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Improving the Manufacturing of Square Flange Gasket Through Lean Practices

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Abstract

This paper reports a case study on production line of square flange gasket at a small and medium-sized enterprise (SME) company. The square flange gasket, a high-demand product used as a seal between two flange faces, is currently produced below satisfactory levels due to delays, causing client dissatisfaction. This study aims to identify the root causes of waste in the production line and propose solutions to improve productivity and speed up production. The methodology used in this study is based on PDCA Cycle, starting with the ‘Plan’ approach that focuses on finding the root problems through Lean Practices such as Ishikawa, Yamazumi Chart, 5 Whys Analysis and Pareto Chart using the information gained from the Gemba visit at the company. Lean Practices revealed that the longest cycle time occurs during the quality check process due to inefficient movement between the machine room and quality check room, and the lack of quick measurement tools. ‘Do’ phase is done by developing a Go/No Go Gauge as the solution for the problems that have been identified and the ‘Check’ phase will involve the implementation of the designed gauge and monitoring the results with its function and suitability. The case study will end in the ‘Act’ phase where we make improvements based on the results during ‘Check’ phases and standardise the right practices. The proposed solution led to significant improvements: a 72.73% reduction in movement distance, a 26.29% reduction in cycle time, and a 26.47% increase in weekly production. The gauge eliminated waste like waiting time and unnecessary motion, speeding up measurements. In conclusion, this study highlights the importance of Lean practice in reducing waste and boosting overall productivity.

1. Introduction

This study examines a manufacturing process at an SME in Kota Bharu, Kelantan. The company specializes in producing engineering parts for industries like oil and gas, petrochemicals, and water systems. Known for their high-quality products, the company prioritizes accuracy in their production process. One of their most in-demand products is the square flange gasket, used to prevent leaks in square flanges, which connect equipment, pipe fittings, or plumbing. By placing a gasket between two flange plates and securing them with bolts, the risk of gas or liquid leaks is minimized, making these gaskets essential for the company's clients.

The production of square flange gaskets at the SME in Kota Bharu involves several steps that can lead to bottlenecks, delays, or waste, slowing down production. Clients have complained that the product takes too long to finish and deliver. This delay is likely due to waste in the production line, which can include idle time, overproduction, or unnecessary movements. Identifying and eliminating these wastes is essential to meeting quality standards, delivery deadlines, and maintaining the company's economic health [1]. Despite producing high-quality products, client satisfaction is crucial for the company's success, so addressing these issues is important.

The complex manufacturing process of square flange gaskets involves many stages and workstations, increasing the risk of waste. Waste is likely to occur, especially during workstation changes, where idle time can slow down production [2]. This slow production has become a significant issue for the company, affecting various aspects of the business. Any action that clients see as unnecessary is considered waste, which they are unwilling to pay for. The term "waste" in manufacturing describes any inefficiencies, flaws, or resources wasted during production but not contributing to the end product's value. Examples of waste include idle time, unnecessary movement, defects, and underutilized talent. This idea is frequently linked to the ideas of Lean manufacturing. For example, Lean practices have been proven to enhance productivity by increasing worker working condition in fastener manufacturing [3]. Lean practices are the most suitable method to be used because of its function at maximizing efficiency, minimizing waste, and improving overall productivity in manufacturing. Lean manufacturing is a soft technology that utilizes computing techniques, together with quantitative and qualitative methods, to show an approach to continuous improvement [4].

The company's gasket manufacturing process's chronic problem of slow production presents a difficult challenge to both their operational effectiveness and client satisfaction. Long periods of production times have become a frequent bottleneck, preventing them from meeting demand and fulfilling orders on time, despite their best efforts. This slowdown is having a domino impact on all aspects of the business, causing inefficiencies to get worse and expenses to rise. As a result of these difficulties, there is an increasing number of dissatisfied clients whose expectations regarding timely service and consistent product availability are not fulfilled. This discontent affects not only the company's present business partnerships but also their capacity to draw in and keep new customers in a market that is becoming more and more competitive. A thorough investigation of the company's gasket manufacturing processes must be done to determine the underlying reasons for inefficiency and delay to make them ready to tackle these urgent challenges. Through the implementation of focused methods aimed at optimizing resource usage, cutting cycle times, and streamlining processes, they can mitigate the effects of slow production and restore command over their operational performance.

To ensure a systematic problem-solving process, the PDCA cycle technique were employed alongside Lean principle. Integrating Lean principles with the PDCA cycle allows for the systematic identification of inefficiencies, implementation of targeted improvements, monitoring of outcomes, and refinement of processes. This approach supports continuous improvement while ensuring alignment with Lean's focus on reducing waste and maximizing value. This combination has been proven to successfully improve quality and reduce overall costs in the packaging and beverage industriesby effectively addressing the targeted issues/problems [5–6].

The implementation of Lean practices involves utilizing tools such as the Ishikawa Diagram, Yamazumi Chart, 5 Whys method, and Pareto Chart. These Lean manufacturing tools are designed to enhance capacity utilization, reduce lead times, cycle times, and inventory, while also improving the value of the final product [7]. The primary focus of applying these methods is to identify the root causes of problems, enabling the proposal of appropriate and effective solutions. For example, a recent study by [8] demonstrated the effectiveness of the Ishikawa Diagram in identifying and addressing the root causes of delays in surgical procedures within a healthcare setting. Similarly, research by Lenawati et al. [9] highlighted the successful combination of the Pareto Chart and Ishikawa Diagram in IT system audits to prioritize issues based on risk and impact.

Thus, the aim of this study is to develop a comprehensive strategy to increase output and reduce waste in gasket manufacturing. The objectives include investigating the root causes of waste in the square flange gasket production line using Lean Practices, proposing a design solution to enhance production efficiency, and evaluating the effectiveness of the proposed design. This study's contributions could lead to improved operational efficiency, reduced production costs, and the potential for broader application of Lean Practices in similar manufacturing settings.

2. Methodology

2.1 PDCA Cycle

All The methodology used in this study is based on Plan-Do-Check-Act Cycle and implementation of selected Lean practice tools find out the root cause for any potential waste in the production line with the focus to decrease waste by proposing the suitable design solution that can show the improvement to productivity of the company. Opportunities for improvement are identified and prioritized once all potential causes have been determined. Subsequently, proposed, and planned system modifications and improvement-related goals are set [10].

Fig. 1 shows the flowchart of work involved in the case study and are divided using PDCA principle. The first step is a Gemba visit to collect data and evaluate the current state of operations. After that, production line issues were looked into, and Lean methods were used to find the source of the problem. If there are any improvements, this process can be standardized and if not, data collection and modification must be restarted. Table 1 outlines the detailed activities at each stage of the PDCA methodology used to study the production line of square flange gaskets at the company. In the "Plan" phase, the focus is on gathering data about the current production situation through Gemba Walks and interviews. This data is then analyzed using Lean Practices tools to identify the root causes of waste. The "Do" phase involves implementing a product development process as a proposed solution to address the identified issues in gasket manufacturing. In the "Check" phase, we assess the effectiveness of the proposed design by comparing the current production efficiency to the improved one. If improvements are achieved, the "Act" phase will standardize the new procedure for the square flange gasket production line at the company

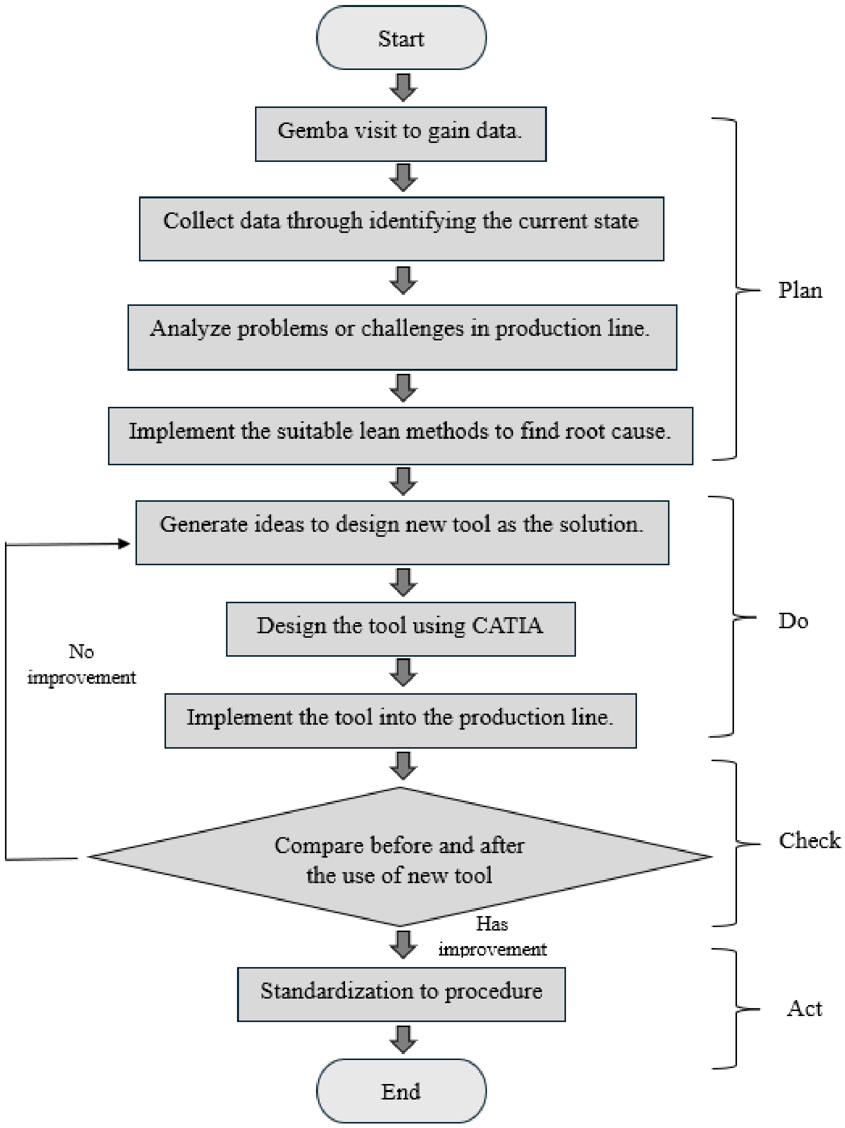


Fig. 1 *Project flow chart*

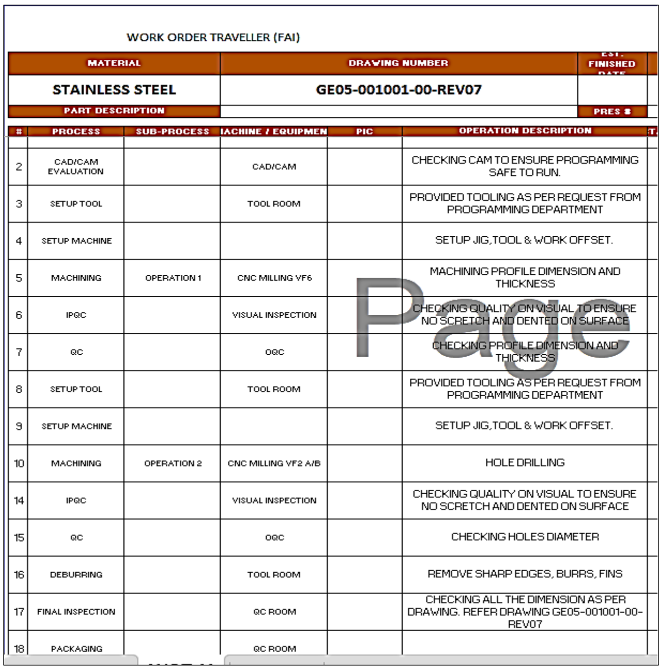
Table 1 *Research methodology base on PDCA cycle*

PDCA	Flow Step	Stage	Methods & Techniques	Goal
Plan	1	Data collection	GEMBA, Interviews	Notice the current flow process in terms of time taken and waste involved in each line of production.
	2	Analysis	Data Analysis, line balancing Analysis, Ishikawa Diagram, Pareto Diagram	Find the area of the problem could occur.
	3	Action plan	Focused Analysis, 5 Whys Analysis	Focused on the area that causes waste in production to identify the root cause.
Do	4	Design	Pugh Chart, Sketching, CAD	Propose the design that could be used to improve the production of gasket.
Check	5	Check	Comparison	Test the designed product and collect the data to compare the differences that the new product made.
Act	6	Standardization	Standard Operation Procedure (SOP), Flow Chart	Systematize the new flow to the production of gasket and make continuous improvements.

2.2 Data Collection and Analysis

GEMBA walk is adapted as a quality management tool to identify and address inefficient (or non-existent) operations in order to resolve the situation [11]. Gemba walking is helpful in finding gaps in between operational staff linked in production line and give exposure to the realities of day-to-day operations. Gemba's visit to the company took place to determine its current situation before the deep research began. The data of such as processes involved, cycle time, workstation layout are being observed to understand the flow of gasket manufacturing at the company.

Fig. 2 illustrates the Work on Traveller sheet employed by the company to monitor the manufacturing process. Fig. 3 visualizes the workpiece facing process using a CNC machine, while Fig. 4 and Fig. 5 depict the square flange gasket and its application in a car carburetor. Data obtained from the company were analyzed to assess the gasket's production rate and idle time. The analysis revealed significant delays in processing, which contributed to the overall slowdown of the production process. Additionally, it was observed that no Lean tools were utilized during the procedure, further exacerbating the inefficiencies.



WORK ORDER TRAVELLER (FAI)

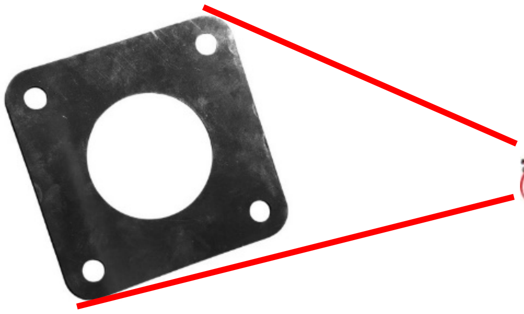
MATERIAL	DRAWING NUMBER	EST. FINISHED DATE
STAINLESS STEEL	GE05-001001-00-REV07	
PART DESCRIPTION		PRES #

#	PROCESS	SUB-PROCESS	MACHINE / EQUIPMENT	PIC	OPERATION DESCRIPTION
2	CAD/CAM EVALUATION		CAD/CAM		CHECKING CAM TO ENSURE PROGRAMMING SAFE TO RUN.
3	SETUP TOOL		TOOL ROOM		PROVIDED TOOLING AS PER REQUEST FROM PROGRAMMING DEPARTMENT
4	SETUP MACHINE				SETUP JIG,TOOL & WORK OFFSET.
5	MACHINING	OPERATION 1	CNC MILLING VF6		MACHINING PROFILE DIMENSION AND THICKNESS
6	IPQC		VISUAL INSPECTION		CHECKING QUALITY ON VISUAL TO ENSURE NO SCRETCH AND DENTED ON SURFACE
7	QC		OQC		CHECKING PROFILE DIMENSION AND THICKNESS
8	SETUP TOOL		TOOL ROOM		PROVIDED TOOLING AS PER REQUEST FROM PROGRAMMING DEPARTMENT
9	SETUP MACHINE				SETUP JIG,TOOL & WORK OFFSET.
10	MACHINING	OPERATION 2	CNC MILLING VF2 A/B		HOLE DRILLING
14	IPQC		VISUAL INSPECTION		CHECKING QUALITY ON VISUAL TO ENSURE NO SCRETCH AND DENTED ON SURFACE
15	QC		OQC		CHECKING HOLES DIAMETER
16	DEBURRING		TOOL ROOM		REMOVE SHARP EDGES, BURRS, FINS
17	FINAL INSPECTION		QC ROOM		CHECKING ALL THE DIMENSION AS PER DRAWING. REFER DRAWING GE05-001001-00-REV07
18	PACKAGING		QC ROOM		

Page

Fig. 2 *Work on traveller (WOT) sheet*

Fig. 3 *CNC machine operation*



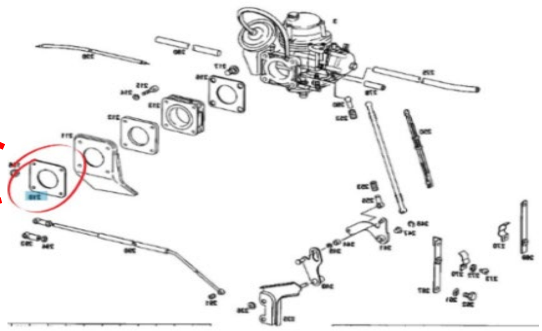


Fig. 4 *Square flange gasket*

Fig. 5 *Gasket placement in car carburetor*

After the observation made during the Gemba Walk, a thorough investigation needs to be done to determine the problems that exist in the production line of square flange gasket. These problems can be identified from the company staff's point of view by conducting the informal interviews. The open-ended interview was conducted with the staffs at the company including Production Engineer, Quality Check Officer, Machine Operators, Design Engineer, and Procurement Engineer. The question given for every staff is "What do you think is the most obvious reason for the slow production of the gasket?".

2.3 Lean Practices Tools

2.3.1 Yamazumi Chart (Line Balancing)

Through classifying the work equally for each workstation, the line balancing approach is to minimize the number of resources in a production line while maintaining the productivity of the line. Any manufacturing production line must be designed, and the line must be balanced, to remove needless trial and error processes and the associated high costs. Many important aspects are involved in the assembly line balance issue (ALBP), and they must be handled while keeping in mind the industry's real-time restrictions [12]. The formulas used in constructing the Yamazumi Chart are as follows [12]:

$$Balancedelay\ (d) = \frac{n.T_c - T_{pc}}{n.T_c}$$

$$Line\ efficiency\ (h) = (100 - d)\% \tag{1}$$

Where;

n = Number of stations

T_c = Takt time (min)

T_{pc} = Total process time (min)

2.3.2 Ishikawa Diagram

An Ishikawa diagram, also called a cause-and-effect or fishbone diagram, visually displays potential causes of a problem [13]. It categorizes issues into areas like manpower, environment, and measurement. Study by Chokkalingam et al. [14] details how the Ishikawa diagram was used to identify and eliminate root causes of defects in automobile body casting, contributing to continuous improvement in manufacturing processes. Fig. 6 shows an example of an Ishikawa diagram used to identify the root cause of product defects.

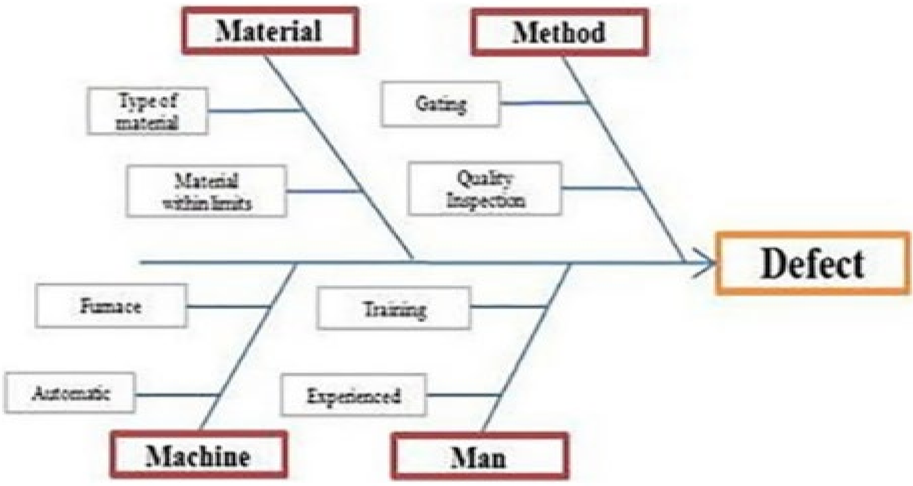


Fig. 6 *Example of Ishikawa diagram* [15]

2.3.3 Pareto Chart

The component in Pareto Chart are the problems that have been identified in Ishikawa Diagram to know the root cause of the slow production process of gasket. Pareto analysis is based on the principle that 80% of a project's benefit can be obtained by completing 20% of the work, or that 20% of the causes of 80% of problems can be identified. Pareto charts are a useful tool for prioritizing tasks. They are helpful in determining a categorical variable's most frequent outcome [16].

3. Result And Discussion

3.1 Plan

3.1.1 Process of Square Flange Gasket Production

Table 2 shows the square flange gasket manufacturing process that is broken down into detail, which also includes relevant information such the process symbol, workstation location, travel time between workstations, and cycle time needed for each step. The first step in the procedure is Material Preparation in the inventory room, which takes 8 minutes and requires a 30 meters travel distance. The next steps are the 3 minutes CNC machine setup for the first operation in the machine room and the 5 minutes facing operation that also takes place in the machine room.

The next step involves moving the in-process square flange 60 meters to the quality check station, where it takes 15 minutes to complete a quality check on thickness and corner radius. Then, the flange is transported another 60 meters back to the machine room, taking 6 minutes, where the CNC machine is set up for the second operation. Five minutes later, the hole drilling operation is completed in the same machine room. The flange is then moved once again, 60 meters back to the quality check room, where a second quality check is performed on each of the five drilled holes, taking an additional 15 minutes.

In total, this process takes 97 minutes and involves 330 meters of movement. This detailed procedure not only outlines the sequential steps, distances, and timeframes involved in producing square flange gaskets but also highlights areas where motion waste and inefficiencies could be identified and addressed.

Table 2 *Detail manufacturing process of the gasket*

PROCESS: MANUFACTURING OF SQUARE FLANGE GASKET				
Process	Symbol	Workstation	Distance (m)	Cycle Time (min)
Material Preparation		Inventory room	30	8
CNC Machine setup for first operation		Machine room	-	3
Facing operation		Machine room	-	5
Quality check on thickness and corner radius		Quality check room	60	15
CNC Machine setup for second operation		Machine room	60	6
Hole drilling operation		Machine room	-	5
Quality check on each of the 5 holes drilled		Quality check room	60	15
Deburring and surface finishing.		Machine room	60	15
Final inspection		Quality check room	60	15
Packaging.		Quality check room	-	10
		Total	330	97

 Transportation	 Operation	 Inspection	 Storage

3.1.2 Production Rate of Gasket

The common demand from the client of the company is around 30-50 units of gasket per week. Based on the current processes, the company could only produce 5 gaskets per day equivalent to 25 gaskets per week.

Production Rate in gaskets/minute;	(1 unit)/ (97 minutes) =0.0103 unit
Production Rate in gaskets/hour;	0.0103 unit × 60minutes/hour=0.636 unit
5 days per week and 8 hours per day;	0.636 unit × 8 hours × 5days =25 gaskets

3.1.3 Line Balancing

The production rate must reach the number of 30 gaskets in a week. But for current situations, the company could only produce 25 gaskets a week given that a week has 5 days and 8 working hours per day.

$$Overall\ Takt\ Time = \frac{Total\ Available\ Time}{Customer\ demand}$$

$$= \frac{2400\ minutes}{30\ units} = 80\ minutes\ per\ unit$$

Fig. 7 shows the line balancing of the process by mapping each stage's processing and idle times against the takt time, which is the rate needed to meet customer demand. Each bar represents an operation, with blue segments for processing times and orange for idle times. The horizontal green line indicates the takt time. To meet the production target, each workstation should complete its tasks in less than 8 minutes, given the overall takt time of 80 minutes per gasket. The quality check process takes the longest, and the chart shows that four workstations experience idle time due to waiting for workpieces. The most significant idle time is due to the lengthy movement time between the machine room and the quality check room. These issues will be listed and categorized using an Ishikawa Diagram to identify potential problems in the production line.

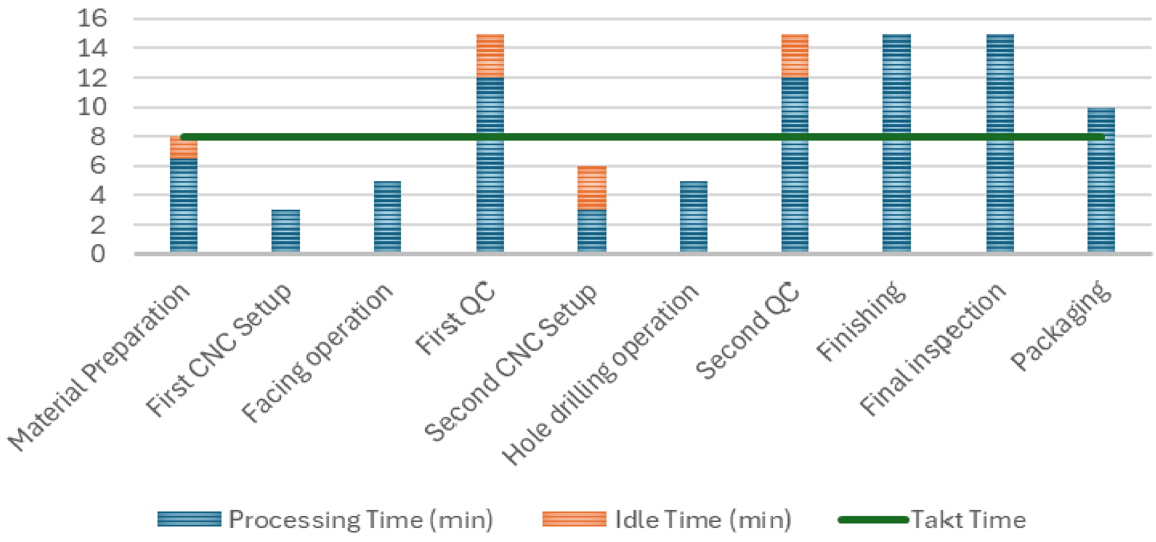


Fig. 7 *Line balancing for gasket production*

3.1.4 Ishikawa Diagram

Several problems have been listed after the analysis and observation have been done, that are likely to be the cause of waste in the production line. Each of the problem are classified into 4 categories.

Fig. 8 shows the Ishikawa chart that categorizes these reasons into four groups: manpower, materials, measurement, and environment. The list of potential problems is then organized and visualized in a Pareto Chart to identify the most significant areas of waste. A study by Zhang et al. [17] demonstrated how a Pareto chart can identify the costliest medical cases that lead to financial losses. The study suggests that better management of these high-cost cases can help hospitals control expenses more effectively.

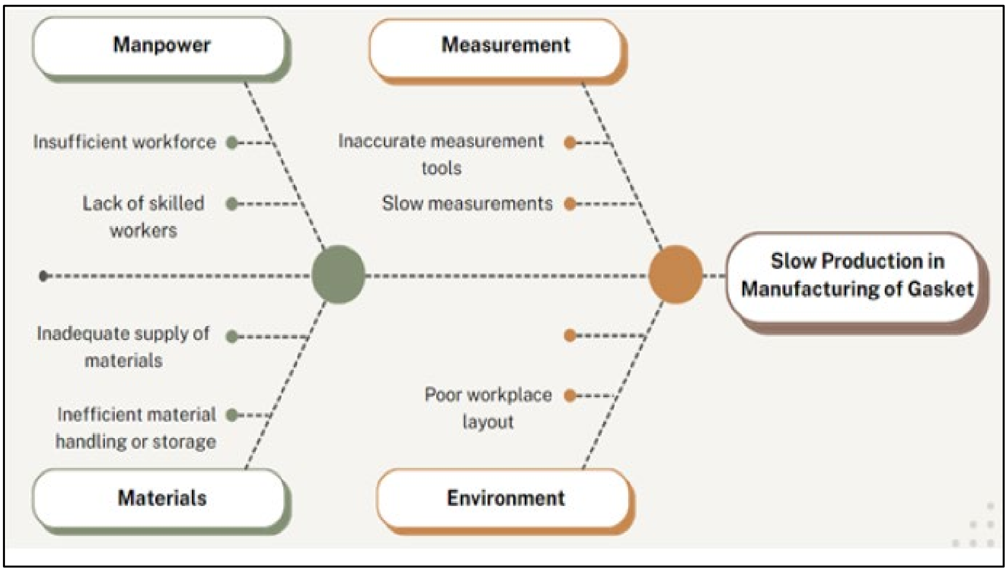


Fig. 8 *Cause and effect diagram*

3.1.5 Pareto Chart

Fig. 9 shows a Pareto chart with four identified problems such as "delay in measurement," "poor workstation layout," "lack of skilled worker," and "inadequate supply of material". "Delay in measurement" has the highest frequency. The bars show the frequency of each issue. This chart aids in prioritizing problem-solving efforts by highlighting the most important problems first. From here, we can conclude that delay in measurement and poor workstation layout is the causes of slow production of square flange gasket

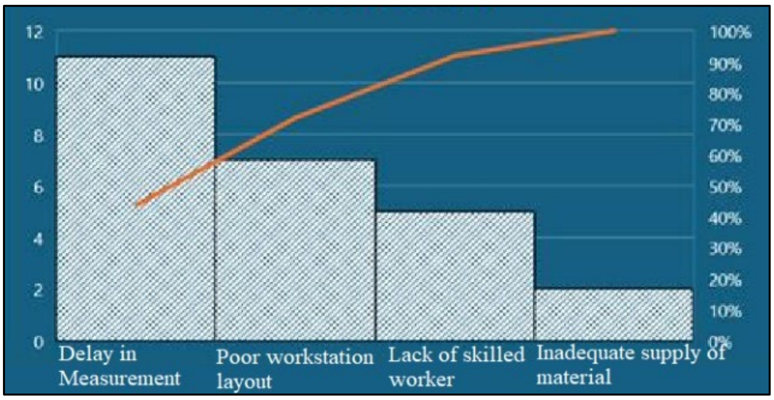


Fig. 9 *Pareto chart*

3.1.6 5 Why Analysis

After identifying the most significant issues through a Pareto chart, 5 whys were employed to identify the root causes of the problems. by repeatedly asking the question "why" five times. Each question tackles the issue more thoroughly, going beyond the obvious signs and symptoms [18].

Fig. 10 shows that the first analysis revealed the lack of a tool that can measure all gasket dimensions simultaneously, leading to repeated changes of measurement tools during quality checks. Fig. 11 shows that the second analysis found no tool for quick measurement in the machine room. This led to moving workpieces to the quality check room, adding non-value time to the production line. The root cause can be addressed by designing a measurement tool that can quickly measure all dimensions of square flange gaskets and be used anywhere in the production process.

Define the problem	The production of square flange gasket has been so slow and need to be improved.
Why is this a problem?	**PRIMARY CAUSE** *Why is this happening?* Because quality check spends the longest time to finish the process *Why is that?* Because quality check spends long time in measurement activity *Why is that?* Because many dimensions need to be measure one by one. *Why is that?* Because it uses various tools and need time to assure the measurement is correct *Why is that?* Because no tools that can quickly measure all the dimensions **THE ROOT CAUSE**

Fig. 10 *5 Why analysis (first probability)*

Define the problem	The production of square flange gasket has been so slow and need to be improved.
Why is this a problem?	**PRIMARY CAUSE** *Why is this happening?* Because quality check spends the longest time to finish the process *Why is that?* Because quality check needs to wait for the workpiece from operation site *Why is that?* Because there is distance between machine room and quality check room Because quality check operation need to be done in quality check room *Why is that?* Because no tools that can be use at machine room to check the quality **THE ROOT CAUSE**

Fig. 11 *5 Why analysis (second probability)*

3.2 Do

A suitable tool for quickly measuring all dimensions of a product is a limit gauge. This device uses two limits—high and low limits—to measure a component. It includes two gauges: the Go Gauge, which the component should pass through, and the No-Go Gauge, which it should not pass through. Limit gauges are commonly used in industries [19]. To improve the quality check process, the limit gauge should: 1) match gasket size specifications, 2) require minimal operator training, and 3) ensure efficiency in both measurement and handling.

3.2.1 Gasket Size Specifications

The gauge must be compatible with the size of the gasket produced by the company. The accurate sizing of gauge is important as the gauge depends on the size of the gasket because the gauge will only be specifically used to measure square flange gasket. Fig. 12 shows the design of the gasket, with its specification in Table 3 that we must follow for designing a Go/No-Go Gauge.

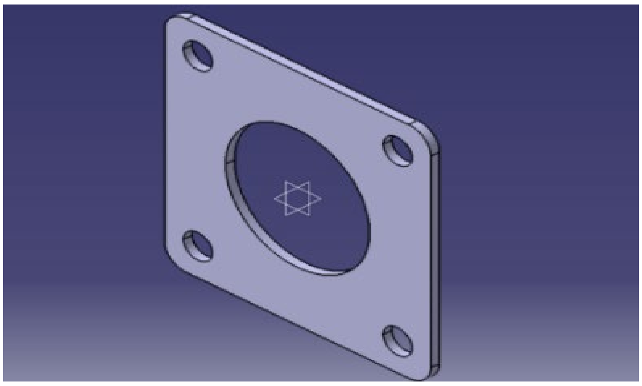


Fig. 12 *Design of gasket*

Table 3 *Gasket size specifications*

Specifications	Sizes
Length (L)	120mm
Width (W)	120mm
Thickness (T)	4mm
Corner radius	10mm
Centre hole diameters	65mm
Bolt holes diameters	10mm

3.2.2 Detail Design

The design integrates both the Go and No-Go gauges into a single unit by inverting the design. Fig. 13 illustrates the Go section of the gauge, which includes slots for checking the corner radius, center hole diameter, bolt hole diameter, and hole distances. These slots are machined with a tolerance of 0.05 mm less than the gasket size. The gasket is inserted into the slots; if it does not fit, it indicates that the gasket meets or exceeds the minimum acceptable dimensions. Additionally, the slot for checking thickness is also reduced by 0.05 mm in tolerance. The gasket must slide through this slot; if it does not, it signifies that the gasket meets or exceeds the minimum acceptable thickness.

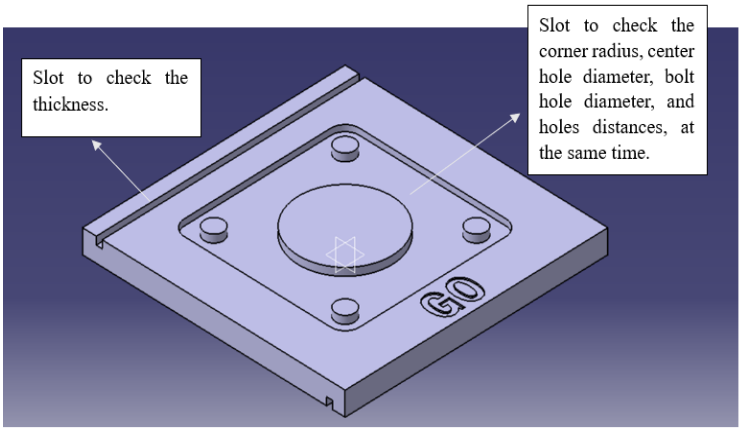


Fig. 13 *Go section*

Fig. 14 shows the No-Go section of the gauge, which includes slots for checking the corner radius, center hole diameter, bolt hole diameter, and hole distances. These slots are machined with an added tolerance of 0.05 mm more than the gasket size. When the gasket is inserted into these slots, if it fits, it indicates that the gasket meets or exceeds the maximum acceptable dimensions. Similarly, the slot for checking thickness is designed with an additional 0.05 mm tolerance. If the gasket slides through this slot, it signifies that the thickness exceeds the maximum acceptable size.

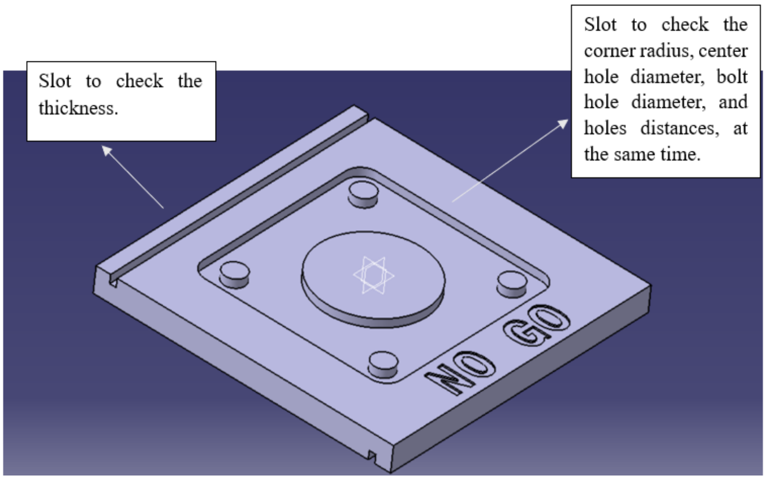


Fig. 14 *No-Go section*

3.3 Check

3.3.1 New Process of Square Flange Gasket Production

The use of designed Go/No-Go Gauge will reduce the movement between quality check room and machine room to do quality check process. It is because of the gauge design criteria of easy to use has allow the machine operator to directly measure the gasket right after every operation without the need to be sent to quality check room. The use of designed Go/No-Go Gauge also eliminate the use of various measuring tools to measure different section such as length, diameter, and corner radius, which has slowed down the measurement process.

Based on table 4, The process starts with material preparation in the inventory room, which is followed by 30 meters walk to the machine room, taking 8 minutes. There is no extra distance required for the initial operation, facing operation, or quality checks on thickness and corner radius, which are all done in the machine room and take 3, 5, and 5 minutes, respectively. The next procedures, which take an additional 3, 5, and 5.5 minutes, involve setting up another CNC machine, drilling holes, and checking the quality of the drilled holes inside the machine room. In the machine room, deburring and surface polishing also take place; these take 12 minutes. It takes 15 and 10 minutes to complete the final packing and inspection in the quality check room, which is a 60 meters distance. With a cumulative cycle time of 71.5 minutes and a total distance covered of 90 meters, the process demonstrates a thorough workflow for efficient manufacturing.

Table 4 *Process of square flange gasket production including the use of Go/No-Go Gauge*

PROCESS: MANUFACTURING OF SQUARE FLANGE GASKET				
Process	Symbol	Workstation	Distance (m)	Cycle Time (min)
Material Preparation	➡	Inventory room	30	8
CNC Machine setup for first operation	⬬	Machine room	-	3
Facing operation	⬬	Machine room	-	5
Quality check on thickness and corner radius	▬	**Machine room**	**0**	**5**
CNC Machine setup for second operation	⬬	**Machine room**	**0**	**3**
Hole drilling operation	⬬	Machine room	-	5
Quality check on each of the 5 holes drilled	▬	**Machine room**	**0**	**5.5**
Deburring and surface finishing.	⬬	**Machine room**	**0**	**12**
Final inspection	▬	Quality check room	60	15
Packaging.	▼	Quality check room	-	10
		Total	**90**	**71.5**

3.3.2 Comparison of Production Rates

The company are able to produce over 30 units of gasket after using the Go/No-Go Gauge as the measurement tool in the production line. It will satisfy the needs of customer that demands 30-40 units of gaskets per week.

Production Rate in gaskets/minute; (1 unit)/(71.5 minutes)=0.014 unit
Production Rate in gaskets/hour; 0.014 unit × 60minutes/hour=0.84 unit
5 days per week and 8 hours per day; 0.84 unit × 8 hours × 5days =34 units

Percent of Improvement,

$$Distance\ of\ Movement = \frac{330\ meter - 90\ meter}{330\ meter} \times 100\% = 72.73\%$$

$$Cycle\ Time = \frac{97\ minutes - 71.5\ minutes}{97\ minutes} \times 100\% = 26.29\%$$

$$Units\ produced = \frac{34\ units - 25\ units}{34\ units} \times 100\% = 26.47\%$$

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3.3.3 New Line Balancing

Fig. 15 shows the line balancing chart that visualized a significant difference from before as idle time has been eliminated at 4 processes especially in quality check department. Even though there are still some processes that surpassed the takt time, the total cycle time indicated that 1 unit needed only 71.5 minutes to finish which is below the overall takt time of 80 minutes calculated before.

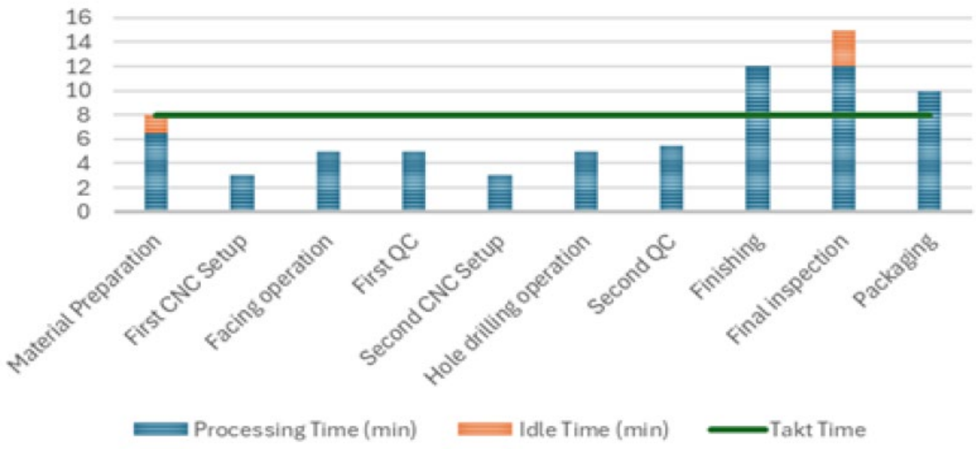


Fig. 15 *New line balancing chart*

3.4 Act

3.4.1 Standard Operation Procedure (SOP)

SOP outlines a series of actions that production team must take to eliminate variation from a task. It is a process document that specifies how an operator should carry out a certain task [20].

Fig. 16 shows the flow chart of process that involved in the manufacturing of the gasket. The process that has been highlight with red colour are the one that involve with the use of Go/No-Go Gauge. The Go/No-Go Gauge is use in the same place where the machining operation going. It removes the movement from machine room to quality check room in the production line. So, machine room become the main workstations that run most of the activities in the manufacturing of gasket. The step to use the Go/No-Go Gauge is very easy and can be done by anyone at the company without the risk of human error.

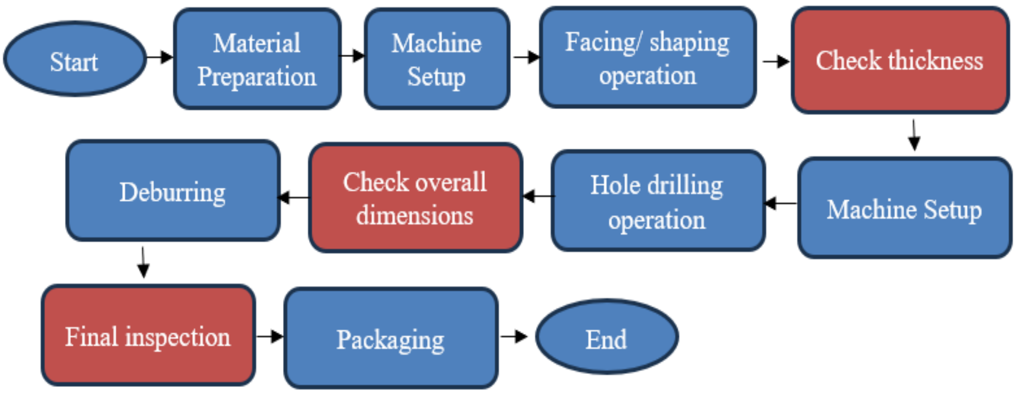
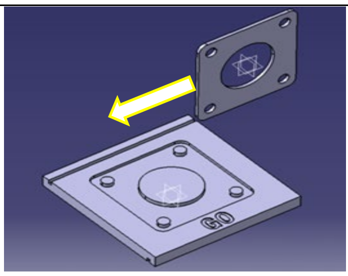


Fig. 16 *SOP of using the Go No Go gauge*

Fig. 17 visualized the Go/No-Go Gauge usage procedure to check the thickness and overall dimensions of gaskets. In the "Go Section," Fig. 17(a) and Fig. 17(c) show that a gasket satisfies the maximum allowable size requirements if it fits into the gauge (for dimensions) or passes through the slot (for thickness). On the other hand, as seen in Fig. 17(c) and Fig. 17(d) of the "No-Go Section," a gasket satisfies the minimum permissible size requirements if it does not fit into the gauge (for dimensions) or pass through the slot (for thickness). This technique gives an unambiguous pass/fail check for every dimension, ensuring that gaskets meet tolerance requirements.

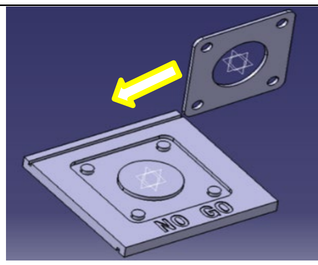
Go Section



The gasket is slid through the slot and if it passes through, the thickness of the gasket has passed the maximum acceptable thickness size.

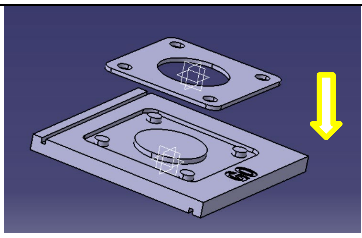
(a) Go Section thickness check

No-Go Section



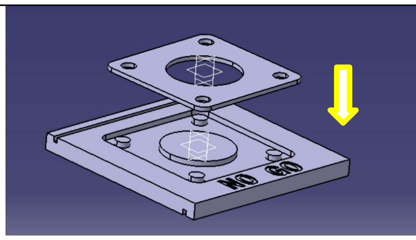
The gasket has to be slid the through the slot and if it does not pass through, the thickness of the gasket has passed the minimum acceptable thickness size.

(c) No-Go Section thickness check



The gasket is slotted inside, and if it fits, the gasket has passed the maximum acceptable dimensions.

(b) Go Section overall dimensions check



The gasket is slotted inside, and if it does not fit, the gasket has passed the minimum acceptable dimensions.

(d) No-Go section overall dimensions check

Fig. 17 *Illustration of using the Go/No-Go Gauge*

4. Conclusion

At the end of the case study, we can conclude that the improvement of square flange gasket through Lean practices has been done successfully at the company. The waste such as motion and waiting time in production line were reduced by implementing the new measurement tool, which is Go/No-Go Gauge in the quality check processes. It significantly has made the time to finish the measuring process become shorter while having an easy procedure to handle it. The tool's nature of easy to use has enabled it to be use by the operator in the machine room without the need to send the workpiece to the quality check room. The improvement in units produced per week was proved by recalculation of production rate that shows the company could produce 34 gaskets unit in a week when using the Go/No-Go Gauge rather than producing 25 gaskets unit before. There is an improvement of 72.73% in distance of movement, 26.47% in units produced and 26.29% in cycle time for whole processes to clearly signify the success of this project. The comparison between before and after the implementation of the gauge has shown that the objective for this case study has been achieved. The cycle time has visualized a proper improvement from 97 minutes to 71.5 minutes to finish 1 unit of square flange gasket. The movement also reduced to 90 meters rather than 330 meters before. It also proof that the idle time caused by movement and waiting time could be eliminated by using the newly designed Go/No-Go Gauge.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Ahsana Aqilah Ahmad, Mohamad Faris Aiman Nor Azaki; **data collection:** Mohamad Faris Aiman Nor Azaki; **analysis and interpretation of results:** Ahsana Aqilah Ahmad, Mohamad Faris Aiman Nor Azaki; **draft manuscript preparation:** Freddawati Rashiddy Wong, Ahsana Aqilah Ahmad, Mohamad Faris Aiman Nor Azaki. All authors reviewed the results and approved the final version of the manuscript.*

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