Optimisation of the Partial Runner Setup Process in Plastic Injection Moulds Using Eight Steps in the Motorcycle Industry

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ABSTRACT

Purpose: This study aims to analyse the causes of partial setup work that is not optimal and provide solutions to the sub-optimal setup work on family-type moulds in type A.

Methodology/Approach: This study uses an 8-Step improvement approach combined with several methods, including Focus Group Discussion (FGD), Quality Cost Delivery Safety Moral (QCDSM), and Specific Measurable Achievable Relevant Timebase (SMART) method.

Findings: This study found the cause of the partial setup work being less than optimal due to problems with the Man, Method, and Machine factors. The results of this study show that the setup time decreased from 240 minutes to 73.4 minutes or 68%. Meanwhile, the process cost for the partial setup itself decreased from $75 to $3 or decreased by 97%.

Research Limitation/implication: This research has limitations in the partial setup process, which is less than optimal in plastic injection family-type moulds in the Motorcycle Industry.

Originality/Value of paper: This research has value in optimising the production of plastic injection family-type moulds by reducing setup time and operational costs for making spare parts in the Motorcycle Industry.

Category: Case study

Keywords: plastic injection; motorcycle industry; optimisation; partial runner; set-up process

Research Areas: Manufacturing Process

1 INTRODUCTION

The automotive industry in Indonesia experienced a 65% decline in sales during the COVID-19 pandemic (Arman, Rahman and Deowan, 2022). Currently, many automotive companies are starting to bounce back from their downturn, as evidenced by a large number of market demands, including the automotive industry for two-wheeled vehicles (Filho and Simão, 2022). Several companies engaged in the Indonesian motorcycle industry sector are making continuous improvements in reducing waste (Siregar, Ariani and Tambunan, 2019; Kosasih, Doaly and Shabara, 2020; Setiawan *et al.*, 2021). Intense competition in the motorcycle industry forces each company to make continuous improvements to reduce operational time and costs in making spare parts (Setiawan *et al.*, 2022; Jaqin *et al.*, 2023).

The plastic injection method is a method of processing thermoplastic materials in which the plunger injects the material that melts due to heating into a cooled mould, and then the material cools and hardens so that it can be removed from the mould (Lo *et al.*, 2022). The component in injection moulding that plays a very important role in the formation of product parts is the mould (Bere, Neamtu and Udroiu, 2020). In the process of making a motorcycle plastic body using a mould component that functions as a mould in the mould-forming process, the mould components will adapt to the needs of the product to be printed (Khan and Mushtaq, 2022). There are several types of prints, one of which is the family print. This mould is designed to print two or more parts with different shapes or dimensions in one mould (Zhao *et al.*, 2022).

The process of making a motorcycle plastic body consists of two parts, namely the normal process and the partial process (Yani *et al.*, 2022). The material for motorcycle plastic bodies is called Acrylonitrile Butadiene Styrene (ABS) plastic, a type of copolymer composed of several forming monomers that are heat stable, chemical resistant, and have high strength (Wibowo *et al.*, 2023). This research only discusses the manufacture of motorcycle plastic bodies in partial processes, meaning that there are special requests from some customers, especially customers from abroad (Mawardi, Jannifar and Lubis, 2019; Kale, Darade and Sahu, 2021). In the partial process with production requests every year for the production of plastic motorcycle bodies, there is a special demand for export production in certain quantities and types, which has an impact on part stocks becoming unbalanced (Sundararajan and Terkar, 2022). Details of the varying amounts of stock in type A can be seen in Figure 1.

Figure 1, it is clear that there is a stock of various types of motorcycle body spare parts, but there is no balance in stock, resulting in the manufacture of additional type A products to fulfil orders. During the process of modifying the mould setup with a partial family type, it was found that several repetitive jobs would lead to a waste of time and modification costs and the potential to cause rejected parts during production (Martowibowo and Khloeun, 2019). Therefore, corrective action is needed on the type A mould family components that can help with partial setup so that setup time can be optimal and reduce operational costs. Based on initial observations, it was found that the setup time was not optimal, so it needed to be increased to the optimal or maximum amount of product output that could be produced by a production facility by achieving the best capacity. (Rahmawati, Puryani and Nursubiyantoro, 2019).

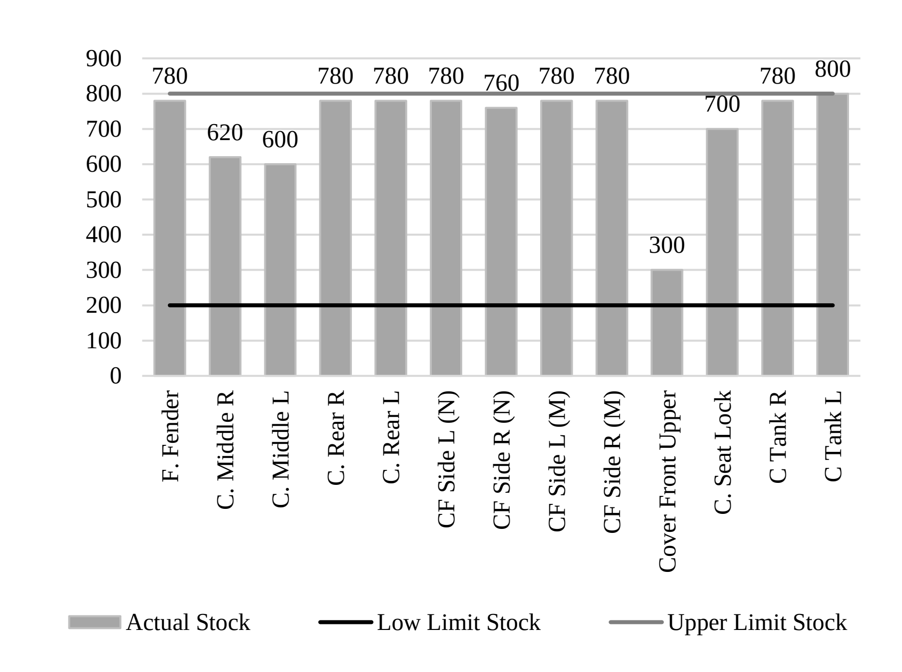

Figure 1 – Type A Stock Material Variation

Based on previous research, the 8-Step approach is used to increase productivity in the distribution of goods in the automotive manufacturing industry (Darmawan, Hasibuan and Hardi Purba, 2018). This approach has a good impact on company optimisation with Kaizen, namely continuous improvement. The impact can optimise company resources (Sousa Silva *et al.*, 2019; Sundararajan and Terkar, 2022). The new approach of this research on the motorcycle plastic body parts industry uses the 8-Step improvement method combined with improvement tools (Kaizen) as an improvement concept so that structured and conceptual improvement steps occur. This study aims to analyse the cause of the partial setup work that is not optimal for moulds with family type in type A and provide a solution for improvement.

2 METHODOLOGY

This research method uses the 8-Step method, including determining themes, setting targets, analysing conditions, analysing problems, planning countermeasures, and evaluating results and conclusions (Suratno and Ichtiarto, 2021). This study uses the primary data needed, among others, partial mould setup time data, field observation data, and interview data. The secondary data used in this study are stock data on type A and monthly production documents.

This research was conducted in the motorcycle industry, which produces several motorcycle variants. This industry is one of the motorcycle companies with the highest sales in Indonesia. The scope of this research focuses on one of the divisions in the company, namely mould maintenance, which focuses on maintenance as well as production support so that it runs optimally. This research was conducted in a motorcycle or two-wheeled vehicle industry located in Karawang, West Java. This research was conducted for six months, from Jan-Jun 2023. The research steps can be seen in Figure 2.

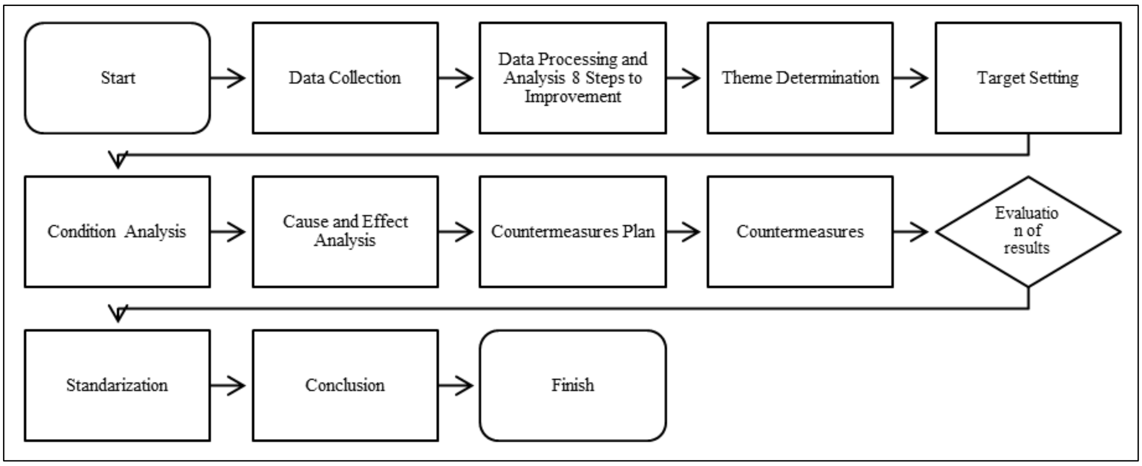

Figure 2 – Research Stages

Figure 2, some activities involve a team-type association called a Focus Group Discussion (FGD) (Sjarifudin *et al.*, 2022; Sukma *et al.*, 2022). FGD functions to formulate problems, find the best solutions to problems, and determine operational targets and budgets for improving (Zulkarnaen *et al.*, 2023). In this study, the task of the FGD was to determine the theme, determine the target, and verify the problem. The FGD team used an assessment and weighting method on the Quality-Cost-Delivery-Safety-Moral (QCDSM) variables related to problems that arose internally in the company. The QCDSM system, as an overall strategy, is used to improve business processes in many industries (Andre, Mokh and Rita, 2018). The scoring system uses a Likert measurement scale in intervals of 1-5. Likert in the interval 1-5 for the question category with answers that strongly disagree with a value of one to answers that strongly agree with a value of five. The Likert scale is a scale based on the sum of respondents' attitudes in responding to questions based on indicators of a concept or variable being measured (Jebb, Ng and Tay, 2021).

3 RESULTS AND DISCUSSION

This section discusses the findings and discussion in each section so that there is a link between theoretical analysis and research data.

3.1 Data Collection

Data collection on the plastic injection section starts from the partial setup process on the runner line. Then, the thermoplastic material is processed, and the melted material is injected by a plunger into a cooled mould. Then, the material is cooled and hardened so that it can be removed from the mould. Components in injection moulding that play a very important role in the formation of product parts are process moulds from partial setups starting with a production request for the production of only one part, which can be seen in Figure 3.

Based on Figure 3, the partial setup is carried out utilising the runner part line that will not be produced and will be closed using welding so that only one product can be printed, and when production demand is fulfilled, the runner area that was welded will be reopened by buffing and grinding processes. An example of closing the runner area can be seen in Figure 4.

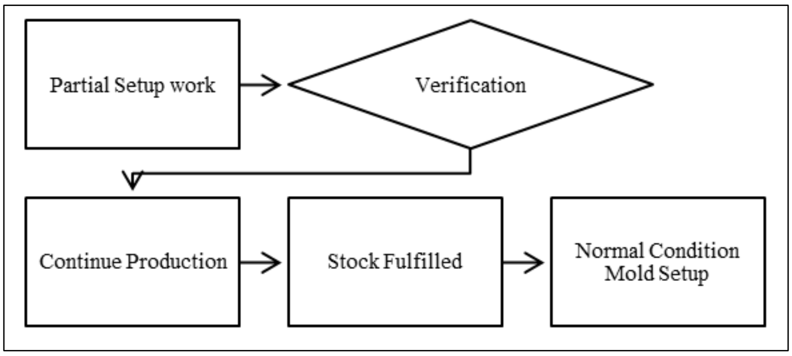

Figure 3 – Partial Setup Request Process

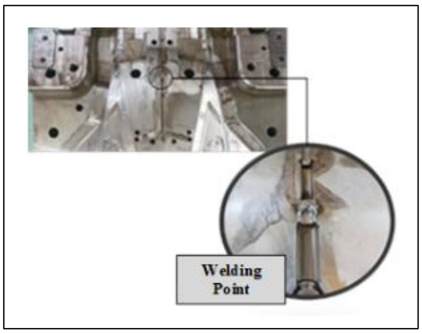

Figure 4 – Welding on the Runner Area

Based on Figure 4, the welding point on the mould component is very decisive because this point is very vital in starting up the mould on the runner line. Then, the author collects data when working on the mould, and the researcher takes three times the time measurement when doing the partial setup. The partial setup results for family-type moulds can be seen in Table 1.

Table 1 – Partial Setup Time on Family Type Moulds

No	Activities	Working Time (minutes)		
		1	2	3
1	Mould comes	0	0	0
2	Tool preparation	4	4	4
3	Mould opened	14	12	14
4	Partial setup process	94	96	100
5	Mould close	14	13	14
6	Mould stand by	0	0	0
Total		126	125	132
Averages		127.6		

Based on Table 1, the average partial setup time for family-type moulds is 127.6 minutes. The measurements were carried out three times, similar to other researchers who have done this at different research sites. Meanwhile, measuring the process time for returning the mould to normal conditions can be seen in Table 2.

Table 2 – Process Time for Returning Mould to Normal Condition

No	Activity	Time (Second)		
		1	2	3
1	Mould comes	0	0	0
2	Tool preparation	4	4	4
3	Mould opened	11	11	11
4	The process of returning the mould to normal condition	88	92	80
5	Mould Close	10	12	10
6	Mould stand by	0	0	0
Total		113	119	105
Averages		112		

Based on Table 2, the results of measuring the processing time for returning the mould to its normal position are an average of 112 minutes. This was done three times in the experiment of the process time for returning the mould to its normal position.

3.2 Theme Determination

The initial part of the eight improvement steps is determining the topic of the problem that will be raised in this research. The theme was determined by forming a Focus Group Discussion (FGD) team of five expert judgments. In their work, the FGD team is part of the company's internal improvement team, consisting of production managers, quality managers, maintenance managers, PPIC managers, and accounting managers. The results of the FGD, one of which is the assessment and weighting of the QCDSM factors related to the problems found, can be seen in Table 3.

Table 3 – Problem Weighting in QCDSM Factors

No	Problems Found	QCDSM weighting					Total (times)	Averages (times)
		Quality	Cost	Delivery	Safety	Moral		
1	Partial mould family setup work on type A Not optimal (Problem A)	4	5	5	4	5	23	4.6
2	Rust appears on the surface of the cavity (Problem B)	4	3	2	3	2	14	2.8
3	Delivery tools when supervision is still less effective (Problem C)	1	1	3	1	3	9	1.8
4	The spare part lifter cupboard is not tidy (Problem D)	1	2	1	2	2	8	1.6
5	The wire welding place is less concise (Problem E)	1	2	1	2	1	7	1.4

Based on Table 3, the results of observations of problems that have been carried out are then created, and a Pareto diagram determines the dominant problems that must be corrected. Pareto diagrams are needed to determine the problems to be discussed or corrected by looking at the diagrams that have the largest percentage of problems. The diagram for determining problem priorities can be seen in Figure 5.

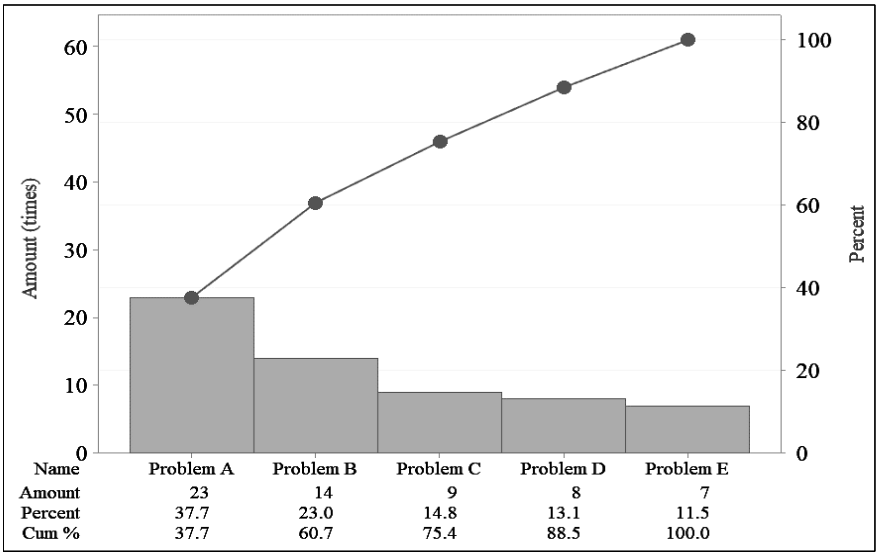

Figure 5 – Pareto Diagram of QCDSM

The information for Figure 5 is that problem A is partial mould family setup work on type A not optimal, and problem B is rust appearing on the surface of the cavity, problem C is delivery tools when supervision is still less effective, problem D, the spare part lifter cupboard is not tidy, and problem E is the wire welding place is less concise. Based on Figure 5, the FGD team agreed to take the theme of the problem to be fixed, problem A, namely partial mould family setup work on type A, which is not optimal.

3.3 Target Setting

In determining targets, this research uses the Specific-Measurable-Achievable-Relevant-Timebase (SMART) method to help determine the targets to be achieved (Bjerke and Renger, 2017). The results of the SMART method analysis in this research can be seen in Table 4.

Table 4 – Target SMART

SMART Method Analysis	
Specific	Making improvements that can help the process of optimising partial setup on moulds with family types in type A
Measurable	Calculation of resource efficiency considering QCDSM
Achievable	Looking at the existing conditions and human resources, improvements can be made
Relevant	This improvement has objectives that are in line with production and maintenance needs
Time Base	This improvement period will be implemented in April - June 2023

Based on Table 4, the FGD team determined or set a target for this research with a 91% reduction in costs from IDR 1,200,000 to IDR 100,000 for each partial process, and the partial setup time target decreased by 50% from 240 minutes to 120 minutes for each partial process.

3.4 Condition Analysis

After knowing the theme of the problem to be corrected and having determined the target, the next research is to analyse the factors causing the main problem using a fishbone diagram. A fishbone diagram is a cause and effect diagram or fishbone diagram, where the causal factors and root causes of problems that can be corrected must be included in the diagram. The results of the fishbone diagram analysis can be seen in Figure 6.

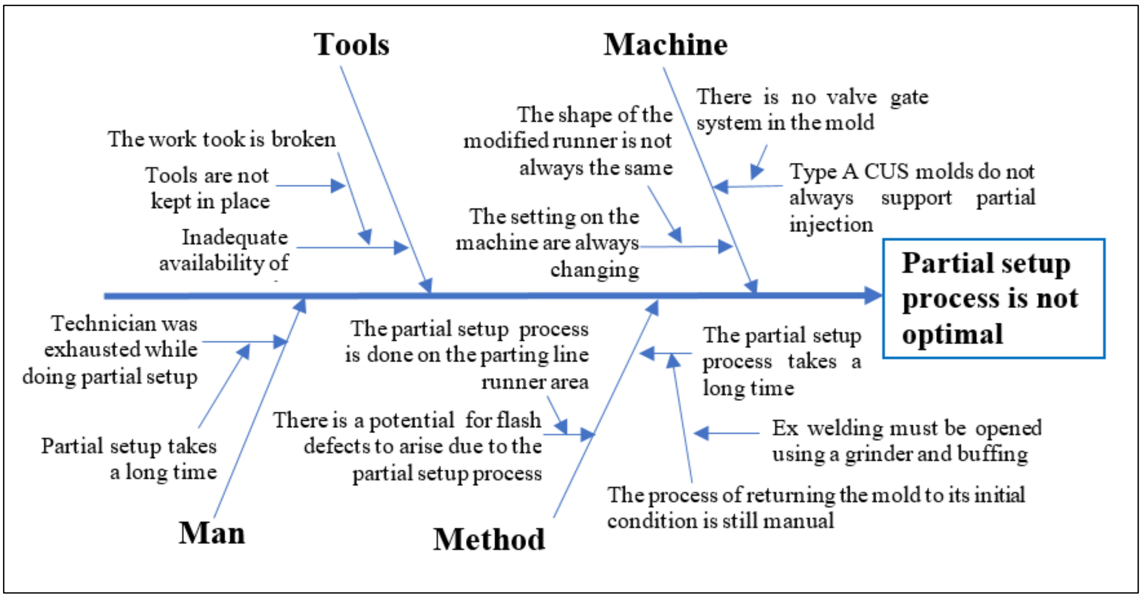

Figure 6 – Fishbone Diagram

Based on Figure 8, the results of the Fishbone analysis were verified on the suspected problem by the FGD team (Aprianto *et al.*, 2022). This verification is carried out so that all forms of improvement adapt to the company's capabilities, both financially and in the system that will be created. The verification results can be seen in Table 5.

Table 5 – Verify Problems Presumptive Problems

No	Factor	The Root of the Problem	Actual Condition	Validation
1	Method	Ex-welding must be opened manually by grinding and buffing	The ex-welding removal process is still manual using grinding and buffing	Potential
		There is the potential for flash defects to arise due to work in the PL runner area	Continuous setup work in the PL runner area has the potential for defects	Potential
2	Man	The partial setup process is tedious and takes a long time	The process of returning the mould to normal condition takes a long time	Potential
3	Machine	The engine settings change because the runner shape has been modified	There is no definite setting for when the mould will be produced	Potential
		Type A moulds do not support partial injection	There are no components that can support partial injection in the mould	Potential
4	Tools	The availability of tools is inadequate because the tools are damaged	The tools in the section are complete and in good condition	Not Potential

Based on Table 5, it is found that the potential factors for the problem of less than optimal partial setup are three factors, including method, man, and machine. Therefore, research continues to immediately plan countermeasures with the company's internal improvement team.

3.5 Mitigation Plan

The plan for insert runner improvement for partial setup on type A moulds is shown in Table 6. The 5W+1H analysis displays several problems with plans and countermeasures collected in one table to make monitoring easier (Wiyatno and Kurnia, 2022; Kurnia *et al.*, 2023). Details of the 5W+1H method in this research can be seen in Table 6.

Table 6 – 5W+1H for Improvement

Item	Action
What	The partial setup process on Mould type A is less than optimal
When	When there is partial demand for type A
Where	Mould Repair Maintenance (MRM) Parts
Who	Moulding Technician
Why	There are problems with the Man, Method, and Machine factors
How	Making Insert Runners that can be easily removed depending on production requests

3.6 Implementation

After carrying out a response plan, the next step taken by researchers is to carry out countermeasures according to the plan that has been made. The first repair activity carried out was to modify the runner part of the type A mould to make a component that could make partial setup easier. The researchers checked the ability of the type A mould to be modified, as in Figure 7.

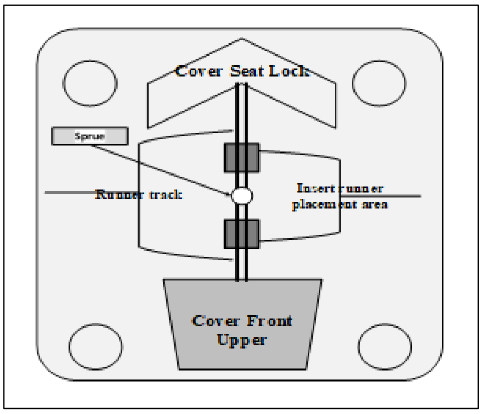

Figure 7 – Type A Mould Components in the Runner Area where Improvement will be carried out

Based on Figure 7, two types of runner inserts are made for the seat lock cover and front runner cover types, where each insert is made for normal production and partial production with runner dimensions that follow the original so that there is no change in the material flow rate. The shape of the runner insert can be seen in Figure 8.

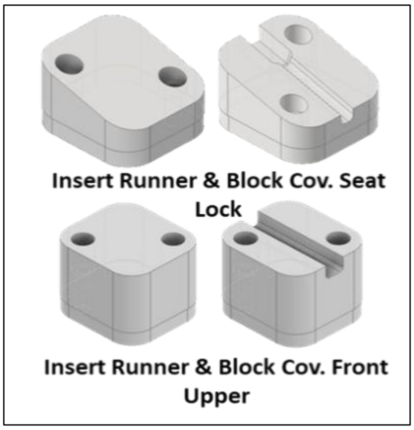

Figure 8 – Insert Runner

Based on Figure 8, the insert that has been made will undergo a trial process for installing the insert. This research tested the installation time three times with different technicians. This experiment aimed to determine the average time required for the insert installation process and obtained results as in Tables 7 and 8.

Table 7 – Partial Setup Time After Repair

No	Activities	Working Time (minutes)		
		1	2	3
1	Mould comes	0	0	0
2	Preparing tool	4	4	4
3	Open mould	12	12	13
4	Partial setup process	9	11	9,2
5	Close mould	14	12	12
6	Mould stand by	0	0	0
Total		39	39	38.2
Averages		38.7		

Table 8 – Insert Return Time After Repair

No	Activities	Time (minute)		
		1	2	3
1	Mould comes	0	0	0
2	Tool preparation	4	4	4
3	Open mould	11	11	11
4	The process of returning the mould to normal condition	9	8	10
5	Close mould	10	12	10
6	Mould stand by	0	0	0
Total		34	35	35
Averages		34.7		

Based on Table 7 and Table 8, these two average results can be concluded that the time required for the work process is 73.4 minutes. This research carried out a machine testing process four times on an injection machine to ensure the effectiveness of the mould. The goal is to find out changes after repairs. This research conducted trials on the machine four times, and the results were obtained after making improvements. The time required to set the machine to achieve an OK product was 5 minutes.

3.7 Evaluation of Results

The results of the improvements made to the runner in the family-type mould were obtained:

a. Quality: The potential for product rejects will not occur because defective runners can be eliminated.
b. Cost: The total cost after improvement decreased from $75 to $3. This decrease can be seen in Figure 9.
c. Delivery: Partial setup time which initially took up to 240 minutes; after improvements the partial setup process became 73 minutes. The results obtained were faster than the specified target, which was 47 minutes faster than the specified target. This data can be graphed and can be seen in Figure 10.

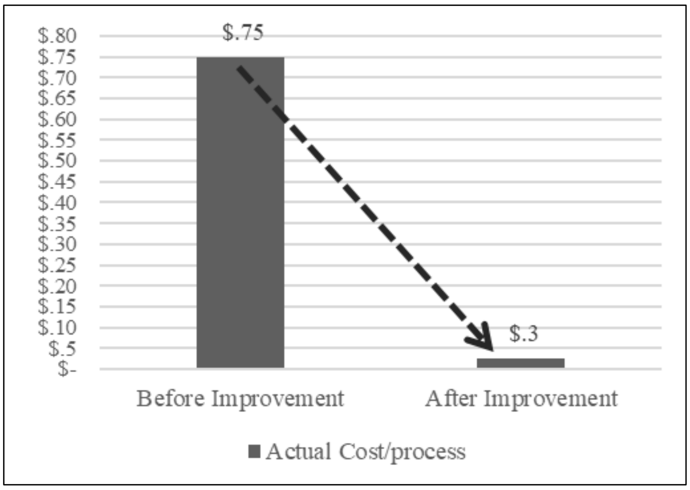

Figure 9 – Cost/process reduction

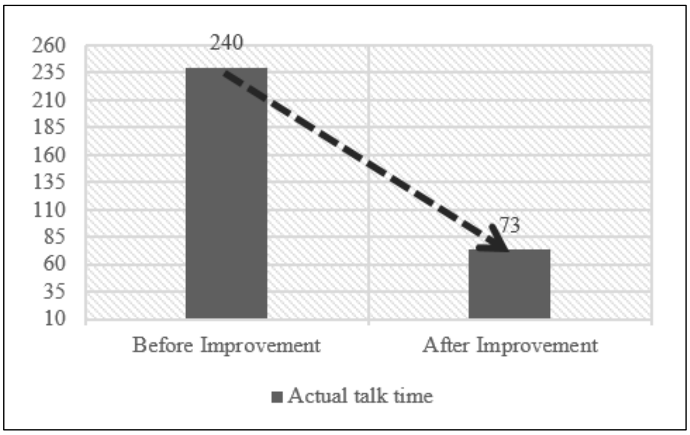

Figure 10 – Comparison of Partial Setup Times

d. Safety: Eliminates the potential for flash, and the production process is safer in operation.
e. Moral: Employee motivation increases because partial setup times become easier and faster.

3.8 Standardisation

The new standardisation of work processes aims to ensure that improvements made in the partial setup process can be implemented in Work Instructions (WI). This WI was created so that all parties in carrying out their work refer to activity instructions, Standard Operational Procedures (SOP), and required work equipment (Asih, Suhariyanto and Ramadhan, 2022). The new WI that has been created can be seen in Table 10.

Table 10 – Work Instructions for Partial Setup and Removal of Insert Runner Process

No	Job description	Standard	Personal Protective Equipment (PPE)
1	Prepare PPE and work equipment to be used	The PPE and equipment used are complete according to the information	Safety shoes, hat, mask and gloves
2	Open the mould where the insert will be partially replaced	Mould open	Gloves
3	Remove the insert locking bolt partially	The bolt is loose	LS key
4	Then insert some	Partial insert detached	Tracker
5	Clean the insert area	The insert area is clean or free from dirt/dust	Face mask
6	Install the replacement partial insert	The insert is installed straight and parallel to the core surface	Safety shoes, hat, mask and gloves
7	Retighten the locking bolt	The locking bolt is not NG and is installed securely	LS key
8	Check the work results again	All work is completed promptly	Safety shoes, hat, mask and gloves
9	Close the mould again	Mould neatly	Safety shoes, hat, mask and gloves
10	Follow the trial mould and monitor the results	Following work instructions	Safety shoes, hat, mask and gloves
11	Clean the work area and return tools and PPE to the place provided	The work area is clean and tools are arranged in their place	Safety shoes, hat, mask and gloves

3.9 Discussion

A process of activities to increase the output or amount of production in an industry is called production optimisation. Meanwhile, the process level that has reached the highest figure in terms of achievement is called capacity. Optimisation in increasing workstation capacity using the Theory of Constraints (TOC) method (Rahmawati, Puryani and Nursubiyantoro, 2019). Much research has been carried out regarding optimisation in various industries; this is to increase the productivity of employee performance in producing automotive spare parts products at these companies. Injection moulding process design based on product analysis tailored to the proposed design meets production needs in an effective time for manufacturing and leads to the development of similar product designs (Lo *et al.*, 2022; Yani *et al.*, 2022).

This research uses an 8-Step improvement method where each repair step is combined with a repair tool to assist in finding repair solutions. This research has resulted in a partial reduction in process time in making plastic motorcycle bodies in the plastic injection process in the motorcycle or two-wheeled vehicle industry. The contribution of this research includes design and manufacturing engineering, where improvements were made to modify the runner part of the type A mould and create two types of runner inserts for the seat lock cover and front runner cover types. In addition, it is hoped that the results of this research can be applied consistently by the motorcycle industry in preparing spare parts, especially plastic bodies, so that the manufacturing process time can be optimal and can increase the fulfilment of orders from customers.

4 CONCLUSION

Based on the analysis in the previous section, this research found that there was a cause of less than optimal partial setup work due to problems with the Man, Method, and Machine factors. This research also provided solutions, including making modifications to the runner part of the type A mould, making two types of runner inserts for the cover type seat lock and front runner cover, for each of which an insert is made for regular production and partial production with runner dimensions that follow the original so that there is no change in the material flow rate. A trial process for installing the insert is carried out. At the standardisation stage, a new WI is created for the partial setup process and installation of the insert runner.

After providing a solution to the less-than-optimal setup work on this type of mould, it can be concluded that the partial setup work is less than optimal because several repetitive and less effective jobs make the setup time take a long time. The results of data processing using the QCDSM method showed that the setup time decreased from 240 minutes to 73 minutes, and the time required to set the machine to produce OK products decreased to 5 minutes or decreased by 68%. Meanwhile, the process costs for the partial setup itself fell from the initial USD 75 to USD 3 or a decrease of 97%.

In theory, the implications of this research for other researchers are additional references in conducting almost the same research. Meanwhile, the practical implications for automotive or motorcycle industry players are that the improvement method that has been carried out using eight improvement steps combined with repair tools can be used as a reference in optimising the partial setup process time for making plastic motorcycle bodies. For the future, the researcher recommends that further research be aimed at reducing wasted material transfer time and reducing production defects between parts using the Lean Six Sigma (LSS) approach because there are still opportunities for improvement to be more effective and efficient in the motorcycle industry.

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CONFLICTS OF INTEREST

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