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Measurement Overall Equipment Effectiveness on Injection Moulding Machine: A Case Study in Injection Moulding Manufacturing Industry

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ABSTRACT

In an injection molding machine, the production process of the ingredients in the form of a plastic seed is inserted into the machine to be qualified to be injected into the molded product mounted on the machine. The calculation of overall equipment effectiveness (OEE) is used to calculate the overall effectiveness of production equipment that refers to indicators of availability, performance and quality. The global standardization of good OEE values is 85%, if there is a value below 85% of the OEE value on a machine means problems with engine availability, engine performance and quality results from the machine. OEE results below 85% were performed with an improvement analysis with a pareto diagram and five why analysis. The calculation of the calculation of the fourth injection molding machine 80 tons obtained machine number one and three are below the 85% standard caused by operator pause. machine redesigning mold cavity molds suitable shrinkage material and water cooling machine used aquadest with pure H₂ O content.

Keywords: Overall equipment effectiveness (OEE), Pareto diagram, Five why analysis.

1. INTRODUCTION

Global industry competition requires companies to always increase the effectiveness in the production process in order to win the market competition. Increased effectiveness in manufacturing industries related to production support equipment. Machine production support equipment is very important to transform raw materials into products. Productivity will increase when the time to produce a quick item and no defective goods during the production process. Productivity is a quantitative relationship between what we produce and what we use as resources to produce it is the arithmetic ratio of the resulting amount (output) to the amount of resources (input), by combining the management concepts and the production system as well as how well the factors of production (land, capital, labor, equipment and energy) to be incorporated into an organization and utilized to accomplish a goal [1]. Due to intense global competition, manufacturing companies have to optimize their productivity to meet customers' changing expectations and finally to gain competitive advantages towards long-term survive and this strategy is totally in accordance with the lean manufacturing perspective [2].

Plastic used for vehicle spare part, house appliance, hospital equipment, office support facilities and cover of many machines made using injection molding machine. With the never-ending market demand resulted in the emergence of new producers producing plastic with injection molding machines. Injection molding is the most widely used polymeric fabrication process, it evolved from metal die casting, however, unlike molten metals, polymer melts have a high viscosity and cannot simply be poured into a mold, Injection molding process is a dynamic process known for its speed and preciseness when compared to other molding processes [3].

In the manufacturing plastic seed processing industry with injection molding machines. The company has 4 injection molding machines with 80 tons of mold capacity. Each machine has a high variant to make an item. Each will produce an item required setup & adjustment, each item has different cycle time and different material. Overall Equipment Effectiveness (OEE) is a performance measurement tool that can measure the production process of effectiveness equipment in the production line and identify potential improvement [4].

How to solve the problems that occur in production at manufacturing plastic seed processing industry with injection molding machines on a Nissei 80ton machine, with a wide variety of products to produce and uncertain product demand. With the goal of finding a solution to the problem of the main problem that arises.

According to Mahadevan in Nomariah et al [5] Overall Equipment Effectiveness (OEE) is a very well-know and common method in measuring performance based on three main components which are availability, performance and quality. The power of OEE comes from its applicability as a measuring method of manufacturing.

The pareto diagram is an illustration that classifies the data from left to right in the order of the highest to the lowest rank, it can find the most important issues to be resolved soon [6]. After the root of the problem is done root search problem by doing 5 times the question why and find the solution or why analysis.

2. LITERATUR REVIEW

Customer demands with low volume but high variety are often highly volatile because of the growing dynamics of today's market [7]. In today's global economy, the survival of companies depends on their ability to rapidly innovate and improve, As a result, an increasing search is on for methods and processes that drive improvements in quality, costs and productivity, they are adopting and adapting best in class; manufacturing practices and improvement processes [8]. The effectiveness of the equipment as a whole, really reduces complex production problem are simple, intuitive presentation of information it helps systematically improve the process with easy-to-reach measurement [1]. Today maintenance is considered as a strategic and integral part of the business process and it is an established fact that "It creates additional value" [9].

Nakajima mentioned that the main motivation to implement TPM is to maximize equipment effectiveness. Total Productive Maintenance is a methodology and philosophy of strategic management tools that focus on the aim to improve the quality of products to maximize the quality of the equipment [10]. The most important metric to track the effectiveness of the TPM implementation in an organization is the OEE [11]. OEE can be expressed as the ratio of the actual output of the equipment divided by the maximum output of the equipment under the best performance condition. OEE is used to measure the overall performance of the equipment and to determine how efficiently a machine is running. OEE depends on the basic three components: Availability, performance and quality [12].

Initially the machine history was analyzed which helped in finding the bottleneck machine, the OEE was found to be 62% in the identified bottleneck machine [13]. Puvanasvaran saying the relationship between historical equipment utilization and the availability of a particular process in the future to accept new customer demand should be studied for a more reasonable production planning and even improvement on availability of the entire production in the future [14]. The calculation of availability is simply the actual production time, the calculation of availability is simply the actual production time, time that is lost due to downtime through machine failure, lack of input material, lack of operator, set up & adjustment. The availability rate is the time the equipment is really running, versus the time it could have been running [15].

So the availability formula as follows:

$$\text{Planned working time} = \text{working time} - \text{planned downtime}$$

$$\text{Actual operating time} = \text{planned working time} - \text{downtime}$$

$$\text{Availability rate} = \frac{\text{actual operating time}}{\text{planned working time}} \times 100\%$$

Performance is also known as "process rate" which is portion of the OEE Metrics, it represents the speed at which the Work Centre runs as a percentage of its designed speed [16]. Performance rate is enhanced by eliminating equipment idling and minor stoppage and reduced speed losses [13]. According to [17] saying the value of performance rate can be defined as the standard time operational machine to produce a number of finished products divided by the actual operating time of the machine, the performance rate calculation requires cycle time, actual output and actual operating time. the core of the performance rate is to measure how effectively the production equipment is used [18].

Writing the formula as follows:

$$\text{Performance rate} = \frac{\text{standard operating time}}{\text{actual operating time}} \times 100\%$$

Quality Rate is the probability value of the quality of the machine [19]. The quality rate only takes into consideration the quality losses (number of item rejected due to quality defect) that happened close the equipment, not the quality losses that appear

downstream [13]. It accounts for manufactured parts that do not meet quality standards [20]. quality takes into account quality loss which accounts for produced pieces that do not meet quality standards, including pieces that require rework [1].

Here's the formula rate quality:

$$\text{Quality rate} = \frac{\text{finish good}}{\text{actual output}} \times 100\%$$

Takt time is included in the calculation of performance ratio, which could reduce the possibility of overproduction at the same time pursuing high machine utilization [21]. The Effectiveness of the equipment is the Actual Output over the Reference Output. Equipment Effectiveness shows how effectively an equipment is utilized, OEE shows the effectiveness of a machine compared to the ideal machine as a percentage, OEE is essentially the ratio of Fully Productive Time to Planned Production Time [22]. performance rate is enhanced by eliminating equipment idling and minor stoppage and reduced speed losses [21]. OEE Word class using the availability of the formula x level of performance x level of quality, the standard of OEE is 85% [23].

Overall equipment efficiency or effectiveness (OEE) is a hierarchy of metrics proposed by Seiichi Nakajima, OEE is an abbreviation for the manufacturing metric Overall Equipment Effectiveness [24]. OEE is a key measurement in indicating how many products the equipment is turning out, how much of the time the equipment is actually working, and what percentage of the output is the good product [25]. (OEE) is a metric for evaluating the progress of Total Productive Maintenance (TPM), which is interpreted as the multiplication of availability, performance and quality [13]. According to Levit in [26] says OEE standards 95% performance rate, 90% availability rate, 99% quality rate. OEE standard 85% gained from performance rate x availability rate x quality rate. This metric has become widely accepted as a quantitative tool essential for measurement of productivity in manufacturing operations [27]. OEE provide scope for manufacturing companies to improve their processes and in turn ensure consistency, quality and productivity [25].

Pareto analysis is a quality control tool that ranks data, in descending order, from the highest occurrence frequency to the lowest frequency of events. Total frequency is equated to 100 percent. The Pareto principle is often called the "80/20 rule", because 80 percent of defects/problems in the system produce only 20 percent of the probable cause [26].

Injection molding is the most widely used polymeric fabrication process. Injection molding is a process of forming an article by forcing molten plastic material under pressure into a mold where it is cooled, solidified and subsequently released by opening the two halves of the mold [3]. Most commonly used materials for injection molding process are Thermosetting and Thermoplastic Polymers, injection molding machine consist of a hopper through which granules of the plastic material enter a screw-type plunger, The screw-type plunger is operated by prime mover or any hydraulic system, Heaters are provided on the exterior side of this plunger which gradually heats the plastic granules as it move forward through the screw, The molten plastic is injected at the nozzle end through a small opening in the mold cavity, The mold core clamps to the cavity and mold area is formed where the filling of molten plastic takes place [23]. Manufacturing Process Injection molding Pellets placed in hopper [24]: (1) Pellets fall into barrel through throat, (2) Pellets packed to form solid bed. (air forced out through hopper), (3) Pellets melted by mechanical shear between barrel and screw, (4) Melted plastic form shot in front of screw (screw moves back as plastic moves forward – reciprocating screw). Screw moves forward to inject plastic into mold cavity, (5) Part cooled and solidifies (next shot is made), (6) Mold opens, (7) Ejection pins move forward to eject part, and (8) Mold closes and process starts again.

3. RESEARCH METHODOLOGY

This research is a case study taken from the plastic injection industry. Each injection molding machine operates to produce a different product, on one machine can produce several products in each month depending on the mold mounted on the machine.

Direct observation on the production floor to see firsthand how the production process on the injection molding machine. The literature study is the process of finding references to the OEE calculation model in the form of a journal. Data collection is obtained from daily production reports which are quantitative models. The study was conducted in January 2018 from 80 tons of injection molding machines. The data collected is obtained from the daily production report in January 2018, some data such as: average cycle time of each machine, availability of engine time, operator break time, settings and conditions, breakdown engine, preventive engine, output target, actual output, product disabled. In the formulation of the problem using 5 reasons analysis by involving experts in some department such as PPIC, production, maintenance and Q C.

4. RESULT AND DISCUSSION

Obtained OEE calculation through the search stage of availability rate, performance rate and quality rate.

Manufacturing plastic seed processing industry with injection molding machine has 4 units of 80 tons injection machines with a variety of products processed on each machine.

4.1 Availability.

Calculation of availability of data obtained are: trouble machine, setup & adjustment start production, preventive maintenance, operator break and working time.

Table 1. Availability rate plastic injection machine

| Machine number | Trouble machine (minute) | Setup & adjustment start production (minute) | Preventive maintenance (minute) | Operator break (minute) | Working time (minute) | Planned working time (minute) | Actual operating time (minute) | Availability rate |
|----------------|--------------------------|--|---------------------------------|-------------------------|-----------------------|-------------------------------|--------------------------------|-------------------|
| 80 ton #1 | 36 | 799 | 0 | 1020 | 43200 | 41381 | 41344 | 99.91 % |
| 80 ton #2 | 102 | 290 | 30 | 60 | 43200 | 4820 | 42718 | 99.76 % |
| 80 ton #3 | 691 | 994 | 15 | 0 | 43200 | 42191 | 41500 | 98.36 % |
| 80 ton #4 | 69 | 0 | 45 | 0 | 43200 | 43155 | 43086 | 98.84 % |

An example of the availability rate calculation on the 80 ton # 1 machine is as follows:

Planned working time = 43200 – (799+0+1020) = 41381

Actual operating time = 41381 – 36 = 41344

$$Availability = \frac{41344}{41381} \times 100\% = 99.91\%$$

The global standard of machine availability on OEE is 90%. the OEE calculations on the four injection plastic machines got above 90%, illustrating that the machine availability in this study is good enough.

1.2 Performance rate

The data needed in the calculation of performance rate are actual output and cycle time.

Table 2. Performance Rate plastic injection machine.

| Machine number | Actual output (pcs) | Cycle time (minute) | Standard operating time (minute) | Actual operating time (minute) | Performance rate |
|----------------|---------------------|---------------------|----------------------------------|--------------------------------|------------------|
| 80 ton #1 | 51066 | 0.41 | 211499 | 41344 | 51.19 % |
| 80 ton #2 | 230491 | 0.18 | 42257 | 42718 | 98.92 % |
| 80 ton #3 | 321118 | 0.10 | 32112 | 41500 | 77.38 % |
| 80 ton #4 | 287637 | 0.14 | 40749 | 43086 | 94.57 % |

Example of performance rate calculation on machine 80 ton # 2 as follows:

Standard operating time = 230491 x 0.18 = 42257 minute.

$$Performance\ rate = \frac{42257}{42718} \times 100\% = 98.92\%$$

In the performance level table only 80 tons of machine number two has a percentage above 90% that is 98.92%, the other three machines are 80 tons number 1, 80 tons number three and 80 tons number four percentage below 95%. The smallest machine is 80 tons number 51.19% and with the difference of 95% - 51.19% = 43.81%. The standard global value of OEE performance is 95%, if there is a performance value below 95% it means that there is a lack of reliability on the machine.

4.3 Quality rate.

The finished output is good and the actual data is needed in the calculation of the level of quality. Calculation results of the four machines under study of machine number three is below the standard value rate of 99%. Quality rate below 99% describes the quality problems in the machine.

Table 3. Quality Rate plastic injection machine

| Machine number | Finish good | Actual output | Quality rate |
|----------------|-------------|---------------|--------------|
| 80 ton #1 | 50126 | 51066 | 98.16 % |
| 80 ton #2 | 22720 | 230491 | 98.60 % |
| 80 ton #3 | 318328 | 321118 | 99.13 % |
| 80 ton #4 | 276860 | 287637 | 96.25 % |

An example of a Quality rate calculation on the 80 ton number three machine is as follows:

$$Quality\ rate = \frac{318328}{321118} = 99.13\%$$

A good percentage of good rate is on the 80 ton # 3 machine with 99.19% percentage gain, the other three machines below the 99% standard set.

4.4 OEE.

Getting an OEE value is obtained from multiplying the three factors of availability level, level of performance and quality level. There are two 80 tons of machine number one and 80 tons number three OEE calculation values below 85% standard. Each with a percentage of 80 tons of number one 50.2% and 80 tons of number three 75.4%. The focus of improvement on the results of calculations performed on machines with OEE values below 85%, on machines with OEE values above 85% is considered good.

Table 4. OEE plastic injection machine

| Machine number | Availability rate | Performance rate | Quality rate | OEE |
|----------------|-------------------|------------------|--------------|--------|
| 80 ton 1 | 99.91 % | 51.19 % | 98.16 % | 50.2 % |
| 80 ton 2 | 99.76 % | 98.92 % | 98.60 % | 97.3 % |
| 80 ton 3 | 98.36 % | 77.38 % | 99.13 % | 75.4 % |
| 80 ton 4 | 99.84 % | 94.57 % | 96.25 % | 90.9 % |

Analysis of problem solvers

Initial analysis looked for non-achievement of the OEE standard using pareto diagrams, of which 20% of the major problem sources affected 80% of non-target achievement. And the second analysis uses 5 why analysis.

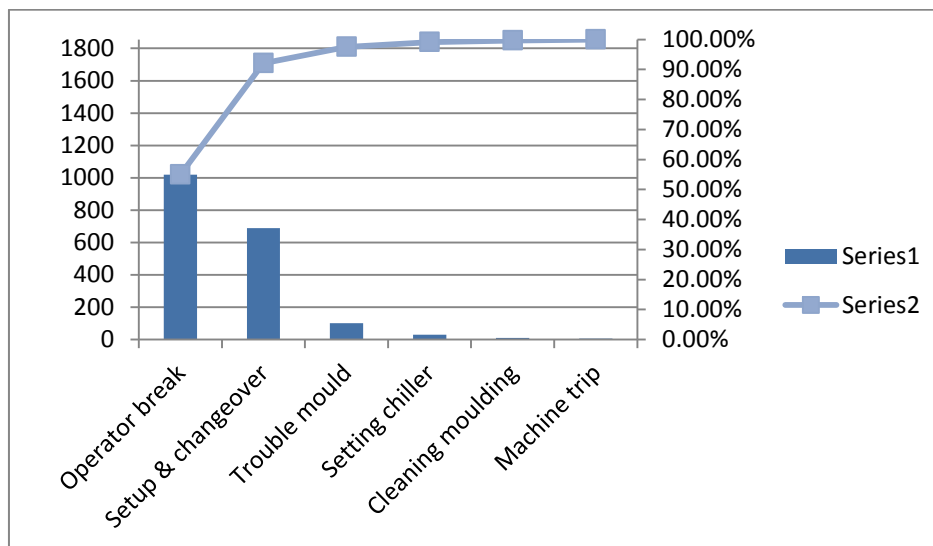


Figure 1 Pareto Diagram Machine 80 Ton #1

The result of the break operator analysis is the biggest problem, the break operator influences the calculation of the availability rate and the performance rate. In each shift every operator has 1 hour of time, during break time the engine is not running so it does not get the production within 1 hour.

Table 5. Five Why analysis problem machine 80 ton #1

| Questions | Answers |
|--|---|
| Why is there a break/operator leaving the machine? | The operator breaks. |
| Why do operators break the machine not the way? | Machines produce with semiautomatic |
| Why is the machine producing with semi-automatic? | Because there is a bending on the product, so the product out of the machine requires a second process using a jig. |
| Why is there a bending on the product? | Design cavity mold too convex |
| Why is cavity mold design too convex? | Because of the error of shrinkage calculation at the moment of cavity mold design |

The root of the problem can already be known why until the operator breaks? because of problems that occur in the design of cavity molds that do not fit shrinkage of the plastic material. Therefore, it is not necessary for the break operator to redesign the cavity mold in accordance with the shrinkage of the plastic material.

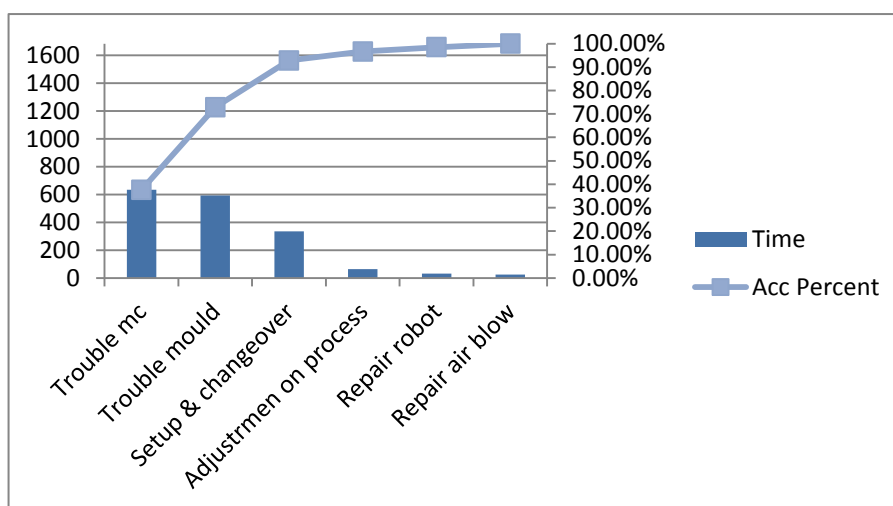


Figure 2. Pareto Machine Diagram 80 Ton #3

The basics in machine image problems affect the performance level calculation results. Where the difference does not reach the largest target in OEE calculation is 95% - 77,38% = 17,6%. the biggest problem affecting the 17.6% figure is from the level of performance. So the problem solving analysis in 5 why is done on the factors affecting the performance rate.

Table 6. 5W analysis machine problem 80 ton #3

| Question | Answer |
|-------------------------------------|--|
| Why trouble machine? | Monitor error |
| Why monitor error? | Because the power supply is not reliable |
| Why power supply is not reliable? | Hot machine temperature |
| Why is the machine temperature hot? | Condenser clogged |
| Why is the condenser clogged? | Water cooling contains lime |

The root of the problem occurs on a 80 ton 3 machine because the cooling water drawn from the soil contains lime. The solution for water uses aquadest of the original mineral content of H₂O. Aquadest is a type of pure H₂O liquid that does not contain minerals and lime, with aquadest expected machine does not occur in electrical problems, especially on the monitor.

5. CONCLUSION

OEE results below 85% were performed with an improvement analysis with a pareto diagram and five why analysis. The calculation of the calculation of the fourth injection molding machine 80 tons obtained machine number one and three are below the 85% standard caused by operator pause. machine redesigning mold cavity molds suitable shrinkage material and water cooling machine used aquadest with pure H₂O content.

Of the four 80-ton machines available, two of them are 80 tons # 1 and the 80 # 3 machine does not meet the specified OEE percentage standard. Both machines are based on the difference from the standard at the performance rate of 80 tons # 1 machine with 43.81% difference and 80 tons # 3 machine with 17.6% difference. On machine 80 ton # 1 the biggest problem because the operator break with the root of his mistake is the error of shrinkage calculation at the design of cavity mold, the solution to avoid break operators need to be redesigned on the cavity mold in accordance with shrinkage material plastic. A trouble machine on the 80 ton # 3 machine is the biggest problem, the biggest problem begins with the lime-water cooling problem, the solution for water using aquadest with the original mineral content of H₂O.

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