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Increasing Factory Productivity Through Casting Machines with Cycle Time Analysis Using Theoretical Value Production & PDCA Methods

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Abstract:- Research was conducted at a company that manufactures automotive components for both two-wheeled and four-wheeled vehicles which are made from aluminum as the raw material. The processes in this company are die casting, machining, assembly, & painting. In this research, the author focuses on examining the die casting process. The OEE value in May, June & July 2023 did not reach the target of 85% of the target set by the company and the forecast for 2024 could not be met.

This research discusses how to increase productivity so that the output from the die casting process increases and increases the OEE results on machines no. 2 and no. 6. Then the value, semi-value and non-value movements were classified using theoretical value production (TVP) and the results of discussions with experienced people in their fields through focus group discussions, obtained a cycle time of 40 seconds with a value movement of 9.95 seconds, semi-value of 23.08 seconds, and non value of 6.91 seconds. Meanwhile, for machine no. 6, the cycle time value obtained was 37 seconds with a movement value of 7.99 seconds, semi value of 22.40 seconds, and non value of 6.61 seconds.

PDCA analysis was carried out on non-value movements through focus group discussions. The results of the PDCA analysis provide improvement ideas based on improvement categories with eliminate, combine, re-range, simplify (ECRS). From the results of the repair simulation, it was found that the cycle time on machine no. 2 was reduced by 6.91 seconds to a total of 33.03 seconds with a productivity of 1.27. Meanwhile, for machine no. 6, it decreased by 6.61 seconds to a total of 30.39 seconds with a productivity of 1.29. This research provides very useful insights and can be implemented on all machines in the company.

Keywords:- *Productivity, Cycle Time, Improvement, OEE.*

I. INTRODUCTION

The company where the author conducted the research is a manufacturing industry company that operates in the automotive sector for the manufacture of aluminum-based four-wheeled and two-wheeled components using the die casting, machining & painting process method. The products made by this company are oil pumps, water pumps, crank case covers and steering racks which are located in Karawang. In each process, the company controls its production efficiency using Overall Equipment Effectiveness (OEE). OEE is a combination of 3 factors: availability, performance, and quality which tells how efficient an asset is during the manufacturing process. Where the current operational challenge is that the production process is not running optimally and there is a lot of process time loss.

The problem experienced by the company regarding production efficiency is that there is still a lack of effectiveness regarding production results or output from production. This company has only taken and calculated its OEE and started in 2018. Then analysis of the OEE results must be carried out to increase productivity which has not yet been carried out. And another problem is the company's lack of capacity to meet customer demand and it also faces increasing labor costs every year. Therefore, the author is interested in conducting research on how to increase productivity and get cost merit in the company. The process that will be used as the object of research is the casting machine process which is used to process parts in motorbike engines.

The following table 1 is data on OEE results for the last 3 months from the parts process using a casting machine:

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Table 1 Casting Machine OEE Results for the Last Three Months

Mesin		1	2	3	4	5	6	7	8	9	10
Hasil OEE	Mei	81.22	80.30	83.56	81.56	85.05	81.54	81.23	83.67	86.23	85.23
	Juni	80.34	81.89	84.70	82.37	84.80	82.90	82.34	80.56	87.21	86.12
	Juli	83.46	80.90	82.56	83.72	85.55	80.20	85.12	83.24	86.23	87.23
Target		Terendah 2 85% Terendah 1									

Mesin		11	12	13	14	15	16	17	18	19	20
Hasil OEE	Mei	81.23	85.33	92.02	82.34	85.23	86.23	83.88	82.34	86.23	93.23
	Juni	83.26	87.34	89.22	85.05	84.32	88.23	89.34	84.56	87.21	89.45
	Juli	88.89	90.24	87.45	84.59	85.05	85.68	85.12	88.23	86.23	90.78
Target		85%									

The following are figures 1 and 2 regarding customer demand data in 2024 compared to machine capacity:

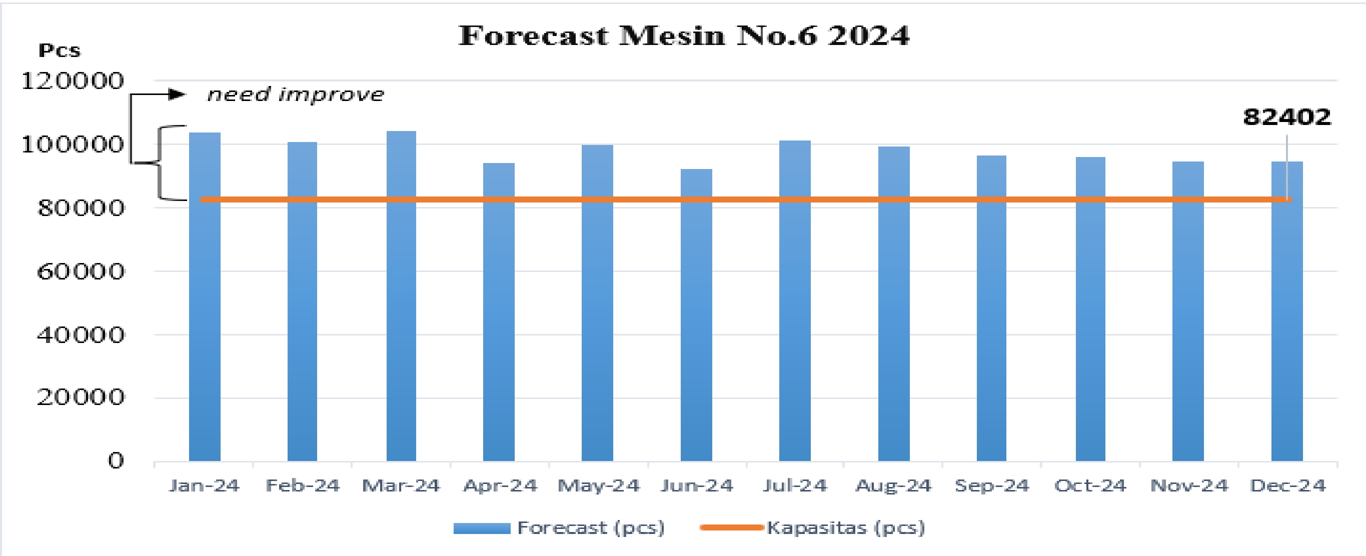

Fig 1 Forecast 2024 Vs Machine Capacity 2 (Tonnage 350T)

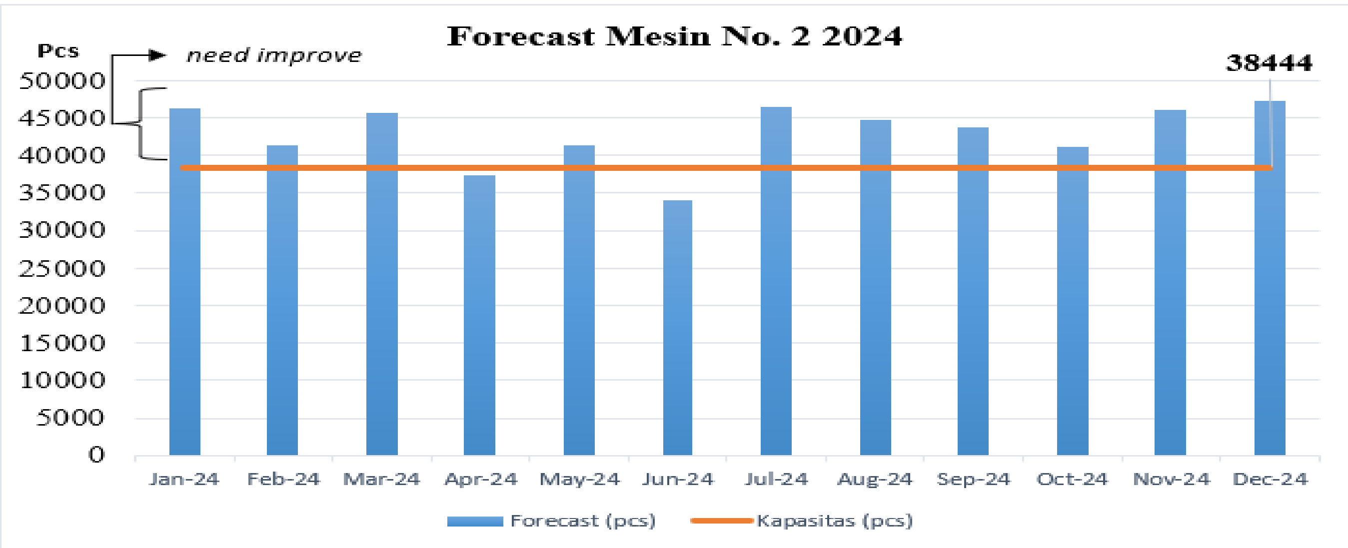

Fig 2 Forecast 2024 Vs Machine Capacity No. 6 (Tonnage 250T)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL828

If we look at the OEE results of part processing with machines no. 2 & no. 6 at the company over the last three months, it can be seen that these results still have not reached 85% of the company's target and are the lowest compared to other machines. Then the cycle time for the output is as in table 2:

Table 2 Comparison of Output on Machines

No. Mesin	Item	Output
2	Cycle Time mesin per 1 pcs	40 Detik
	Output perjam OEE 80.9%	72 pcs/H
6	Cycle Time mesin per 1 pcs	18.5 Detik
	Output perjam OEE 80.2%	156 pcs/H

By looking at table 2 above, the author made the initial research standard in July, namely machine 2 with an output per hour of 72 pcs with an OEE of 80.9% and machine 6 with an output per hour of 156 pcs with an OEE of 80.9% because in that month and machine number the results were the lowest. . And then the results of this research can later be used for other machines.

II. LITERATUR REVIEW

A. *Theoritical Value Production (TVP)*

Theoritical value production (TVP) is a theory to increase product efficiency and reduce losses based on OEE performance results, then categorizes work process movements into 3 types, namely value, semi-value and non-value. In general, the definition of theoretical value production (TVP) is a system of manufacturing perspective that allows the production of output or production results that adhere to quality, cost and delivery, as well as implementing continuous improvement or kaizen. The TVP theory is often used by the Japanese manufacturing industry, one of which is the Yamaha company [1].

B. *Lean Manufacturing*

Lean Manufacturing, proposed by Gasperz (2007), is defined as a theory for identifying and eliminating waste or non-value-added activities through radical continuous improvement with a method of flowing products (material, work in process, output). and information using pull systems from internal and external customers to seek excellence and perfection in the manufacturing industry [2].

C. *Waste*

Waste in the production system which is categorized into 7 definitions of waste according to Suhartono (2007) is as follows:

- *Overproduction*

Waste caused by excessive production, which means producing more products than are needed or producing earlier than the schedule that has been made.

- *Waiting*

Waste occurs due to waiting for the next process. Waiting is a time interval when the operator does not use the time to carry out value adding activities because he is waiting for the product flow from the previous process.

- *Transportation*

Transportation is an important activity but does not add value to a product. Transportation is the process of moving material or work in process (WIP) from one work station to another, using either a forklift or conveyor.

- *Excess processing*

Waste occurs when the work method or process work sequence used is deemed not good and flexible. This can also happen when the existing process is not standard so the possibility of damaged products is high. There are variations in the methods used by operators.

- *Inventories*

Less necessary supplies. What this means is too much material inventory, too much work in process between one process and another so it requires a lot of space to store it, the possibility of this waste is a very high buffer.

- *Motion*

Unnecessary activities or movements carried out by operators that do not add value and slow down the process resulting in long lead times.

- *Defects*

Products that are damaged or do not comply with specifications. This will lead to a less effective rework process, high levels of complaints from consumers, and very high levels of inspection [3].

D. *Time Management*

According to Atkinson (2012), using time productively is characterized as a kind of ability that is identified with all types of efforts and activities carried out by individuals in a planned manner so that the individual can utilize their time [4].

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E. Production Efficiency

According to Mulyamah (1987) effectiveness is an action that compares the regular use of information sources and actual use or all actual use [5].

F. Manufacturing Time Cycle

- *Cycle Time*

In general, process duration is the time required to complete the manufacture of one unit from start to finish. By being aware of the length of the process, it will be easy for us to increase the process duration or what is usually called reducing the process duration.

- *Motion and Time*

According to Barnes, motion and time investigation is a science that consists of procedures and standards to obtain the best plan from a framework [6].

G. Overall Equipment Effectiveness (OEE)

According to Nakajima (1988), Overall Equipment Effectiveness (OEE) is a method of measuring the level of effectiveness of using equipment or systems by including several points of view in the calculation process [7].

H. Framework

The thinking framework according to Sugiyono (2021) is a conceptual model of how theory relates to various factors identified as important problems. The thinking framework will explain the relationship between the variables to be studied [8].

The framework for thinking in this research, namely analyzing and measuring value added and OEE to obtain corrective action, can be explained in Figure 3.

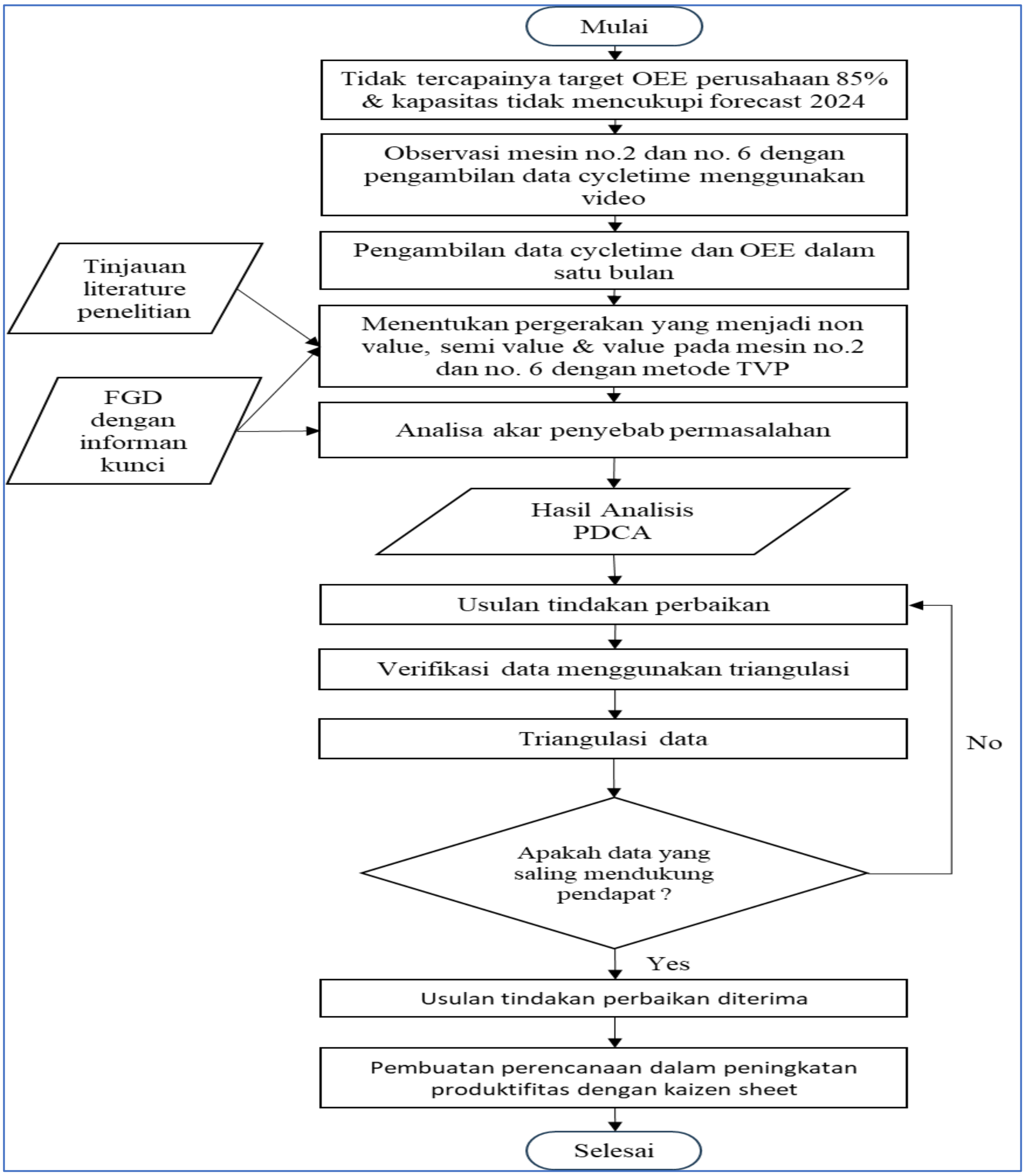

Fig 3 Framework

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III. RESEACH METHOD

The research design used in this research combines a quantitative research design where observations are made on the casting machine and a qualitative method for analysis of improvements using PDCA by means of FGD. The activities carried out in this research include preliminary study strategies, problem formulation, problem definition, research objectives, data collection by taking videos of machine movements. Then analyze the data and classify the movement of the casting machine in one process cycle which includes value where the main movement converts the material into a product, semi value where the movement supports the value movement with a minimum distance, and non value added where the movement is not needed based on TVP theory. The classification is analyzed & provides ideas for improvement with PDCA by means of focus group discussions with several informants who have authority and long experience and provide conclusions & suggestions.

IV. RESULT & DISCUSSION

A. *Observe Machine Movement*

The results of observing the movement of the casting machine by analyzing videos of the movement of the machine in one process cycle showed several movement processes, namely:

- *Mold Close Process*

On machine no. 6 in this process has a semi value movement of 337mm with a movement time of 0.84 seconds and a non value of 63mm with a movement time of 0.17 seconds. On machine no. 2 in this process has a semi value movement of 350mm with a movement time of 0.7 seconds and a non value of 100mm with a movement time of 0.37 seconds, which can be seen in Figure 4.

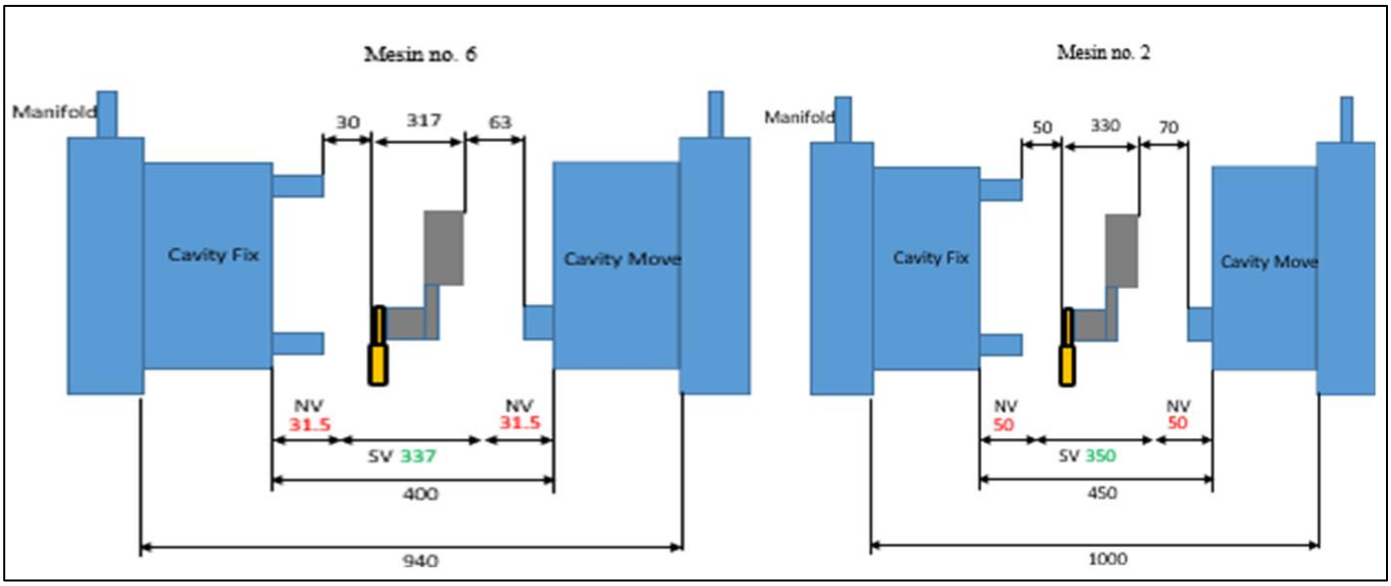

Fig 4 Mold Closes Process

- *Pouring Process*

On machine no. 6 in this process has a semi value movement at laddle position 540 with a movement time of 4 seconds and a non value movement at laddle position 470 with a movement time of 0.8 seconds. On machine no. 2 in this process has a semi value movement at laddle position 540 with a movement time of 4.9 seconds and a non value movement at laddle position 470 with a movement time of 0.9 seconds which can be seen in Figure 5.

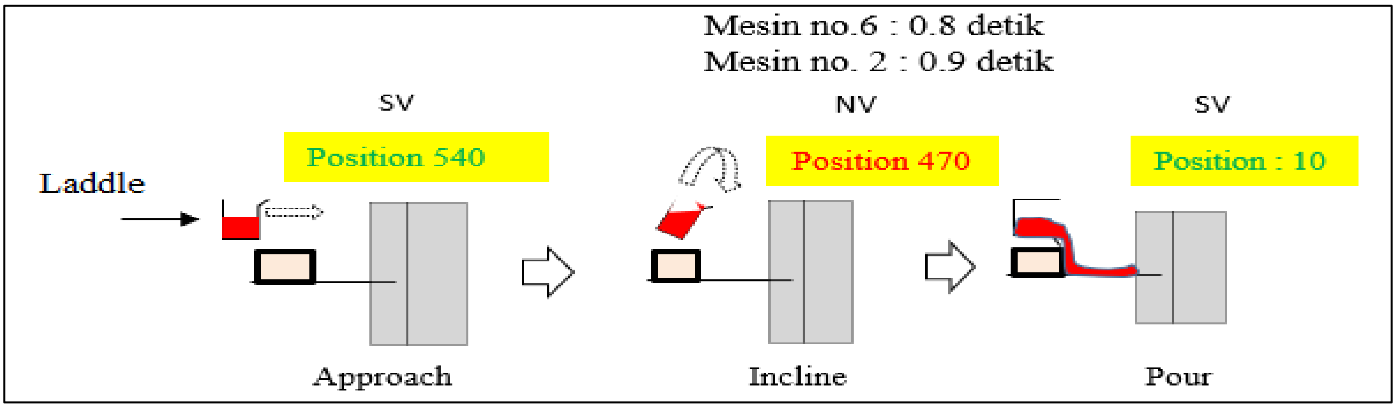

Fig 5 Pouring Process

- *Inject Process*

On machine no. 6 in this process has a semi-value movement by pushing the material towards the mold, the time required is 2.25 seconds. And on machine no. 2 in this process has a semi-value movement by pushing the material towards the mold, the time required is 2.13 seconds. It can be seen in figure 6.

Fig 6 Inject Process

- *Holding Process*

On machine no. 6 in this process has the main movement in forming the material into a product and includes the value movement with a processing time of 7.99 seconds. And on machine no. 2 value movements with a processing time of 9.95 seconds. It can be seen in figure 7.

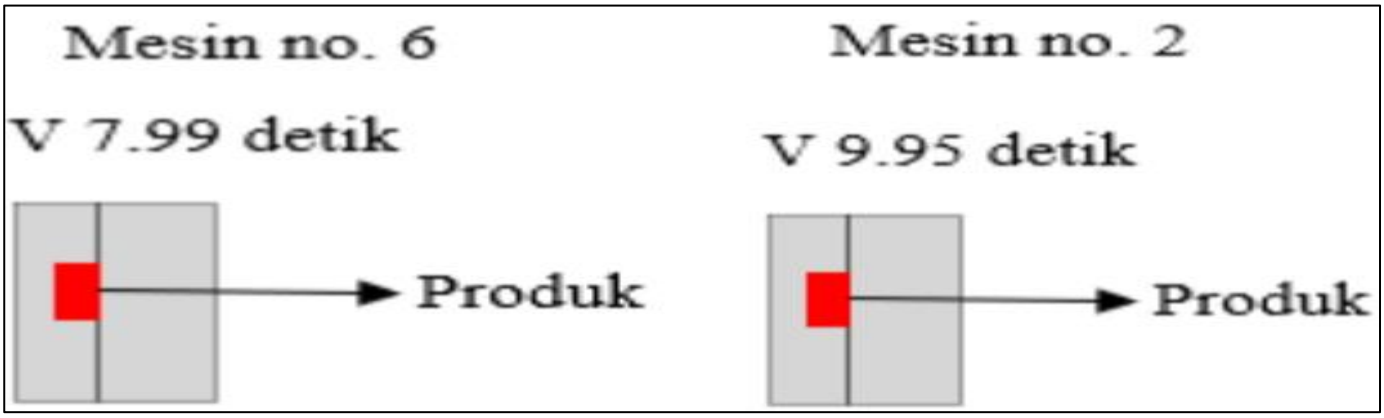

Fig 7 Holding Process

- *Mold Open Process*

On machine no. 6 in this process has a semi value movement of 337mm with a movement time of 0.84 seconds and a non value of 36.5mm with a movement time of 0.26 seconds. On machine no. 2 has a semi value movement of 350mm with a movement time of 1.11 seconds and a non value movement of 50mm with a movement time of 0.7 seconds. It can be seen in figure 8.

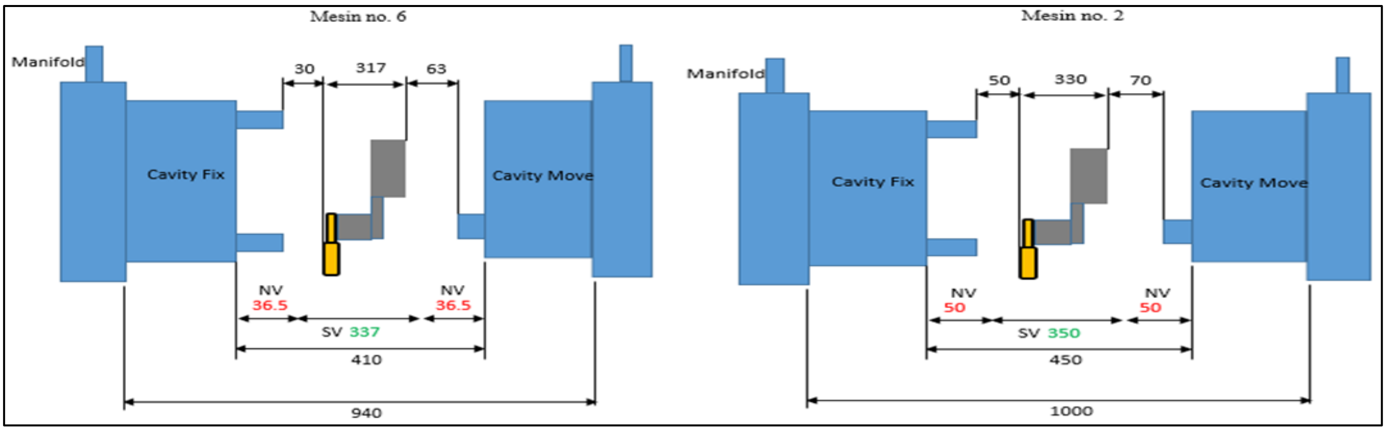

Fig 8 Mold Open Process

➢ *Robot Process*

On machine no. 6 in this process has a semi value movement of 100mm with a movement time of 5.59 seconds and a non value of 149mm with a movement time of 1.05 seconds. And on machine no. 2 in this process has a semi value movement of 100mm with a movement time of 4.49 seconds and a non value of 120mm with a movement time of 1.84 seconds. It can be seen in figure 9.

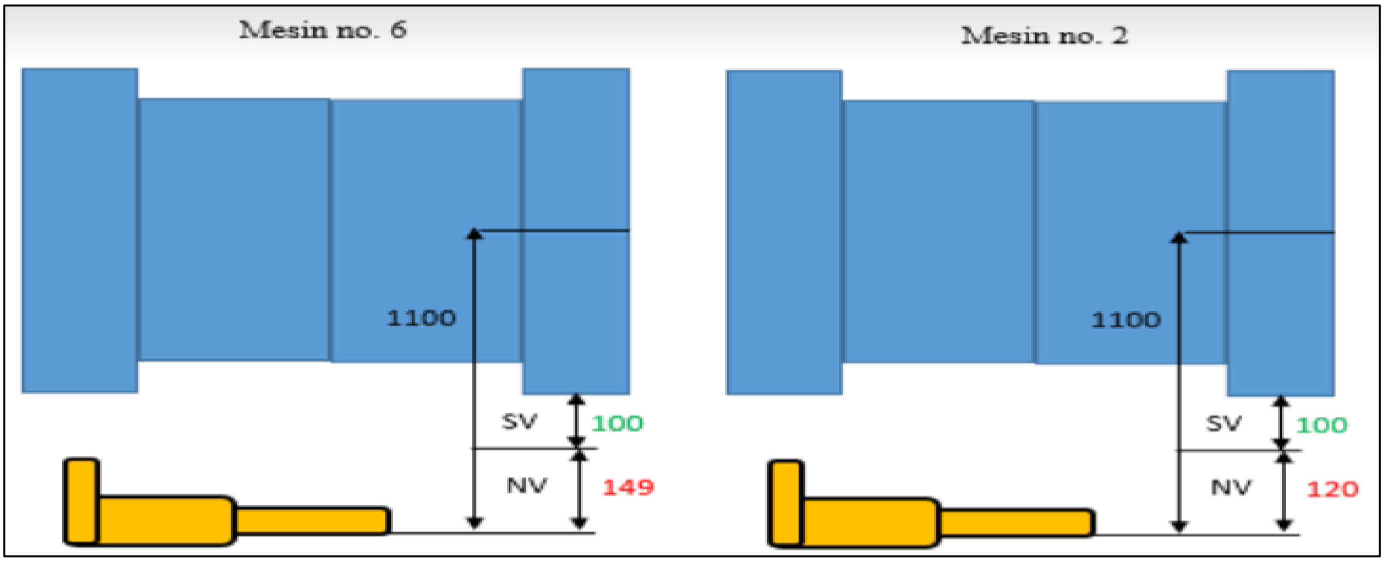

Fig 9 Robot Process

➢ *Spray Process 1*

On machine no. 6 in this process has a semi value movement of 10mm with a movement time of 3.79 seconds and a non value of 40mm with a movement time of 1.08 seconds. On machine no. 2 has a semi value movement of 10mm with a movement time of 5.80 seconds and a non value movement of 70mm with a movement time of 1.25 seconds. It can be seen in figure 10.

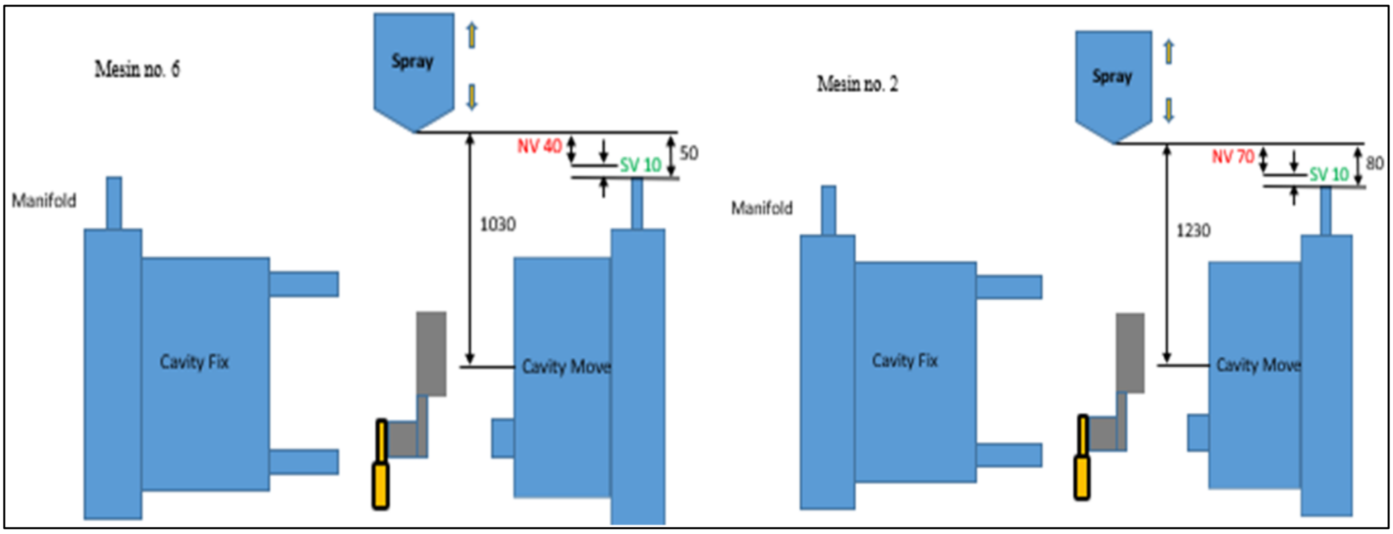

Fig 10 Spray Process 1

➢ *Spray Process 2*

On machine no. 6 in this process does not have semi value movement and the spray movement rotates 90° including non value movement time of 3.05 seconds. On machine no. 2 has a semi value movement with a spray movement rotating 45° with a time of 1.85 seconds and a spray rotating to 90° including non value movement with a movement time of 1.85 seconds. It can be seen in figure 11.

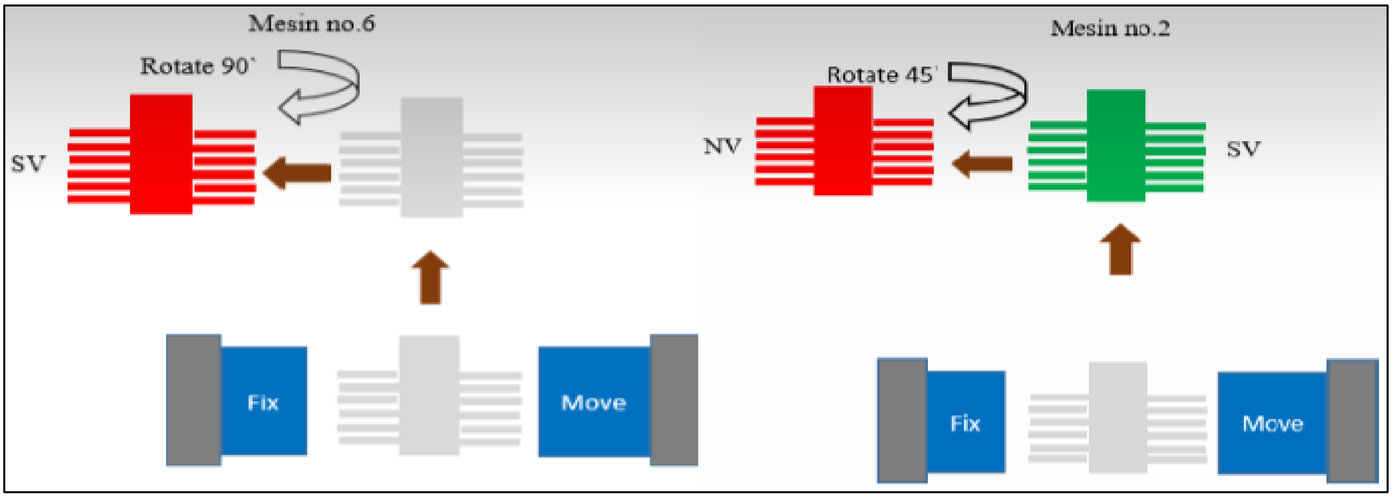

Fig 11 Spray Process 2

From the movement classification, the time for each category is obtained in one cycle process. It can be seen from pictures 12 and 13.

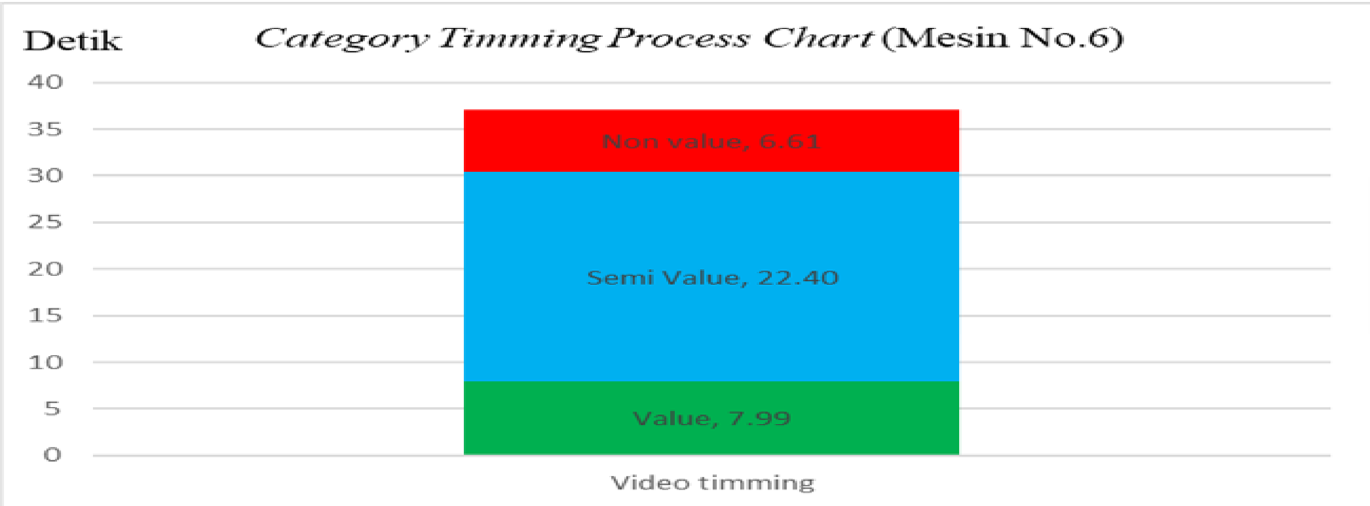

Fig 12 Timming Process Machine No. 6

On machine no.6 the total time includes value movements of 7.99 seconds, semi value 22.40 seconds and non value movements of 6.61 seconds where these non value movements will later be eliminated.

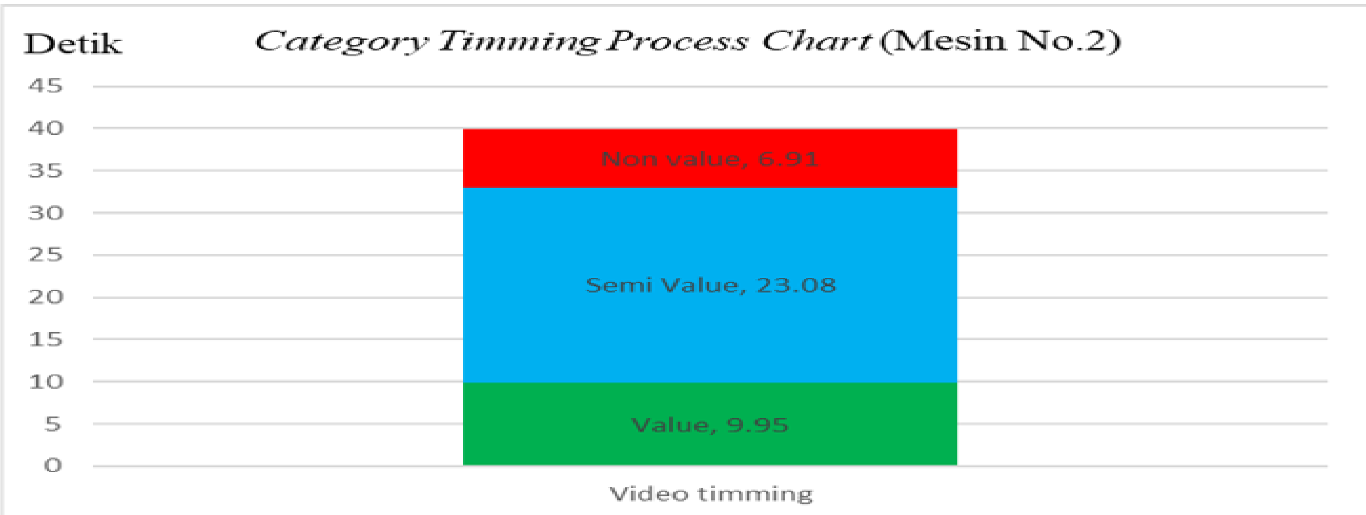

Fig 13 Timming Process Machine No. 2

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On machine no.2 the total time includes value movements of 9.95 seconds, semi value 23.08 seconds and non value movements of 6.91 seconds where these non value movements will later be eliminated.

B. Analysis and Evaluation with PDCA Through FGD

➢ *Analysis of Machine Process Movements*

With the data that has been obtained, problem analysis, planning, implementation, inspection, improvements are carried out on non-value movements on machines no. 2 and no. 6 through discussions with informants through focus group discussions. The results of this PDCA are:

- Machine no.2 and machine no.6 can be improved using the same method. by eliminating movements that are non-value added.
- Requires tools & methods to support improvement.
- Inspection of safety after making improvements.
- Making standards after making improvements.
- Calculation of OEE and productivity to be achieved for the company.
- Improvements can also be carried out on all existing casting machines in the same way.

C. Ideas for Improving Machine Process Movements

➢ On mold closing process, researchers provide improvement ideas so that the distance between the two sides of the mold before it closes is shortened and the mold closing speed is increased. This improvement idea is included in the "Rearrange" category. On machine no. 6 by reducing the position distance before the mold closes from 400 mm to 337. In addition, the speed of the mold closing process is increased from 396 mm/s to 400 mm/s. The time required for the mold close process is reduced from 1.01 seconds to 0.84 seconds. So the effect of reducing cycle time is 0.17 seconds. On machine no.2 by reducing the position distance before the mold closes from 450 mm to 350. In addition, the speed of the mold closing process is increased from 420 mm/s to 500 mm/s. The time required for the mold close process is reduced from 1.07 seconds to 0.7 seconds. So the effect of reducing cycle time is 0.37 seconds.

➢ On pouring process researchers provide an improvement idea by positioning the laddle angle from 0° to 45° so that it can reduce the movement time to 45°. This improvement idea is included in the "Reduce" category. Then the incline position can be eliminated. This improvement idea is included in the "Eliminate" category. On machine number 6, the time required for the pouring process can be reduced from 4.8 seconds to 4 seconds. So the effect of reducing cycle time is 0.8 seconds. On machine no. 2, the time required for the pouring process can be reduced from 4.9 seconds to 4 seconds. So the effect of reducing cycle time is 0.9 seconds.

➢ On mold open process researchers provide improvement ideas so that the distance between the two sides of the mold before it opens is shortened and the mold opening speed is increased. This improvement idea is included in the "Rearrange" category. On machine no.6 by reducing the position distance before the mold opens from 410mm to 337. In addition, the speed of the mold opening process is increased from 373 mm/s to 400 mm/s. The time required for the mold open process is reduced from 1.1 seconds to 0.84 seconds. So the effect of reducing cycle time is 0.26 seconds. On machine no.2 by reducing the position distance before the mold opens from 450mm to 350. In addition, the mold opening process speed is increased from 405 mm/s to 500 mm/s. The time required for the mold open process is reduced from 1.11 seconds to 0.7 seconds. So the effect of reducing cycle time is 0.41 seconds.

➢ On robot process researchers provide improvement ideas so that the robot's initial position distance is closer to the machine area and the robot's movement speed is increased. This improvement idea is included in the "Rearrange" category. On machine no. 6, by resetting the initial position of the standby robot from a distance of 249 mm from the mold to a distance of 100 mm from the mold. Then the robot movement speed was increased from 165.6 mm/s to 170 mm/s so that the time required for this process could be reduced from 6.64 seconds to 5.59 seconds or reduced by 1.05 seconds. On machine no.2 by resetting the initial position of the standby robot from a distance of 220 mm from the mold to a distance of 100 mm from the mold. Then the robot movement speed was increased from 168.4 mm/s to 208.9 mm/s so that the time required for this process could be reduced from 6.53 seconds to 4.69 seconds or reduced by 1.84 seconds.

➢ On spray process 1 researchers provided an improvement idea so that the initial position distance of the spray casset is closer to the top of the mold and the speed of movement of the spray casset is increased. This improvement idea is included in the "Rearrange" category. On machine no.6 by resetting the initial position of the spray cassette from a distance of 50 mm from the mold to a distance of 10 mm from the mold. Then the speed of movement of the spray cassette was increased from 211 mm/s to 261 mm/s so that the time required for this process could be reduced from 4.87 seconds to 3.79 seconds or reduced by 1.08 seconds. On machine no.2 by resetting the initial position of the spray cassette from a distance of 80 mm from the mold to a distance of 10 mm from the mold. Then the speed of movement of the spray cassette was increased from 174 mm/s to 200 mm/s so that the time required for this process could be reduced from 7.05 seconds to 5.80 seconds or reduced by 1.25 seconds.

➢ On spray process 2 researchers provide improvement ideas to eliminate the rotation process so that the home position is above the mold. This improvement idea is included in the "Eliminate" category. On machine no.6 by eliminating the rotation of the spray cassette and changing the home position to above the mold, the time required for this process can be reduced from 3.05 seconds to 1.5 seconds or reduced by 1.55 seconds. On machine no.2 by eliminating the rotation of the spray cassette and changing the home position to 45°, the time

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required for this process can be reduced from 3.7 seconds to 1.85 seconds or reduced by 1.85 seconds.

D. Calculation of Productivity and OEE

For these improvement ideas, productivity and OEE are calculated as explained in table 3..

Table 3 Productivity Calculations

M/C	Part Name	No Of Cav		C/T	Output/hour	Productivity
2	2DP CCH	1	Before	40	72.81	1.27
			After	33.09	92.48	

M/C	Part Name	No Of Cav		C/T	Output/hour	Productivity
6	B6H CCHS3	2	Before	37	156.06	1.29
			After	30.39	201.38	

Productivity on machine no.2 is 1.27 with a cycle time of 33.09 seconds in one process cycle. And on machine no.6 it is 1.29 with a cycle time of 30.39 seconds in one process cycle.

And for the OEE calculation as follows:

1. Mesin No.2

Jika waktu kerja = 1440 menit, stop time/hari = 170 menit, rata-rata loss time/hari = 90 menit, dan rata rata NG/hari = 100 pcs, maka :

a. OTR

OTR = (*Operation time* – Loss Time) / Waktu bersih x 100%

= ((1440 – 170) - 90)) / (1440 – 170) x 100%

=1180/1270 = 92.9%

b. PER

PER = (*Cycle Time* x *Qty Prod after reduce CT*) / *Operation time* x 100%

= ((40/60) x ((60/**33.09**)x1180)) / 1270 x 100% = 112.3 %

c. QR

QR = (*Qty* Produksi – *Qty NG*) / *Qty Prod* x 100%

= (1426– 100) / 1426 x 100% = 93.0 %

OEE = 92.9% x 112.3% x 93.0% = **97.03%**

On machine no.2, the OEE obtained was 97.03%, reaching the OEE target of 85%.

2. Mesin No.6

Jika waktu kerja = 1440 menit, stop time/hari = 170 menit, rata-rata loss time/hari = 120 menit, dan rata rata NG/hari = 200 pcs, maka :

a. OTR

OTR = (*Operation time* – Loss Time) / Waktu bersih x 100%

= ((1440 – 170) - 120)) / (1440 – 170) x 100%

=1150/1270 = 90.6%

b. PER

PER = (*Cycle Time* x *Qty Prod after reduce CT*) / *Operation time* x 100%

= ((37/60) x ((60/**30.39**)x1150))/ 1270 x 100% = 110.2 %

c. QR

QR = (*Qty* Produksi – *Qty NG*) / *Qty Prod* x 100%

= (2270– 200) / 2270 x 100% = 91.2 %

OEE = 90.6% x 110.2% x 91.2% = **91.08%**

On machine no.6 the OEE obtained was 91.08% reaching the OEE target of 85%.

V. CONCLUSION

Based on cycle time analysis using the therictical value production (TVP) method and supported by informants, the results for the value, semi-value and non-value categories on machines no. 2 and no. 6 are as follows:

➢ *Machine no.2 :*

- Value movement for 9.95 seconds in the holding close process when the aluminum flow enters the mold.
- Semi value movement for 23.08 seconds in mold close process, pouring process, inject process, mold open process, robot process, spray process 1 and spray process 2.

- Non value movement for 6.91 seconds in mold close process, pouring process, inject process, mold open process, robot process, spray process 1 and spray process 2.

➢ *Machine no.6 :*

- Value movement for 7.99 seconds in the holding close process when the aluminum flow enters the mold.
- Semi value movement for 22.40 seconds in mold close process, pouring process, inject process, mold open process, robot process, spray process 1 and spray process 2.
- Non value movement for 6.61 seconds in mold close process, pouring process, inject process, mold open process, robot process, spray process 1 and spray process 2.

From discussions with PDCA through focus group discussions (FGD), improvement ideas were generated to eliminate non-value movements so that it could reduce the cycle time of machine no.2 to 33.09 seconds with a productivity of 1.27 and machine no.6 to 30.39 seconds with a productivity of 1.29 so that it could achieve the OEE target. above 85% and meet customer demand in 2024.

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