delivery (Kurnia and Sugiyanto, 2021). This concept is then derived as a company objective defined as increasing machine productivity, reducing reject rates, improving work safety, increasing the efficiency of the production process (Ajitomo, 2019), survival, benefits, and income (Voronkova, Punchenko and Azhazha, 2020).

The production process consists of many stages and processes, each with a time standard. Considering the significance of the time function in the company's sustainability, many activities are carried out to improve the efficiency of process time. One of the efforts made is to minimize line stops. Line stop is a condition that causes the production process to stop. The more line stops occur, the longer it takes to complete one product, resulting in low production efficiency (Ajitomo, 2019).

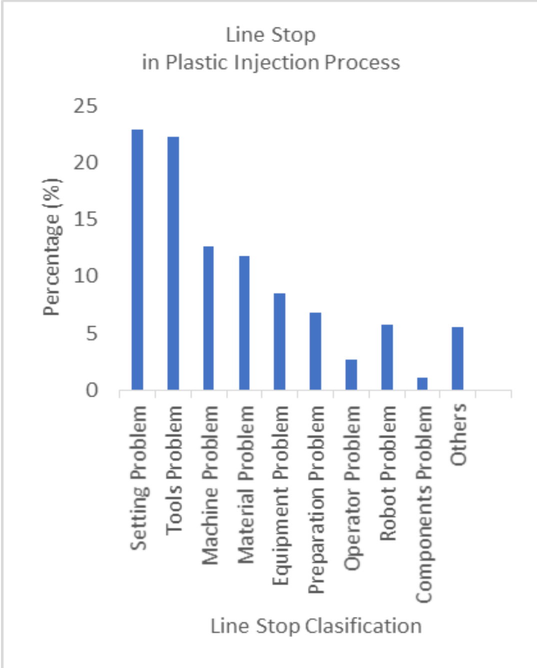

Figure 1. Line stops in plastic injection process.

Line stops are caused by various reasons or activities such as setting processes, problems with tools, problems with machines, problems with materials, problems with robots, problems with operators, or other things. Dandori is a Japanese term for the process of changing tools within the production process. In a broader meaning, dandori can be preparation activities before main production activities. Due to it happening before the main production activities, dandori generates a line stop. Therefore, dandori falls under the category of line stop in general and other things in particular. Based on the primary data in the plastic injection process, other types of line stops contribute to 6% of the total line stop time, as described in Figure 1. Although it is a small percentage, 6% of line stop is equivalent to 43 working hours or 1 week's worth of working hours.

The line stops in the other group consist of 4 types: quality control, power failure, movement, and dandori. Figure 2, derived from plastic injection process data, explains the details of the Pareto diagram for line stops in the other group. In the line stop others group, dandori occupies a high percentage of 89%. 89% of dandori time is equivalent to 38 working hours.

In Pareto's theory, disturbances with a large percentage are the most important and urgent things that need to be resolved immediately. Figure 2 explains, from a Pareto point of view, that the position of the line stops due to dandori.

In previous studies, the cause of the line stops should be systematically tracked so that it does not happen again, and special attention should be given to stopping it. Thus, productivity will be regained. This reinforces the need for special attention to dandori (Chairudin, Ginting and Fajri, 2020).

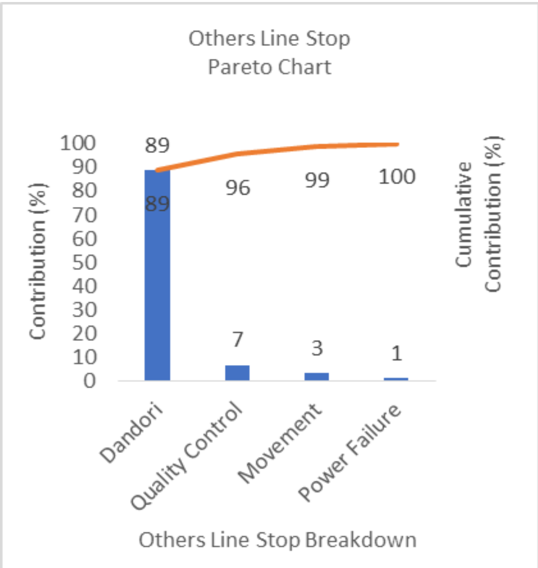

Figure 2. Line stop contribution.

Although line stops in general and dandori, in particular, have been explored by many previous researchers (Inayah, Wahyudin and Herwanto, 2023), dandori specifically in the plastic injection molding area by using the work element observation approach, utilizing automation with microcontrollers, and robots by utilizing the 5W+1H analysis method is still a research challenge. This unique study introduces the case of dandori time that is reduced using working analysis in multiple aspects. This research aims to apply the analysis method combined with the utilization of technology to reduce the number of line stops above 30%. This research includes standardized time observations (Sari and Darmawan, 2020), work elements, analysis using the fishbone diagram, further analysis using the 5W+1H method, and followed countermeasure activities.

2. METHODOLOGY

This study case takes dandori time as an object of research. This dandori time takes place on plastic injection machine A08, especially when the injection mold replacement process is carried out. While the injection mold replacement is carried out, some other activities are also performed, such as preparation, changing the locating ring, installing the clamping shoes, picking up the robot jig storage, and draining the cooling.

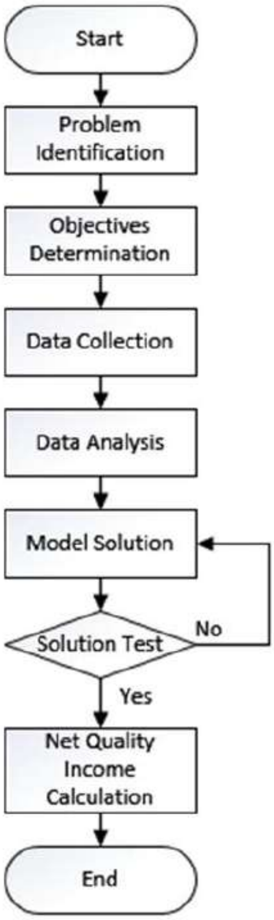

Figure 3. Research flow process.

In this study, the process of reducing line stop time due to dandori is carried out by following the research stages as described in Figure 3, with the following description:

1) The first stage is problem identification. The problem found was the high line stop time of 6%, of which 89% was caused by dandori.
2) The next stage is objectives determination, which is to reduce the line stop due to dandori by 30%.
3) The next stage is data collection where data related to dandori that occurs in the plastic injection process include dandori duration data, dandori frequency data, and machines that experience dandori.
4) In the next stage, the collected data was analyzed. The analysis is done by evaluating the dandori work elements and analyzing the cause of the problem using the fishbone diagram.
5) Next, using the 5W+1H approach, further analysis is carried out to develop a proposed solution model.
6) The next stage is the solution test where the proposed solution model is tested, and its impact is seen. The solution test lasts four weeks. The solution will be approved if the result achieves a duration reduction of at least 30%.
7) The calculation of net quality income is an attempt to see the quantitative impact of the proposed solution model in currency units. In another place, NQI is known as a potential benefit. The formula of the net quality income is:

$$NQI = TAP - CI \qquad (1)$$

where TAP is Total Annual Profit and CI is Cost of Improvement.
8) Finally, the study activity to reduce the line stop time due to dandori was completed. Conclusions and implications based on the analysis and testing are presented at the end of this study.

In addition to observing in currency, this study also provides the benefit-cost ratio to show how feasible the proposed solution is in a macro view. The formula of the benefit-cost rasio is:

$$BCR = {}^{Benefit}/_{Cost} \qquad (2)$$

where BCR > 1, the solution is feasible, otherwise not feasible.

3. RESULTS AND DISCUSSION

The analysis was carried out using the fishbone diagram and 5W+1W approach, starting with a study of the dandori process flow and dandori work elements.

3.3. Work Elements Dandori Duration Data

Table 1 describes the work elements of dandori that will be reduced in duration. This table contains the activities, and the duration required in minutes.

Table 1 shows that the duration for one dandori is 46.5 minutes. Dandori is divided into 5 groups: dandori preparation, take out mold 8.7 minutes, pick up mold 20 minutes, pick and set robot 2.8 minutes, and trial setting 15 minutes.

Table 1. Dandori work elements.

No	Activities	Duration (min)
1	Dandori Preparation	
	Pick up Mold	Offline
	Prepare Tools	Offline
2	Take out Mold	
	Unplug Limit Switch	0.5
	Drain Cooling	3.4
	Unplug the hose	0.5
	Unclamp	2.5
	Put Down Mold	1.8
3	Pick up Mold	
	Assy Locating Ring	7
	Pick up Mold	4
	Centering	1.2
	Thickness	2.1
	Clamp	4.6
	Plug Limit Switch	0.3
	Assy Hot Runner	0.3
	Plug hose	0.5
4	Pick and Set Robot	2.8
5	Trial Setting	15
	Duration Total	46.5

3.2. Data Analysis

Based on the line stop data in Figure 1, it is known that the line stops others group has a percentage of 6% which, if converted in hours, is equivalent to 40 working hours or 5 working days. Based on the Pareto data in Figure 2, it is known that the line stops others group is dominated by dandori at 89%. Based on the Pareto principle, line stop dandori will be a priority problem that needs to be resolved immediately.

Within each activity group in Table 1, there are activities with longer durations such as drain cooling, installing locating rings, and installing clamps. The total duration required for these three activities is 15 minutes. This figure is equivalent to 32% of the total dandori time. This dominance will be a concern in the work element evaluation process.

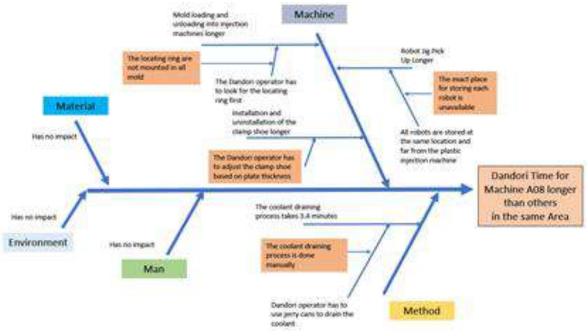

Figure 4. Dandori analysis fishbone diagram.

Based on this description, an analysis was conducted to identify the causes of line stops. The analysis conducted in this study uses a fishbone diagram approach with 4M + 1E factors, namely man, machine, method, material, and environment as shown in Figure 4. Every factor represents an aspect of that matter and its relatedness. In the case of the machine factor, investigation will probe the root cause of the problem on the machine and its relatedness. The question of why this happens from the machine's point of view escalated until no more questions could be created. Repeat this question for every factor. In most cases, this escalation of questions will reach the dead point on the fifth question.

This study focuses on machine and method factors because this project is part of engineering department activities even though man-machine optimization is the most cost-effective activity (Ghosh, 2024).

Based on the fishbone analysis of the method factor, 1 root cause was generated. The coolant draining process, which is done manually, is considered a root cause of the longer dandori time for machine A08. Three root causes were generated for the machine factor. They are considered the root cause of the longer dandori time for machine A08 on the machine factor.

3.3. Model Solution

Based on the analysis conducted on the work elements data in Table 1 and the factors in the fishbone diagram in Figure 4, several factors can be found that cause the appearance of old dandori. These factors are in the machine and method factors.

The machine factor is that not all molds have been fitted with locating rings, the condition of the clamp shoe varies resulting in each new mold installation requiring clamping adjustment, and there is no place for a robot jig for each machine. The unavailability of robots resulted in long robot retrieval. The long dandori occurs in the drain cooling activity in the method factor because the draining process is still done manually.

The analysis was carried out using the fishbone diagram and 4M+1E approach, followed by analysis using the 5W+1H approach to get the final solution. The details of each solution are subjected to the 5W+1H method for each root cause found.

Table 2. 5W+1H answers for locating ring.

No	Question	Answer
1	What	The operators must look for the locating ring first
2	When	Within 2 months
3	Where	Plastic Injection Machine
4	Who	A Team (2 man power from Engineering Department)
5	Why	Locating rings are used interchangeably
6	How	Make a mold without the locating ring.

3.3.1. Solution for Locating Ring

The root causes found in the fishbone diagram are further analyzed using the 5W+1H method to get a suitable solution. This advanced analysis will lead to the right solution. The solution to the locating ring problem is described in Table 2. The locating ring problem led to the solution of making the mold without using the locating ring.

3.3.2. Solution for Clamping Shoe

The solutions that emerged for the various root causes of the clamping shoe problem are described in Table 3. The clamping shoe problem led to the solution of modifying the clamping system by adding a spring to shorten the adjustment time.

Table 3. 5W+1H answers for clamping system.

No	Question	Answer
1	What	Installing and uninstalling the clamping system takes time
2	When	Within 1 month
3	Where	Plastic Injection Machine
4	Who	A Team (2 manpower from Engineering Department)
5	Why	The operator must adjust the clamp shoe for every mold
6	How	Modify the clamp shoe by adding the spring to shorten the adjustment time

3.3.3. Solution for Robot Jig Storage

Table 4 describes the solutions found to address the root cause of the robot jig storage problem.

Table 4. 5W+1H answers for robot jig storage.

No	Question	Answer
1	What	Pick up and install robot takes time
2	When	Within 1 month
3	Where	Plastic Injection Machine
4	Who	A Team (2 manpower from Engineering Department)
5	Why	There is no storage for robot jigs in the plastic injection machine area
6	How	Make dedicated storage for robot jigs in the plastic injection machine area

3.3.4. Solution for Cooling Drain

Table 5 describes the proposed solution to address the root cause of the old drain cooling problem.

3.4. Solution Testing

Testing is carried out on solutions implemented in the plastic injection machine area. Testing was carried out for 4 weeks where the average duration of dandori was calculated each week. The test duration was determined for 4 weeks to see the trend of the improvement results and the consistency of the improvement results.

Detailed test results are shown in Figure 5 and Table 6. Table 6 clearly shows a difference of 13.1 minutes or 28%. In Figure 5, in the 4-week test, the average dandori duration obtained was 31.4 minutes or an improvement of 32.5%.

Table 5. 5W+1H answers for drain cooling.

No	Question	Answer
1	What	The cooling drain takes 3.4 minutes
2	When	Within 1 month
3	Where	Plastic Injection Machine
4	Who	A Team (2 manpower from Engineering Department)
5	Why	The cooling drain process is done manually
6	How	Create an automatic cooling drain system

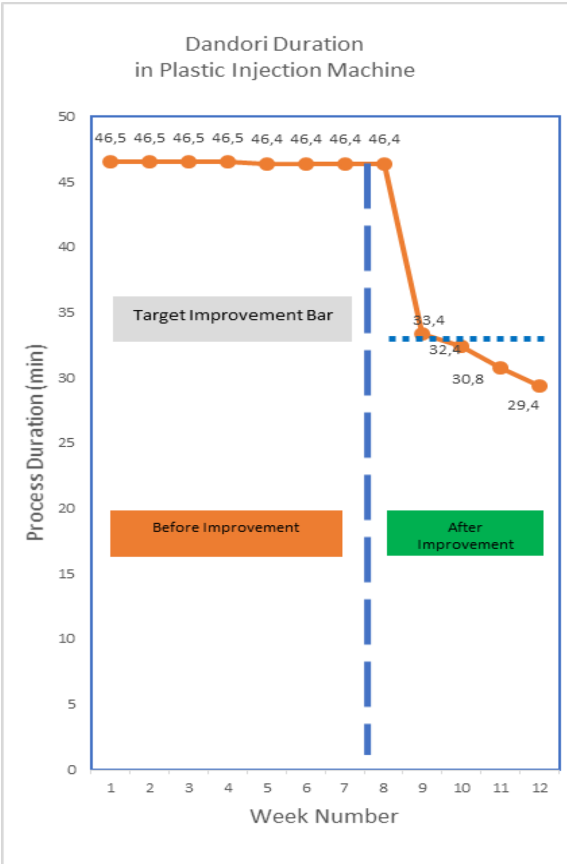

Figure 5. Dandori duration improvement.

Table 6. Dandori duration work elements.

No	Activities	Duration (min)	
		Before	After
1	Dandori Preparation	-	-
2	Take out Mold	8.7	5
3	Pick up Mold	20	11.5
4	Pick and Set Robot	2.8	1.9
5	Trial Setting	15	15
	Duration Total	46.5	33.4

3.5. Net Quality Income Calculation

The industrial world is profit oriented. Because of this, improvement numbers are often not strong enough to serve as evidence until they can be converted into a currency value. Because project implementation is a function of time, and improvements have not been implemented for a long time, a formulation is needed to account for the conversion of the currency value equivalent to these gains. This is known as net quality income.

From the results of multiplying the saving value of the dandori duration of 15 minutes with a frequency of occurrence of 20 dandori per month, and the cycle time per product is 1 minute, a savings of Rp. 108,000,000/year is obtained. After deducting the cost of improvement, the net quality income obtained is Rp. 102,826,000.

Apart from obtaining NQI, which represents the potential benefits of the proposed solution, the managerial level also requires information about how feasible the proposed solution is. The benefit-cost ratio value can provide information at the managerial level as a decision maker and the potential sustainability of this solution. The greater the value of the benefit-cost ratio, the more feasible the solution is. Based on calculations, a benefit-cost ratio of 20.9 is obtained, which means this solution is feasible and has positive and convincing sustainability potential.

3.6. Discussion

Based on the dandori work element evaluation, there are 5 groups of dandori. The time-consuming groups are taking out mold, picking up mold, and trial setting. In accordance with Pareto theory, these are the first should be solved (Inayah, Wahyudin and Herwanto, 2023). The fishbone analysis highlights method and machine as two main factors. Considering these two matters, the proposed model solution is the locating ring component which is part of the machine factor; the clamp shoe component, which is part of the machine factor, provides a place for the jig robot, which is part of the machine factor, and the coolant draining which is part of method factor. This follows previous research that man machine is the most cost-effective optimization (Ghosh, 2024).

The initial implementation activities found that the proposed solution generates a time reduction of 13.1 minutes or 28% which is close to the target of 30%. During 4 weeks of improvement trial, the average dandori reduction generates an average dandori time of 31.4 minutes. It is equivalent to 32.5%. This confirms the literature study that dandori evaluation can be done using work element analysis (Sari and Darmawan, 2020). Utilizing a multi-aspect-based approach increases the efficiency of the production process (Sarkar, Omair and Choi, 2018).

4. CONCLUSION

This study shows that the line stop due to dandori on the plastic injection machine can be solved using a fishbone diagram approach enriched with 5W+1H analysis. The root cause of the problem related to the availability of locating rings is solved by designing a mold without locating rings. The clamping shoe variation problem was solved by adding springs, the robot jig storage problem was solved by setting up dedicated storage, and the cooling drain system problem was solved by automating the cooling drain system. With these solutions, the target of reducing line stop time due to dandori by 30% was passed with a final achievement of 32%. The improvements also provided a net quality income of Rp. 102,000,000 per year. Considering the cost-benefit ratio which is 20.9, the solution model is very feasible to be implemented in other machine areas.

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Dengan hormat,

Yang bertanda tangan di bawah ini, menerangkan bahwa:

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adalah dosen-dosen yang sedang melakukan pembuatan penelitian bersama di lingkungan Program Studi Mesin Otomotif dan Pembuatan Peralatan dan Perkakas Produksi Politeknik Astra dengan judul:

"Line Stop Time Reduction through Dandori Evaluation in Plastic Injection Process Production (Pengurangan waktu line stop melalui Evaluasi Dandori dalam Proses Injeksi Plastik)"

yang diterbitkan di: "JURNAL ASIIMETRIK: JURNAL ILMIAH REKAYASA DAN INOVASI".

Surat keterangan ini dibuat untuk keperluan administrasi laporan kinerja dosen di lingkungan Kopertis III.

Demikian surat ini dibuat dengan sebenar-benarnya agar dapat digunakan sebagaimana mestinya.

Jakarta, 28 Juni 2024
Hormat kami,

Ir. Budi Wahyu Utomo, M.T.
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Mohon Bapak/Ibu/Saudara/i dapat melihat naskah yang terbit pada bulan **Juli 2024** di *website* Jurnal Asiimetrik: Jurnal Ilmiah Rekayasa Dan Inovasi dengan alamat: http://journal.univpancasila.ac.id/index.php/asiimetrik/issue/archive.

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