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# Integration of DMAIC, VSM and Valsat to Reduce Waste in Disk Brake Cutting Process Using DMAIC, VSM and Valsat Method Approach (Case Study: Company IM)

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## ABSTRACT

The Company IM is a manufacturing company that produces two-wheeled automotive spare parts. One of the products currently being supplied to several two-wheeled customers is the disc brake, rear sprocket, and drive sprocket. The opportunity to increase production output adjusted to high customer demand can be done by reducing waste activities. Therefore, an approach with a lean six sigma approach is needed using the integration method of DMAIC (Define, Measure, Analyze, Improve, and Control), VSM (Value Stream Mapping), and VALSAT. This study aims to reduce production waste and reduce cycle time, affecting increasing production output to balance according to customer needs. Waste identification is explained in the Define stage at DMAIC using a big mapping image in Value Stream Mapping. A more in-depth analysis is carried out using the VALSAT tools at the Analyze stage supported by WRM and WAQ questionnaire data. The Analyze stage was then carried out by analyze using the FMEA method. Control is carried out by standardization and outreach to employees. This study aims to identify and reduce the waste in the production area, especially line-cutting disks. Based on the integration results of lean six sigma with the DMAIC, VSM, and VALSAT methods, the efficiency is obtained from 72% to 96%.

***Keywords:*** Lean Manufacturing; DMAIC; Value Stream Mapping; Value Stream Mapping Analysis Tools; Waste; PFMEA

## INTRODUCTION

Development of industrial manufacturing and services is growing increasingly tight, causing competition that is open to scale nationally and internationally. Each company will always strive as much as possible to increase the quality and quantity of production to continue to earn the customers' trust. Because it is in case, it needs to be the one factor that can help maintain the product in the market. To survive and compete in the market, a company always strives to be ahead of the competitors by creating productivity high, product efficiency, and quality high, to be able to compete in the market [1]. Issues on Company IM itself are in a period of development is the cycle time, a process that is not stable between the one with the other and not can meet customers' needs are high for the production of bulk. It is happening because of imbalances in track production on cutting the disk due to inequality in distributing the burden of work at each station work. The imbalance has an impact on work productivity performance. The following is the cutting disk cycle time data in the production process section.

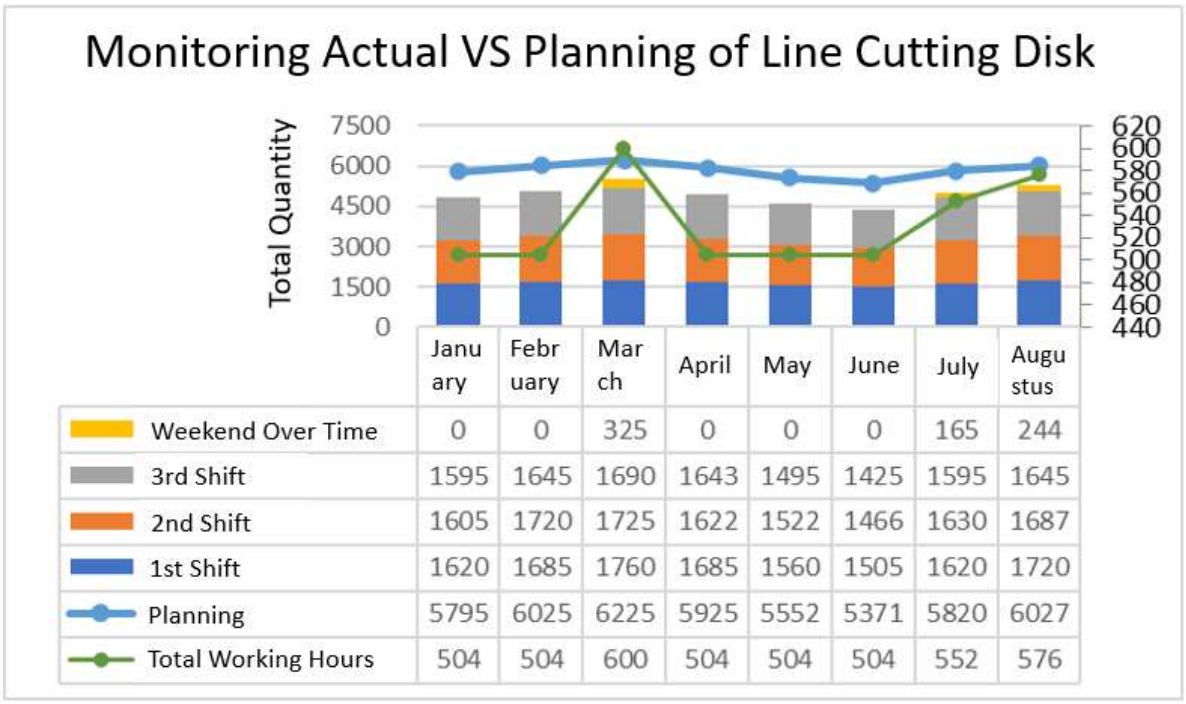
When this in-line production of cutting disk such as that shown in the table at the top, the cycle time in the process Inner diameter cutting is 283 seconds and Outer diameter cutting the cycle time 297 seconds. While cutting, it is still in the line of products that is part of cutting.

**TABLE 1:** Cycle Time Cutting Disk, 2020

| No. | Process Name | Total Man Power | Process Cycle Time / pcs (second) |
|---|---|---|---|
| 1 | Inner Diameter Cutting | 1 | 283 |
| 2 | Outer Diameter of Cutting | 1 | 297 |
| 3 | Mounting Hole Drilling | 1 | 179 |
| 4 | Mounting Hole Chamfering | 1 | 59 |
| 5 | Counter Bore | 1 | 111 |
| 6 | Counter Bore Chamfering | 1 | 58 |

The combined total cycle time produced from Inner diameter cutting and outer diameter cutting is 580 seconds when converted into 10 minutes. The bottleneck resulting in a build-up of Work in Process after the Inner diameter of the cutting head on the Outer diameter cutting the lead to productivity line of production in cutting the disk is reduced and is not efficient. Time is long enough for a production process and material set up. Meanwhile, for the mounting hole drilling, mounting hole chamfering, a counter bore, and counter bore chamfering are still in the process of separately so that the time of waiting and movement takes a long time.

The Company IM faces the problems: the division of the burden of work for line balancing production on line cutting disc. The purpose of balancing the cutting disk production line is to identify the production process by identifying waste, reducing disruptions, increasing production capacity and work efficiency at each work station, and carrying out a series of continuous improvement activities. Efficiency is often associated with the performance of an organization because efficiency reflects the ratio between output (output) and input (input) [2].




| | January | February | March | April | May | June | July | August |
|---|---|---|---|---|---|---|---|---|
| Weekend Over Time | 0 | 0 | 325 | 0 | 0 | 0 | 165 | 244 |
| 3rd Shift | 1595 | 1645 | 1690 | 1643 | 1495 | 1425 | 1595 | 1645 |
| 2nd Shift | 1605 | 1720 | 1725 | 1622 | 1522 | 1466 | 1630 | 1687 |
| 1st Shift | 1620 | 1685 | 1760 | 1685 | 1560 | 1505 | 1620 | 1720 |
| Planning | 5795 | 6025 | 6225 | 5925 | 5552 | 5371 | 5820 | 6027 |
| Total Working Hours | 504 | 504 | 600 | 504 | 504 | 504 | 552 | 576 |

**FIGURE 1:** Line Cutting Disc Comparison Chart, 2020

From the data above, it can be concluded that the cutting process is not achieved every month, which causes the remaining production to be carried out by a third party. It is made of productivity in cutting the disk decreases and makes the process done in the third party increased.

## LITERATURE REVIEW

### Lean Manufacturing

Lean is a system of management that is entirely focused on efficiency, is a philosophy of growth period of long- past efforts increase the value of customers, society, and the economy to reduce costs, accelerate time services, and improve quality through the elimination of waste in total [3].

The principles of lean thinking are looking for a way to create value in the best possible order, arrange the activity of this without interruption, and explain it more and more effectively [4]. Lean thinking provides a way to be with a bit of human, equipment, time, and space, but it is getting close to the consumer. According to [4], there are several stages in lean thinking, namely, understand waste, set goals, understanding the Big Picture, detailed mapping, Involving suppliers and customers, and Reviewing back plans are made. The application of lean will provide many benefits for the company, such as can reduce cycle times (lead time), increase productivity, reduce work in process (WIP), can improve product quality, can utilize the space either by decreasing the distance According to [4].

### Waste Category

[5] explain Taichi Ohno book The Toyota Production System: Beyond Large Scale Production of classifying waste (waste) into seven categories:

a) Waste of Waiting, waiting time is a waste (for example: Waiting for materials to arrive, waiting for decisions/instructions).
b) Waste of Overproduction, making products that are more than customer demand is a waste.
c) Waste of Over processing, a process that is more than the desired customer, is waste.
d) Waste of Defect, reject or repair the waste that can be directly be seen.
e) Waste of Motion, movements that are not necessary and not ergonomics, adds to the time the process is a waste.
f) Waste of Inventory, getting a lot of inventory stored, will increasingly much wastage occur. Wastage of the form: the value of the inventory that is silent (not productive), the value of space which must be provided to save, load administration management, and others.
g) Waste of Transportation, waste which is caused by transport which is not regular.

### DMAIC

*Define (D)*

Define aims to identify the products or processes that will be fixed and determine the sources (resources) needed to implement the project [6]. This stage is the first operational step in the Six Sigma quality control program.

The things that need to be defined Six Sigma project selection criteria, Roles and responsibility of those involved in the project Six Sigma, training needs for the people involved, key processes in a Six Sigma project and its customers, Specific requirements of customers, and statement of Six Sigma project objectives.

*Measure (M)*
Three main things must be done beforehand, namely, select or define key CTQ quality characteristics that relate directly to the customer's specific needs. CTQ can help to improve quality by identifying the critical process to reduce defects [7]. Develop a data collection plan through a measurement that can be performed after the level of the process, output, or outcome. Measure current performance at post-process level, outputs, or outcomes to establish as a baseline for post-start Six Sigma project performance. In connection with measurement, the data can be divided into Data Attributes and Data variables. Data attributes that the qualitative data can be counted for recording and analysis. The data variable is the data quantitatively measured for analysis. Examples are tube length, pipe diameter, box volume, glass height, and others.

*Analyze (A)*
Is the third stage in Six Sigma quality control where things need to be done, among others:

a) Establish targets performance of the characteristics of quality (CTQ) which will be improved in project Six Sigma
b) Identifying the sources and root causes of defect or failure
c) Convert many failures to the cost of the failure of the quality

The tool is used the Pareto chart. Pareto chart is a graph rod that shows the problem is based on the sequence number of events. The problem that most lots going on is shown by the graph rod first the top and placed on the left side, and so on until the problem less happened graph rod past the room and placed in the most right.

*Improve (I)*
The development plan is one of the important activities in the Six Sigma quality improvement program. In this stage, the Six Sigma improvement team decides the achievement, the reason, usefulness of the plan of action, the person in charge, and the plan of action how to implement the plan of action it as well as the benefits positive that approved of implementation of the plan of action was. Every improvement involve workforce because it is one of the factor that can impact significantly to the company [8].

*Control (C)*
It is the final operational stage in a Six Sigma quality control project. Control is the stage where the performance result is documented and disseminated. Practice the best success in improving the process is standardized and disseminated. Procedures are recorded and used as guidelines for labor standards and ownership or responsibility in charge of the process, which means project Six Sigma end at this stage.

**Value Stream Mapping (VSM)**
Value stream mapping is used to identify and eliminate waste. Systems work value stream mapping focuses on the complete mapping in waste to eliminate waste [9]. Value stream can describe activities such as product design, the flow of product, and the flow of information, which supports the activities.

Value stream mapping or commonly known premises Big Picture Mapping is a tool used to describe the system as a whole and the value streams therein. This tool describes the flow of material and information in a value stream.

**Value Stream Analysis Tools (VALSAT)**
According to [10], Value stream analysis tools are used as a tool to help to map out in detail the flow of value (value stream), which focuses on the value-adding process. Detailed mapping is then be used to find the cause of the waste that occurs. There are seven kinds of straightforward mapping tools that are most commonly used, Process Activity Mapping, Supply Chain Response Matrix, Production Variety Funnel, Quality Filter Mapping, Demand Amplification Mapping, Decision Point Analysis, and Physical Structure.

**Process Failure Mode & Effect Analysis (PFEMA)**
FMEA is a system of activities that identify and evaluate the level of failure (failure) the potential that exists in the system, product, or process, especially in parts of the roots of the function of the product or process on the factors that affect product or process [11]. FMEA consists of Design Failure Mode Effect Analysis (DFMEA) and Process Failure Mode Effect Analysis (PFMEA). In the research of waste in the audio bracket assembling production line at PT X, the FMEA analysis carried out is a type of PFMEA by analyze the failures that occur in the initial to final process stages. FMEA is done to generate the value of the RPN by way of multiplying the value of the RPN ( Risk Priority Number ) by way of multiplying the value of rating severity, occurrence, and detection [12].

**RESEARCH METHODS**
This research begins with knowing the problem that the high cycle time in the manufacture of the disc brake in the cutting production line of the Company IM. It's become a problem for the production of bulk. The Company IM cannot meet the needs of the customer's production with the amount that is high in one month. An initial study was conducted to obtain information about the research that will be done. Study Preliminary done for a feasibility study regarding the research procedure and respect others who are still not clear.

Data Collection is carried out in two stages. First, a Literature study observes the production process, time measurement, and trajectory balance in the production area. Next, Field observations are carried out by direct interviews with production operators and direct observations in the field in the production area. The existence of an imbalance of the track production in the manufacture of disk brake line cutting disk in Company IM then does the test try to use the methods of eliminating waste with lean manufacturing approaches are as DMAIC, VSM, and VALSAT.

**RESULTS AND DISCUSSION**
**Analysis of Waste with the Integration of DMAIC, VSM, and VALSAT**
The problem which becomes discussion in empirically is a cycle that is too high in the line of production that caused their waste or waste that does not give a value-added to the product.

**Define**
On stage define, with the goal identify main waste on line cutting disc is integrated with a method Value Stream Mapping (VSM) to describe the big picture / current state mapping. Map conditions can be seen in figure 4. At this stage, potential activities can be identified by identifying Value Added (VA) and Non-Value Added (NVA).

**TABLE 2:** VA and NVA results

| Process | Waktu | | Grand Total |
|---|---|---|---|
| | NVA | VA | |
| Inner Diameter Cutting | 184 | 99 | 283 |
| Outer Diameter Cutting | 184 | 113 | 297 |
| Mounting Hole Drilling | 105 | 74 | 179 |
| Mounting Hole Chamfering | 46 | 13 | 59 |
| Counter Bore | 48 | 63 | 111 |
| Counter Bore Chamfering | 47 | 11 | 58 |
| Total | 614 | 373 | 987 |

Based on table 2, the value of NVA very high, so do the analysis is more advanced on the stage of measure and analysis with integration tools VALSAT to reduce cycle time, process and reduces waste in line production of cutting disks.

**Measure**

The calculation phase in this study was carried out to measure the average cycle time in the previous condition to know the efficiency of the previous condition. The goal is to identify the station's workpiece with a load of work excess done balancing the workload at each station work.

**TABLE 3:** Line Cutting Disc Cycle Time

| Station | Cycle Time (second) |
|---|---|
| Inner Diameter Cutting | 282 |
| Outer Diameter Cutting | 290 |
| Mounting Hole Drilling | 179 |
| Mounting Hole Chamfering | 59 |
| Counter Bore | 110 |
| Counter Bore Chamfering | 59 |

Based on table 3, the time cycle highs are in the process of outer cutting, so defined as a bottleneck and a production cycle. Based on the time cycle at the top with a production capacity in one shift able to produce 70 pcs per shift, the efficiency of production capacity is 72%.

In efforts to increase the efficiency and capacity of production, subsequently carried out stages of analysis is more about the tools VALSAT using a questionnaire Waste Relationship Matrix (WRM) and the Waste Assessment Questionnaire (WAQ).

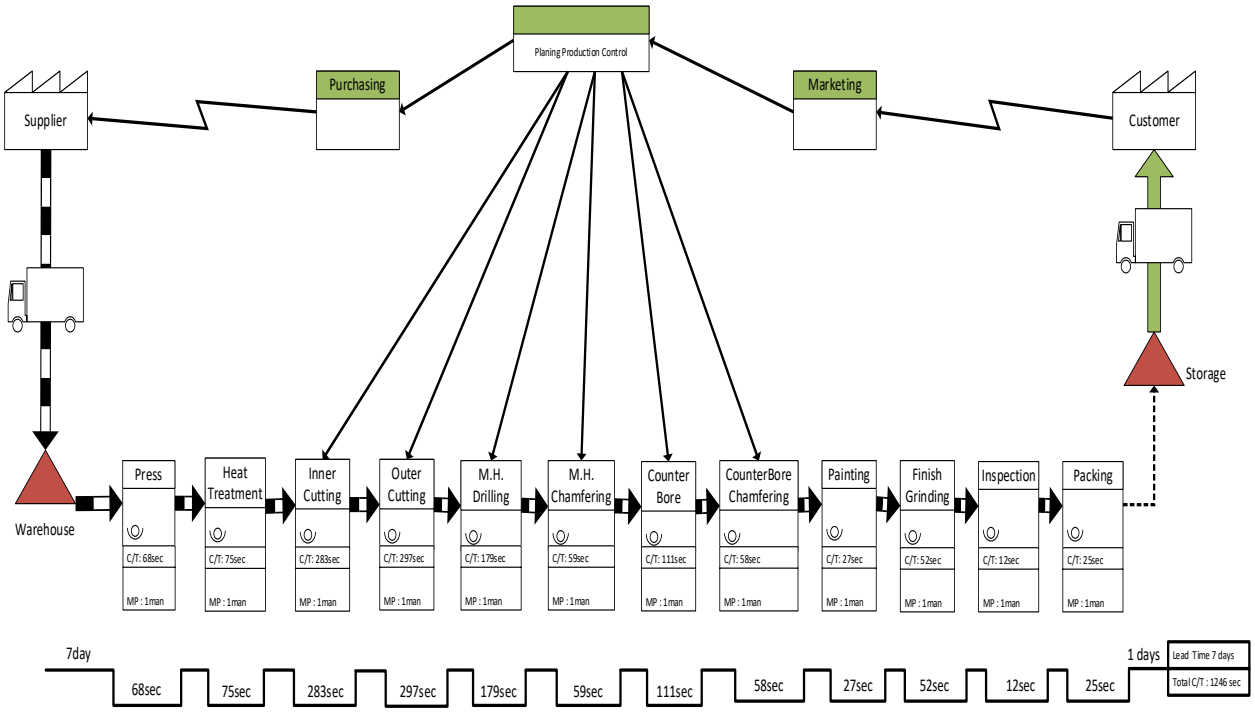



**FIGURE 4:** Current State Value Stream Mapping Line Cutting Disk

**Analyze**

Stage analysis is carried out by processing the data from the results of the deployment questionnaire to several departments Production, Quality, PPIC, and Warehouse) linked from the level of staff to the leader who contributes directly to the production of these. The following is a chart of questionnaire data processing results.

Based on the chart Pareto chart, note that the six categories of waste significantly affect the production process on the line cutting disk. The analysis subsequently selected the six largest categories.

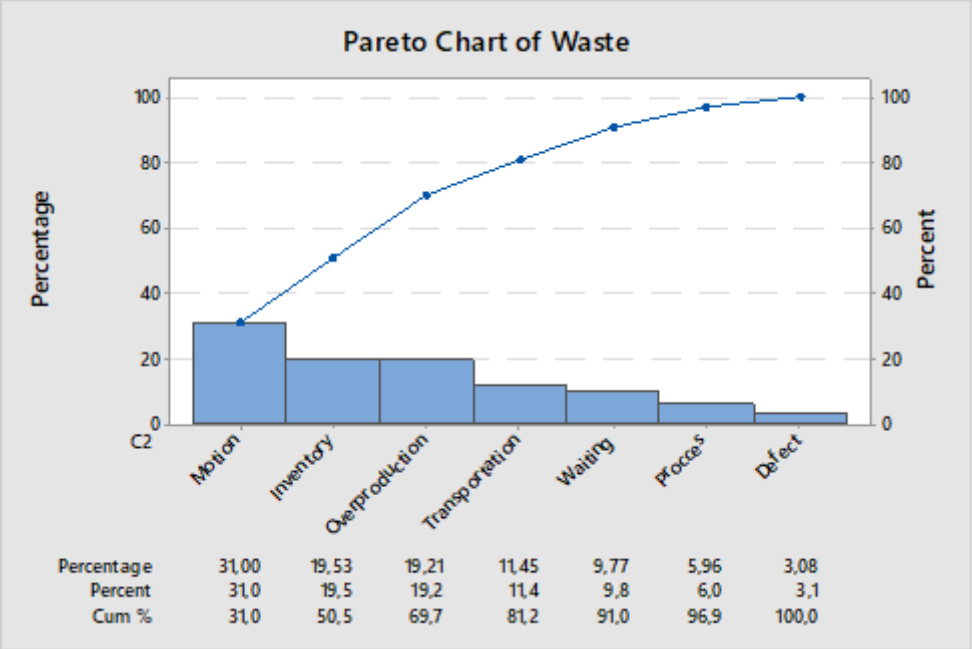



**FIGURE 5:** Percentage of Line Cutting Disc Waste Rate

The analysis further using tools PFMEA to determine the activity of improvement based on the value of the RPN to know the recommendation improvements by priority greatest. Here are the results of the analysis of FMEA to the six categories of waste were selected. The PFMEA table can be seen in TABLE 4.

Determine the value of severity, occurrence, and detection based on analysis and brainstorming to some departments related. Based on the results of the NDP on the table PFMEA on top of a known sequence of RPN highest that is in the process of inner and outer cutting the lead to wastage of the highest because they use two engines and two workforces in the process set up.

**TABLE 4:** PFMEA Analysis of Types of Waste *Line Cutting Disc*

| No. | Type of Waste | Failure | S | Potential Failure Effects | O | Potential Causes | D | Recommendation | RPN |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Motion | The setting process for JIG cutting is too long | 6 | Design and soft jaw chuck are still less efficient to do the set up early | 9 | The movement to set up Chuck and Soft Jaw too long because there are two components to one time set up | 7 | Combining the design between the chuck and soft jaw into one component | 378 |
| 2 | Motion | Time waiting at the time of the inner and outer cutting | 7 | In the inner and outer cutting process using 2 machines and 2 workforces | 10 | Design chucks are used still separate between the inner and outer cutting so that the process uses two machines | 6 | Changes in design chuck incorporated into the inner and outer cutting the stopper is on the Reduction Holes Part | 420 |
| 3 | Inventory & Overproduction | Stacking of WIP after the MH Drilling process | 5 | Balance process between M.H Drilling and chamfering not balance | 10 | Stacking material after MH Drilling for the division of the burden of work is not evenly distributed so that the buildup of inventory processes chamfering and overproduction in the MH Drilling | 7 | Combining MH Drilling and Chamfering processes. With the inclusion of the NC program for the chamfering process | 350 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | Transportation & Motion | The taking of each WIP is still too far | 5 | Time wait between each method requires a long | 10 | The location between the engine inner-outer, drilling, chamfering, and counter bore is less efficient because the distance between the engine was still too far away | 6 | Re-layout and created a new concept called "U LINE" for all cutting processes | 300 |
| 5 | Process | The failure of the current process (chamfering back) counter bore | 5 | Dimensions of the chamfer back on the counter bore not been stable | 9 | There is no stopper on the chamfering machine so that the operator can only detect it visually | 6 | Addition stopper fix for setting the height of the tools to prevent the occurrence of over-spec at the time of the process | 270 |

**Improvement**

Activities improvements were recommended in tools PFMEA effects that significantly increase the efficiency of capacity and reduce production cycle time. The following are improvement activities that were carried out.

JIG Setting Process That Is Too Long

Improvements are done to combine the soft jaw and chuck into one component. The improvements are be obtained to decrease the cycle time set up from the previous 30 minutes or 1800 seconds into 10 minutes or 600 seconds. Decrease the cycle time set up by 20 minutes or 1200 seconds.

10 minutes: 480 minutes = 0.020 minutes

(1.25 seconds / 1 second)

The Waiting Time for the Inner and Outer Cutting Process is Still Too Long

Improvement combines the inner and outer cutting into one process by changing the chuck design into one component. Before improvement, the data for the inner cutting process was on the outer, and the datum's outer cutting process was on the inner. After the design is changed to one component, the datum is in the Weight Reduction Hole material.

Once the inner and outer cutting process is coupled, it obtained results of improvements made that a decrease in the cycle time of the process, a reduction in the use of machines of two machines into one machine, and workforce reduction.

WIP Stacking After MH Drilling Process

Once done improvement process between MH Drilling, Counter Bore, and Mounting Hole Chamfering be used as one process. Brother NC machine using a hydraulic clamp with a 4 - 5 bar wind pressure. Do not need any handling of materials between one process to the other.

The counter bore process does not use a manual process with a long setup time. Everything has become a component of the process, only setting tools in the NC program to determine the offset height. With a total cycle time of 357 seconds to three processes with the time running.

Taking of Each WIP Is Still Too Far

After going through the inner and outer cutting process, the material will be processed by mounting hole drilling. The location between the inner and outer cutting machines with the mounting hole drilling is still too far away, creating a long movement time and requiring additional transportation.

Layout line cutting disk improved to be re-layout into a U LINE. U- shaped line to make it easier for operators when handling material from each process. From the changes in the line cutting disk layout, it is found that the cycle time is efficient to make it easier for operators during material handling.

Failure in Current Process Counter Bore Chamfering

Improvements were made that added stopper on the machine to prevent the occurrence of human error. The improvements are made in the form of addition of stopper bolts on the engine to facilitate the operator when a process does not happen by human error. The addition expected will increase the effectiveness of the machine and increase the production output [13]. And the obtained results were stable following the dimensions of the process sheet that has been determined is 0.6 to 0.8 mm.

**Control**

At the control stage of the improvement process, socialization was carried out to related parties, namely the cutting disk department, with documentation of making new standards in Standard Process, Check Sheet, and 4M.

**RESEARCH RESULT**

**VA and NVA results**

Reduction of waste in the manufacture of disk brake line cutting disk, the following is a comparison of Value Added Time and Non-Value-Added Time. Table 5 shows there are time reduction after the improvement. The total of process reduced from six processes to three processes.

**TABLE 5:** Comparison of VA & NV A

| Before Improvement Process | Time | | Grand Total | After Improvement Process | Time | | Grand Total |
|---|---|---|---|---|---|---|---|
| | NVA | VA | | | NVA | VA | |
| Inner Diameter Cutting | 184 | 99 | 283 | Inner & Outer Diameter Cutting | 151 | 94 | 245 |
| Outer Diameter Cutting | 184 | 113 | 297 | Mounting Hole Drilling, Chamfering, & Counter Bore | 250 | 107 | 357 |
| Mounting Hole Drilling | 105 | 74 | 179 | Chamfering Counter Bore | 35 | 13 | 48 |
| Mounting Hole Chamfering | 46 | 13 | 59 | Total | 436 | 214 | 650 |
| Counter Bore | 48 | 63 | 111 | | | | |
| Counter Bore Chamfering | 47 | 11 | 58 | | | | |
| Total | 614 | 373 | 987 | | | | |

**Reduction of Cycle Time**

Minimizing waste in disc brake line cutting disks reduces cycle time from 979 to 645 second.

**Increased Production Capacity Efficiency**

The following is a comparison of capacity efficiency before and after making improvements to the manufacture of disc brake line cutting disks.

**TABLE 6:** Comparison of Production Capacity Efficiency

| Improvement | Before | After |
|---|---|---|
| Working time (minutes) | 480 | |
| Cycle Time (second) | 297 | 118 |
| Production Capacity (pcs / hour) | 12 | 31 |
| Actual Production daily (pcs) | 70 | 235 |
| Net Working time (hours) | 5.775 | 7.70 |
| Net Working time (minutes) | 346,5 | 462,167 |
| Capacity Efficiency | 72% | 96% |

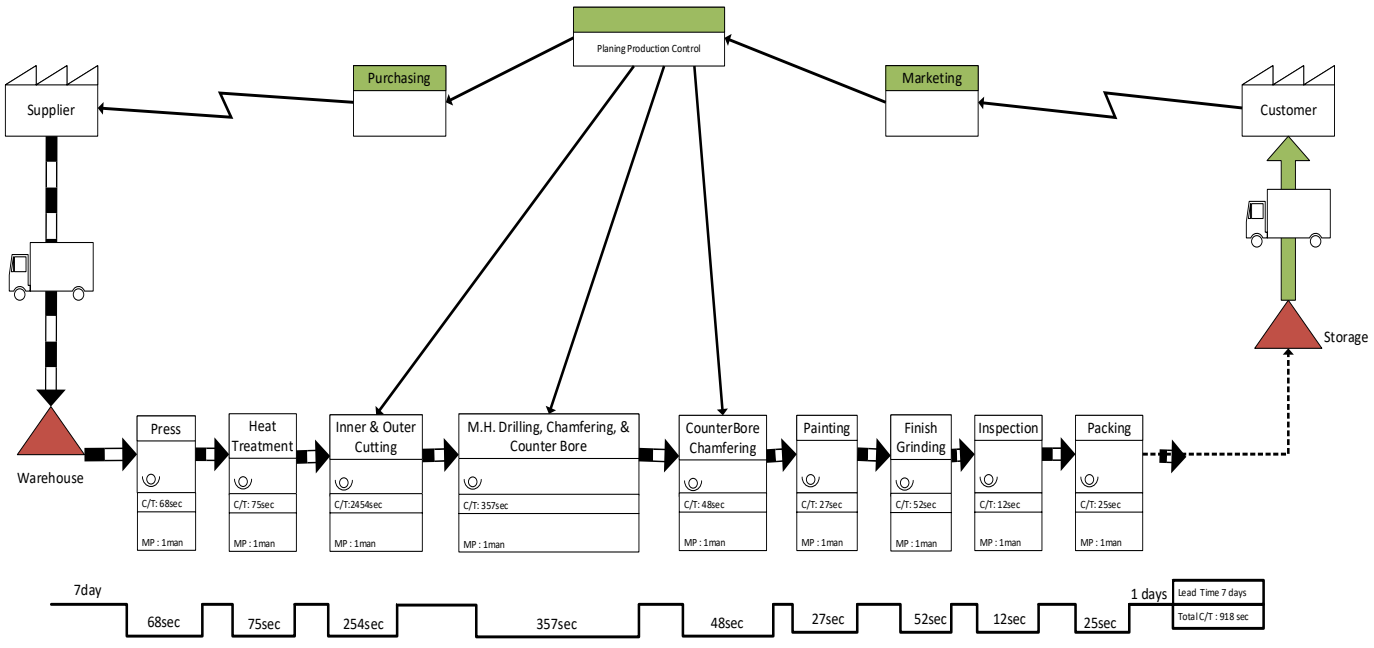



**FIGURE 10:** Future State Value Stream Mapping Line Cutting Disk

**CONCLUSION**

Based on the results of integrating lean six sigma with the DMAIC, VSM, and VALSAT methods, it can be seen that the causes of waste that occur in disc brake manufacturing in line cutting disks are motion, inventory, overproduction, transportation, waiting, and process.

The total time of the current activity is 979 seconds, with a bottleneck on the outer cutting is 290 seconds. After the improvement stage, the total cycle time was reduced to 645 seconds. Outer cutting becomes 246 seconds with two processes using one machine. The reduced cycle time resulted in a capacity efficiency that increased from 72% to 96%.

Based on the analysis of the causes of waste in disk brake line cutting discs, some improvements can be waged. First, setting chuck and soft jaw with modifications that combine with the soft jaw and chuck into one component. The second, waiting for the inner and outer cutting is still too long. Improvements were made which combines the inner and outer cutting into one process by changing the chuck design into one component. Before improving the datum for the inner cutting process, it was on the outer and vice versa in the outer cutting process. The datum was on the inner. After the design is changed to one component, the datum is in the Weight Reduction Hole material, which previously used two engines and two workforces. After improvement, it became one engine and one workforce. The third is the accumulation of work in process (WIP) after the mounting hole drilling improvement process between MH Drilling, Counter Bore, and Mounting Hole Chamfering. It can be used as a process by using a machine, NC Brother using the clamp hydraulics with pressure-wind 5 bar.

Do not need any handling of materials between one process to the other. The counter bore process does not use a manual process with a long setup time. Everything has become a component of the process, only setting tools in the NC program to determine the offset height. With a total cycle time of 357 seconds to three processes with the time running. Fourth, each work in process (WIP) is still too far away for improvements that of the layout line cutting disk done re-layout into a U LINE. U- shaped line to make it easier for operators when handling material from each process, so that before improving from six processes to three processes with only one operator. Fifth, failure when the counter bore chamfering Improvements were made that added stopper on the machine to prevent human error.

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