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TPM Implementation in Automotive Component Manufacturing Companies to Analyze Efficiency Injection Machine

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PAPER INFO	ABSTRACT
Chronicle: *Received: 10 September 2019* *Revised: 11 November 2019* *Accepted:* 14 December 2019 **Keywords**: *OEE.* *Six big losses.* *TPM.* *Maintenancee.* *Eequipment.*	The development of motorcycle industry in Indonesia is quite rapid. The mode of transportation is a favorite the people of Indonesia, especially in industrial area. The average motorcycle user is a company employee because it facilitates access and avoids traffic. Motorcycle component production in Indonesia is spread across several companies, one of the companies that manufactures components made of plastic material has 16 injection machines. These machines have different performance, when analyzed using the OEE approach it is known that Machine 16 has the lowest performance compared to others at only 91.2%. Factors that affect the low efficiency of the machine due to the 7 biggest losses namely Dandori, Mold Repair, Machine Damage, re-setting, Material jams, robot damage and Cleaning Mold.

1. Introduction

The development of the motorcycle industry in Indonesia is quite rapid. This can be seen from the growing number of motorcycle component manufacturers. In industrial era 4.0 which is digital era, motorbikes are a mode of transportation that is quite reliable compared to four-wheeled vehicles. The emergence of start-up modes of online transportation benefits the vehicle industry. The need for vehicles that facilitate access to travel is proportional to the increase in assembly production. The increasing demand for vehicle products also has an effect on increasing the production of its components. These components are usually produced by motorcycle assembly suppliers, one of the suppliers that manufactures motorcycle components is PT. MI Indonesia is a supplier for one of the largest vehicle brands in Indonesia. In the last few months motorcycle sales have decreased, as seen from the AISI 2019 sales data in January to July 2019 in July sales were only 10.3% lower compared to the previous months which reached an average of 15%. For average sales increased by 14.3%, compared to sales in 2018 for 1 year the average sales were in the range of 10%. To continue to increase sales, companies must continue to maintain quality, improve service, be sensitive to consumers, markets, and even continue to innovate so as not to lag behind competitors. Nowadays everything is easily accessible including information about technology, technology in vehicles is one of features that is very attractive to consumers. Factors influence consumers to buy something because there are interesting and different

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from others or have one uniqueness compared to others. In addition, the features and color display technology can also affect consumers,

As one of the Japanese companies that produce two-wheeled vehicle components with color variants, in order to maintain the color quality and appearance according to consumers and to control all activities in production and non-production environment Injection molding companies apply TPM with the PQCDSM principle (Production, Quality, Cost, Delivery, Moral). One part of TPM is OEE, OEE can provide useful guidance on aspects of production to identify critical points for improvement through effective maintenance strategies [1]. In measuring machine efficiency there are three parameters that must be done including availability, performance and quality (Manjeet Singh, 2017). In injection molding process all relevant parameters need to be considered to produce an optimal process in terms of design to reduce process uncertainty and eliminate errors that occur in the process (Ranđelović et al., 2015)

2. Literature Review

Beginning of the emergence TPM in the 1900s by Henry Ford, but was perfected in Japan in the 1950s when preventive maintenance was introduced in Japan from the United States. Nippon denso, part of Toyota, first company in Japan to introduce Preventive Maintenance to all factories in 1960.

Fig. 1. *From preventive maintenance to TPM [4].*

The face of problems faced mainly in Japanese industrial world, first time developing and introducing the concept of Total Productive Maintenance was in 1971. Nakajima in the book [5] defines TPM as a process to continuously improve all operational conditions in daily production system activities. TPM is a proactive approach aims to identify problems and prevent problems before they occur. In TPM it is famous for the motto "zero error, zero accident related to work and zero loss". The philosophy of TPM emphasizes independent maintenance, each employee is responsible for work along with his machine in addition to being responsible for quality of products produced. Self-maintenance or autonomous maintenance is carried out as a preventive measure to prevent downtime, the occurrence of downtime can hinder or stop production so it needs to be evaluated by calculating OEE and six big losses by giving proposals to implement TPM [6].

The purpose of the TPM is to use all equipment with maximum effectiveness by eliminating waste resulting from equipment failure, reduced speed, and the effect of the product being processed. Some other definitions of TPM according [5] namely maximizing the effectiveness of equipment, building a comprehensive preventive maintenance system for equipment throughout its lifetime, can be implemented by various departments, such as line operations, maintenance, engineering, etc., involving every employee from top management Hinggatoko, a worker on the floor, is based on promoting preventive maintenance through motivation.

Using OEE to evaluate effectiveness urban transport transportation system capable of optimizing quality, performance, and time availability, the proposed methodology provides 'tactical' and operational evaluations in making decisions made by companies in configuring urban transport transportation systems [7]. Research by [8] machines that often experience downtime lead to increased overtime hours of employees so that costs incurred by the company are higher, OEE is used as a solution for evaluating. In addition, OEE is also used in analysis of Environmental Equipment Effectiveness or OEEE identified from OEE which includes availability, quality and performance in each step of production and OEEE combines sustainable concepts based on environmental impacts [9]. OEE is a comprehensive measure identifies level of machine/equipment productivity from performance in theory. This measurement very important to know which areas need to be increased in productivity or efficiency. To increase productivity in global competition, the need for OEE performance measurement is described as a tool for analyzing types of production losses and process improvement [10].

As the first country to trigger TPM, Japanese companies in Indonesia are also more concerned about implementing TPM. Some researchers are interested in going deeper into this problem [11] combining Overall Equipment Effectiveness, Six Big Losses, Fault Tree Analysis, and TPM in analyzing the root causes of damage and the probability of failure while for the final recommendation of TPM as a reference. The care methodology was appropriately adopted to define maintenance and improvement plans that were integrated with the principles of TPM and RCM methods to support decision makers and make recommendations in planning, implementing maintenance improvement [12]. Research conducted [13] states that the TPM and RCM foundation began in the 1950s with breakdown maintenance, the goal of TPM achieving zero breakdown, zero defect and zero accident while RCM to maintain function. Both are linked together through lean tools to improve product quality, equipment reliability, increase safety, and increase profits.

Table 1. *The six losses due to poor OEE.*

No	OEE Measure	Six Loss Category	Reason For Loss	Countermeasure
1	*Availability*	*Planned downtime or external unplanned event*	*1. Changeovers* *2. Planned maintenance* *3. Material shortage* *4. Labor shortage*	▪ *Planned Downtime Management* ▪ *5S Workplace Organization* ▪ *ABC Planning*
2	*Availability*	*Breakdown*	*1. Equipment Failure* *2. Major Component failure* *3. Unplanned Maintenance*	▪ *Kaizen Blitz* ▪ *proACT* ▪ *root cause analysis* ▪ *Asset Care*
3	*Performanc e*	*Minor Steps*	*1. Fallen product* *2. Obstruction* *3. Blockage* *4. Misalignment*	▪ *Opportunity Analysis* ▪ *5S Workplace Organization* ▪ *Management Routines* ▪ *Line Minor Stop Audits*
4	*Performanc e*	*Speed Loss*	*1. Running Lower than rated speed* *2. Untrained operator not able to run at nominal speed* *3. Misalignment*	▪ *IFA Opportunity Analysis* ▪ *Line Balance Optimization* ▪ *Management routines*

No	OEE Measure	Six Loss Category	Reason For Loss	Countermeasure
5	*Quality*	*Production Rejects*	1. *Product out of spesification* 2. *Damaged product* 3. *Scrap*	▪ *IFA Opportunity Analysis* ▪ *Six sigma* ▪ *Error Proofing*
6	*Quality*	*Rejects on startup*	1. *Product out of spesification at start of run* 2. *Scrap created before nominal running after changeover* 3. *Damaged product after planned maintenance activity*	▪ *Planned downtime management* ▪ *5S Workplace Organization* ▪ *Standard Operating Procedures* ▪ *Precision Settings*

Source: [5].

TPM activities are team activities require participation from all those in a company from the lowest level to highest level. TPM activities involve all elements of department related to production, quality, cost or costs, delivery, safety and morals. Operator level not only operates machine but also performs maintenance independently or autonomously, the goal of independent maintenance to prevent damage so that machine efficiency remains high, product defects are low and reduce time wasted/loss. To achieve a world-class manufacturing system the application of TPM is carried out at automotive component manufacturing companies, the concept is implemented on CNC machines, based on the results of research conducted [14], the application of all TPM pillars is able to eliminate losses thereby increasing the performance of CNC machines. In addition to machine efficiency, losses are also caused by low product quality, while improving quality can encourage companies to remanufacture when introducing new products, but remanufacturing inhibits improvement in product quality when production costs for low quality products [10].

To meet market demand, manufacturing companies need reliable machines, with reliable machines, they can produce quality products with maximum capabilities, but with various constraints the machine is usually not able to achieve the desired performance. Performance will affect productivity, measurement techniques with OEE are good methods of measuring machine performance. The research conducted [15] is able to present a practical framework for implementing OEE and explain in detail each proposed step. The low performance of hydraulic machine is due to the influence of idle and minor stoppages that occur on the machine [16]. in addition to the OEE method to increase machine effectiveness and productivity, to find the root cause of machine damage is done by the Fuzzy and FMEA methods [17].

Some other definitions of TPM [5]: aim at maximizing the effectiveness of equipment, building a comprehensive preventive maintenance system for equipment throughout its lifetime, can be implemented by various departments, such as line operations, maintenance, engineering, etc., involving every employee from top management to shop , workers on the floor and based on the promotion of preventive maintenance through motivation. In addition to the definitions in TPM there are also eight eight TPM pillars that have been applied in Japan & now Japanese companies in Indonesia are also adopting TPM, namely Individual Improvement (Kobetsu Kaizen), Independent Care (Jishu Hozen), Planned Care (Keikaku Hozen), Quality Care (Hinshitsu Hozen), Education and Training (Kyoiku), Administration & Control (Office & PPIC Field), Safety (Anzen) and New Models

Six factors cause losses that effect of effectiveness machine, in research conducted by [18] the biggest loss against total loss time is due to adjustment and adjustment, reduced speed loss and breakdown. Research conducted [19] concludes that one of the six big losses decreases machine performance is downtime losses, speed losses and defect losses, TPM strategy analysis with OEE model is used to reduce damage, failure and unplanned downtime to improve the performance and quality of production [20]. To ensure the smooth assembly process of the TPM as an instrument in managing and maintaining an ideal machine, the OEE part of the TPM is used as a measure when deviations occur [21]. In general, the OEE global standard is 85%, if the OEE value of machine is below 85%, then several problems occur related to availability, performance and quality. Two of the four machines OEE values below 85% are caused by operator pause, redesign of the mold, shrinkage and cooling machine used [22].

Research [23] in precision tube mill plant has successfully implemented and implemented TPM on a sustainable basis so that it has benefit of improving performance and supporting the manufacturing industry in India. The TPM implementation strategy can contribute significantly to improved performance, increased efficiency and overall machine productivity through OEE can be used for improvements in the manufacturing process [24]. The application of TPM is not only in large industries or organizations but in the research conducted [25] it was found that 52% of SMEs out of a total of 50 SMEs have adopted TPM in their organizations the rest have not implemented it for certain reasons. Application of TPM for small and large industries is very important to measure productivity of operating machines, if the productivity machine is low, it will cause losses for the company, the use machines are not effective and efficient. There are 6 loss factors that occur in the company called Six Big Losses, including:

1. Equipment failure losses.
2. Losses caused by damage to machinery and equipment. Machine damage that often occurs is the machine dies suddenly so that the production process stops.

$$\text{Equipment Failure losses} = \frac{\text{How long it takes to repair}}{Loss\ time} x100\%$$

3. Setup and adjustment losses
   Loss that occurs because after the setup is done, the machine can not start.

$$\text{Setup and Adjustment Losses} = \frac{Set\ up\ and\ adjustment}{Loss\ time} x100\%$$

4. Idle and minor stoppages losses.
5. Represents losses caused by the machine stop momentarily. This is because operators working there in place during the production process, the material which came late to the workstation or for their power cut.

$$Idle\ and\ Minor\ Stoppage\ Losess = \frac{(Planned\ Production - output) x\ ideal\ cycle\ time}{Loss\ time} x100\%$$

6. Reduce speed losses (losses due to a decrease in operating speed)
   Represents losses due to a decrease in machine speed so that the machine does not can operate with a maximum.

$$\text{Reduce Speed Losses} = \frac{\begin{pmatrix}\text{Actual cycle time} - \\ \text{ideal cycle time}\end{pmatrix} \text{x total processed products}}{\text{Loss time}} \text{x}100\%$$

7. Defect in process losses (losses due to defective products)
   Represents losses caused by defective products.

$$\text{Defect Losses} = \frac{\begin{pmatrix}\text{Reject Total x} \\ \text{ideal cycle time}\end{pmatrix} \text{x total processed products}}{\text{Loss time}} \text{x100\%}$$

8. Reduce yield losses (losses at the beginning of production).
   Losses at the beginning of production until they reach stable production conditions.

$$Reduce\ Yield = \frac{\text{Ideal cycle time x Total Defective early Production}}{\text{Loss time}} \text{x100\%}$$

The purpose of analyzing six big losses is to identify some losses such as equipment damage, losses during preparation, losses due to damage to parts / products, and several other losses that can result in company losses.

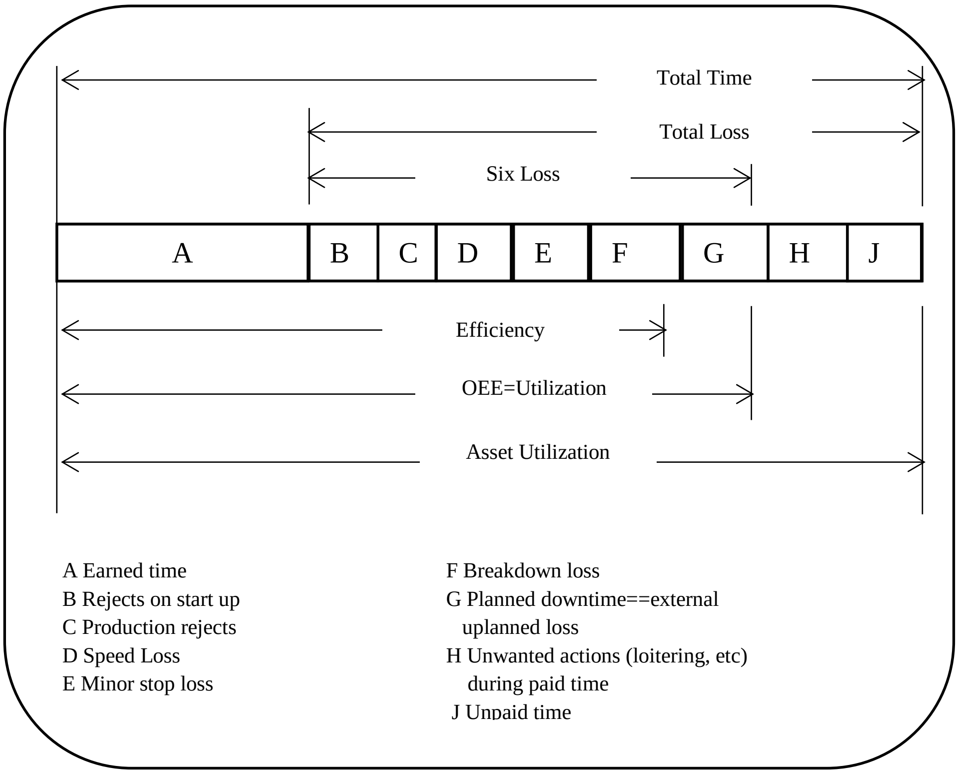

Fig. 2. *Illustration of the six OEE losses [5].*

Overall Equipment Effectiveness (OEE) calculation begins with determining the value of availability ratio, performance efficiency, and the rate of product quality. To calculate availability, performance and quality:

- Availability = Available Time/Scheduled Time.
- Performance = Actual Rate/Standard Rate.
- Quality = Good Units/Units Started.

OEE is the result of 3 important parameters such as availability, performance and quality ratio. Some parameters used to calculate OEE [26], The description of OEE improvement techniques [27] as follows:

- availability:
  - Reduces unplanned downtime.
  - Identifying and eliminating specific and general causes.
  - Analyze and improve MTBF, MTTR, and other reliability issues.
  - Using the TPM and maintenance team quickly.
  - Prioritize preventive maintenance.

$$\text{Availability Ratio} = \frac{\text{Loading time} - (\text{Failure \& repair} + \text{set up \& adjustment})}{\text{Loading time}} \text{x}100\%$$

- Performance:
  - Increase performance to limit ideal cycle times.
  - Identify Takt time and increase Tact and cycle time.
  - Define appropriate resources to identify and close gaps.
  - Identify and close the operating imbalance gap with the appropriate operator or process flow.
  - Identification of any operations that are not appropriate and not standardized.

1. Ideal Cycle Time: Time required to produce 1 product.
2. $\text{Actual Cycle Time} = \frac{\text{Operating time}}{\text{Product Amount}}\text{x}100\%.$
3. $\text{Operating Speed Rate} = \frac{\text{Ideal Cycle Time}}{\text{Actual Cycle time}} x100\%.$
4. $\text{Net Operating Rate} = \frac{\text{Operating amount x actual cycle time}}{\text{Operating time}}\text{x}100\%.$

Performance Efficiency = Net Operating Rate * Operating Speed Rate

- For Quality:
  - Identification of measurements, and repair of scrap and rework.
  - Identify problem areas and record errors or proofs of errors.
  - Identify and communicate sample boundaries.
  - Allocate resources and process problems according to experts to solve problems that might arise in OEE development.

$$\text{Rate of Quality Product} = = \frac{\text{Planned production} - \text{Reduced Yield} - \text{Reject and rework}}{\text{Planned Production}}\text{x}100$$

OEE= Availability Ratio * Performance Efficiency * Rate Quality of Product

3. Research Methods

Research is carried out by taking the following steps:

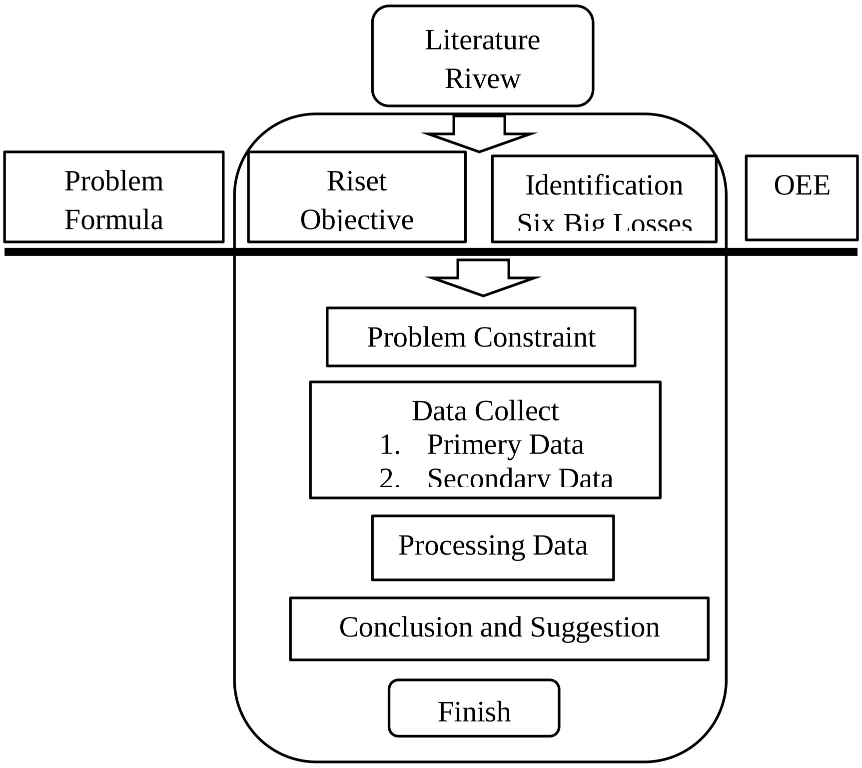

Fig. 3. *Study framework.*

TPM activities are not only prevention of damage machine so as to minimize downtime. Many factors cause losses because machine efficiency is too low. The low OEE is due to a lot of losses occur in companies, some of these losses are commonly referred to as six big loss. Efficiency is a measure in companies to find out how much effective percentage produce quality products according company standards. To perform data processing, steps are carried out by collecting data related to six big loss, some of categories included in the six big loss in the injection company are as follows:

- Some losses are categories of damage if they occur above 10 Minutes (Equipment failure losses).
  - Power outages are caused by internal company panel damage.
  - Machine damage.
  - Repairing mold.
- Loss that occurs due to preparation or adjustment losses.
  - Conducting morning meeting or shift meeting.
  - Loss due to late employee pickup.
  - Checking the machine before working.
  - Re-setting.
  - Waiting for heater heat.
  - Preparation for work.
  - Loss caused by employees not finished preparation.
- Loss time of initial 5S work, end of work, stopping for a moment (Idle and minor stoppages losses).
  - Loss the start of work doing 5S.
  - Cleaning mold.

- The machine stops under 10 minutes.
- Loss material discharged.
- A short break.
- Loss due depleted carrier.
- Loss due clogged material for sponge depleted.
- Loss for plastic consumables.
- End of Work.

- Loss due to a decrease in velocity (Reduce speed losses).
  - Loss because machine is not running optimally.
- Loss due to product defects (Defect in process losses).
  - Loss due defective products.
- Dandori losses and material change (Reduce yield losses) losses.
  - When changing molds.
  - Losses when changing material.

4. Analysis and Discussion

OEE calculations are carried out on machines Injection, a machine operates to produce components of two-wheeled vehicles made from plastic, amounting to 16 machines. Each machine has a different performance. To see the performance of these machines, the application of OEE is one of the right steps. Before the calculation is performed several loss categories are identified to determine the six big loss as a reference in OEE calculation.

Table 2. *OEE average (Machine-1).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate Of Quality Product	OEE
1	*643,5*	*621,5*	*1072*	*44415*	*0,6*	*566*	*96,6%*	*94,9%*	*98,7%*	*90,5%*
2	*655,5*	*636,8*	*1053*	*46562*	*0,6*	*594*	*97,1%*	*99,2%*	*98,7%*	*95,1%*
3	*673,8*	*658,9*	*1070*	*49928*	*0,6*	*464*	*97,8%*	*97,5%*	*99,1%*	*94,4%*
4	*683,9*	*659,7*	*1097*	*50261*	*0,6*	*414*	*96,5%*	*96,4%*	*99,2%*	*92,3%*
5	*630,7*	*612,7*	*1004*	*41437*	*0,6*	*347*	*97,1%*	*91,8%*	*99,2%*	*88,4%*
6	*635,1*	*613,6*	*997*	*43200*	*0,6*	*287*	*96,6%*	*97,5%*	*99,3%*	*93,5%*
7	*654,8*	*627,3*	*1002*	*38377*	*0,6*	*444*	*95,8%*	*95,8%*	*98,8%*	*90,7%*
8	*634,7*	*609,5*	*980*	*44395*	*0,6*	*450*	*96,0%*	*96,4%*	*99,0%*	*91,7%*
Average OEE										*92,1%*

Machine 1 has an average OEE of 92.1% with the lowest OEE occurring in May of 88.4% while the highest in February of 95.1%.

Table 3. *OEE average (Machine-2).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*638,7*	*616,7*	*911*	*30234*	*0,7*	*510*	*96,6%*	*99,0%*	*98,3%*	*94,0%*
2	*674,8*	*630,1*	*924*	*37665*	*0,7*	*292*	*93,4%*	*98,2%*	*99,2%*	*91,0%*
3	*694,3*	*677,2*	*955*	*39301*	*0,7*	*312*	*97,5%*	*99,5%*	*99,2%*	*96,3%*
4	*760,6*	*728,4*	*991*	*39811*	*0,7*	*610*	*95,8%*	*99,0%*	*98,5%*	*93,3%*
5	*685,1*	*668,4*	*935*	*36151*	*0,7*	*457*	*97,6%*	*99,6%*	*98,7%*	*95,9%*
6	*617,6*	*604,7*	*772*	*28494*	*0,8*	*416*	*97,9%*	*98,7%*	*98,5%*	*95,3%*
7	*636,8*	*619,7*	*892*	*27433*	*0,7*	*369*	*97,3%*	*99,9%*	*98,7%*	*95,9%*
8	*617,7*	*599,8*	*837*	*33246*	*0,7*	*182*	*97,1%*	*98,8%*	*99,5%*	*95,4%*
Average OEE										*94,6%*

The average OEE achievement on Machine 2 was 94.6% and for 8 consecutive months OEE reached more than 90%.

Table 4. *OEE average (Machine-3).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*626,6*	*604,9*	*1058*	*36075*	*0,6*	*448*	*96,5%*	*99,7%*	*98,8%*	*95,1%*
2	*633,8*	*618,3*	*1084*	*35425*	*0,6*	*256*	*97,6%*	*99,9%*	*99,3%*	*96,8%*
3	*640,3*	*624,8*	*1002*	*36670*	*0,6*	*78*	*97,6%*	*99,4%*	*99,8%*	*96,8%*
4	*646,2*	*640,4*	*1134*	*36798*	*0,6*	*46*	*99,1%*	*99,1%*	*99,9%*	*98,1%*
5	*609,2*	*599*	*1028*	*35476*	*0,6*	*92*	*98,3%*	*99,6%*	*99,7%*	*97,6%*
6	*547,4*	*537,1*	*901*	*31726*	*0,6*	*185*	*98,1%*	*99,0%*	*99,4%*	*96,6%*
7	*655,8*	*627,8*	*1014*	*29876*	*0,6*	*258*	*95,7%*	*98,5%*	*99,1%*	*93,5%*
8	*588,0*	*555,4*	*834*	*32420*	*0,7*	*523*	*94,5%*	*99,9%*	*98,4%*	*92,8%*
Average OEE										*95,9%*

The average OEE on machine 3 was 95.9% with the highest achievement being 98.1% in April, however for 8 months it was still above 90%.

Table 5. *OEE average (Machine-4).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*620,7*	*587,1*	*847*	*30045*	*0,7*	*136*	*94,6%*	*99,6%*	*99,5%*	*93,8%*
2	*622,7*	*594,7*	*853*	*32693*	*0,7*	*166*	*95,5%*	*99,0%*	*99,5%*	*94,0%*
3	*590,0*	*566,5*	*807*	*31603*	*0,7*	*114*	*96,0%*	*99,7%*	*99,6%*	*95,4%*
4	*665,1*	*637,4*	*883*	*31864*	*0,7*	*130*	*95,8%*	*99,8%*	*99,6%*	*95,2%*
5	*665,0*	*635,5*	*871*	*31638*	*0,7*	*98*	*95,6%*	*98,7%*	*99,7%*	*94,0%*
6	*585,4*	*553,7*	*768*	*27551*	*0,7*	*76*	*94,6%*	*99,8%*	*99,7%*	*94,2%*
7	*628,5*	*582,8*	*800*	*26209*	*0,7*	*192*	*92,7%*	*98,8%*	*99,3%*	*90,9%*
8	*578,9*	*542,9*	*741*	*38758*	*0,7*	*452*	*93,8%*	*99,6%*	*98,8%*	*92,3%*
Average OEE										*93,7%*

Aaverage OEE was 93.7%, over 8 months OEE began to decline until August.

Table 6. *OEE average (Machine-5).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*644,4*	*622,7*	*863*	*46183*	*0,7*	*559*	*96,6%*	*96,8%*	*98,8%*	*92,4%*
2	*662,2*	*636,5*	*886*	*41823*	*0,7*	*461*	*96,1%*	*98,9%*	*98,9%*	*94,0%*
3	*605,9*	*585,2*	*798*	*40948*	*0,7*	*297*	*96,6%*	*99,6%*	*99,3%*	*95,5%*
4	*639,0*	*617,3*	*820*	*40693*	*0,8*	*310*	*96,6%*	*99,6%*	*99,2%*	*95,5%*
5	*634,2*	*596,9*	*728*	*48495*	*0,8*	*454*	*94,1%*	*91,5%*	*99,1%*	*85,3%*
6	*582,3*	*549,4*	*650*	*36835*	*0,8*	*606*	*94,3%*	*97,2%*	*98,4%*	*90,2%*
7	*671,8*	*634,7*	*784*	*38544*	*0,8*	*606*	*94,5%*	*99,0%*	*98,4%*	*92,0%*
8	*640,2*	*597,1*	*700*	*46461*	*0,8*	*636*	*93,3%*	*97,4%*	*98,6%*	*89,6%*
Average OEE										*91,8%*

Aaverage OEE of 5 Machine is lower compared to the previous 4 machines which was only 91.8% and for 8 months there were twice OEE under 90% ie in May by 85.3% and August 89.6%.

Table 7. *OEE average (Machine-6).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*607,9*	*572,3*	*955*	*38569*	*0,6*	*467*	*94,1%*	*99,8%*	*98,8%*	*92,8%*
2	*618,1*	*587,7*	*917*	*33821*	*0,6*	*320*	*95,1%*	*99,9%*	*99,1%*	*94,1%*
3	*596,0*	*569,5*	*985*	*35520*	*0,6*	*246*	*95,6%*	*99,7%*	*99,3%*	*94,6%*
4	*662,1*	*633*	*965*	*38932*	*0,7*	*178*	*95,6%*	*99,0%*	*99,5%*	*94,3%*
5	*633,3*	*608,5*	*901*	*39811*	*0,7*	*341*	*96,1%*	*99,2%*	*99,1%*	*94,5%*
6	*556,4*	*509*	*748*	*30463*	*0,7*	*251*	*91,5%*	*99,2%*	*99,2%*	*90,0%*
7	*660,7*	*620*	*724*	*32437*	*0,9*	*188*	*93,8%*	*99,8%*	*99,4%*	*93,1%*
8	*620,2*	*578,7*	*647*	*31417*	*0,9*	*338*	*93,3%*	*100,0%*	*98,9%*	*92,3%*
Average OEE										*93,2%*

Average OEE for machine 6 is 93.2% with the achievement for 8 months still above 90%.

Table 8. *OEE average (Machine-7).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performanc e Efficiency	Rate of Quality	OEE
1	*658,1*	*623,1*	*694*	*39580*	*0,9*	*571*	*94,7%*	*99,1%*	*98,6%*	*92,4%*
2	*682,6*	*643,8*	*935*	*47563*	*0,7*	*575*	*94,3%*	*98,8%*	*98,8%*	*92,0%*
3	*635,4*	*609,1*	*999*	*47225*	*0,6*	*369*	*95,9%*	*98,4%*	*99,2%*	*93,6%*
4	*650,1*	*614,9*	*936*	*41828*	*0,7*	*454*	*94,6%*	*99,0%*	*98,9%*	*92,6%*
5	*638,7*	*607,8*	*782*	*41554*	*0,8*	*687*	*95,2%*	*99,0%*	*98,3%*	*92,7%*
6	*562,3*	*525,1*	*682*	*33813*	*0,8*	*516*	*93,4%*	*99,8%*	*98,5%*	*91,8%*
7	*640*	*588,1*	*761*	*25731*	*0,8*	*460*	*91,9%*	*99,7%*	*98,2%*	*89,9%*
8	*639,6*	*595,7*	*679*	*42668*	*0,9*	*488*	*93,1%*	*99,8%*	*98,9%*	*91,9%*
Average OEE										*92,1%*

Aaverage OEE on machine 7 only reached 92.1%.

Table 9. *OEE average (Machine-8).*

Month	**Loading Time**	**Operating Time**	**Quantity Shot**	**Processed Amount**	**Ideal CT**	**Defect Amount**	**Availability Ratio**	**Performance Efficiency**	**Rate of Quality**	**OEE**
1	*670,4*	*656,1*	*869*	*28981*	*0,8*	*512*	*97,9%*	*99,3%*	*98,2%*	*95,5%*
2	*689,6*	*687,6*	*845*	*26612*	*0,8*	*340*	*99,7%*	*99,6%*	*98,7%*	*98,0%*
3	*683,4*	*670,1*	*901*	*33735*	*0,7*	*237*	*98,1%*	*99,5%*	*99,3%*	*96,9%*
4	*693,7*	*684,9*	*830*	*33147*	*0,8*	*234*	*98,7%*	*99,5%*	*99,3%*	*97,6%*
5	*667*	*656,8*	*829*	*31347*	*0,8*	*158*	*98,5%*	*99,7%*	*99,5%*	*97,7%*
6	*580,4*	*575,6*	*713*	*24265*	*0,8*	*129*	*99,2%*	*99,5%*	*99,5%*	*98,1%*
7	*691,5*	*677,4*	*879*	*23556*	*0,8*	*283*	*98,0%*	*98,7%*	*98,8%*	*95,5%*
8	*576,5*	*561,1*	*695*	*24880*	*0,8*	*106*	*97,3%*	*99,1%*	*99,6%*	*96,1%*
Average OEE										*96,9%*

Aaverage OEE of 8 machines was 96.9% higher than average OEE 7 of the previous machine, while highest OEE in June was 98.1%.

Table 10. *OEE average (Machine-9).*

Month	**Loading Time**	**Operating Time**	**Quantity Shot**	**Processed Amount**	**Ideal CT**	**Defect Amount**	**Availability Ratio**	**Performance Efficiency**	**Rate of Quality Product**	**OEE**
1	*606,9*	*580,2*	*829*	*46846*	*0,7*	*749*	*95,6%*	*97,2%*	*98,4%*	*91,4%*
2	*604,8*	*582,4*	*811*	*49451*	*0,7*	*787*	*96,3%*	*98,9%*	*98,4%*	*93,7%*
3	*615,1*	*592,5*	*819*	*38347*	*0,7*	*348*	*96,3%*	*99,5%*	*99,1%*	*95,0%*
4	*627,7*	*604,2*	*871*	*33309*	*0,7*	*326*	*96,3%*	*99,4%*	*99,0%*	*94,8%*
5	*641,3*	*614,5*	*859*	*34561*	*0,7*	*370*	*95,8%*	*99,3%*	*98,9%*	*94,1%*
6	*541,1*	*509,1*	*733*	*24492*	*0,7*	*174*	*94,1%*	*99,3%*	*99,3%*	*92,8%*
7	*659,3*	*617,8*	*769*	*26372*	*0,8*	*120*	*93,7%*	*99,6%*	*99,5%*	*92,9%*
8	*615,4*	*582,5*	*704*	*24719*	*0,8*	*221*	*94,7%*	*99,1%*	*99,1%*	*93,0%*
Average OEE										*93,5%*

Aaverage OEE of Machine 9 was 93.5%.

Table 11. *OEE average (Machine-10).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*627,8*	*599,3*	*910*	*33373*	*0,7*	*1584*	*95,5%*	*99,5%*	*95,3%*	*90,4%*
2	*627,5*	*606,5*	*878*	*28651*	*0,7*	*1151*	*96,7%*	*99,9%*	*96,0%*	*92,7%*
3	*664,9*	*646,7*	*935*	*36380*	*0,7*	*208*	*97,3%*	*99,7%*	*99,4%*	*96,4%*
4	*674,3*	*655,4*	*922*	*34771*	*0,7*	*229*	*97,2%*	*99,7%*	*99,3%*	*96,3%*
5	*634*	*610*	*860*	*28525*	*0,7*	*144*	*96,2%*	*99,9%*	*99,5%*	*95,6%*
6	*632,3*	*607,6*	*851*	*29161*	*0,7*	*114*	*96,1%*	*98,8%*	*99,6%*	*94,5%*
7	*663,8*	*637,2*	*888*	*50691*	*0,7*	*150*	*96,0%*	*99,7%*	*99,7%*	*95,4%*
8	*653,4*	*629,9*	*817*	*29396*	*0,8*	*173*	*96,4%*	*99,2%*	*99,4%*	*95,1%*
Average OEE										*94,6%*

Machine 10 achieved an average OEE of 94.6% with lowest OEE in January 90.4%.

Table 12. *OEE average (Machine-11).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*660,2*	*631,1*	*903*	*67303*	*0,7*	*1596*	*95,6%*	*98,7%*	*97,6%*	*92,1%*
2	*665,7*	*638,8*	*900*	*66018*	*0,7*	*1111*	*96,0%*	*98,6%*	*98,3%*	*93,0%*
3	*697,5*	*672,3*	*938*	*78758*	*0,7*	*637*	*96,4%*	*99,7%*	*99,2%*	*95,4%*
4	*694,0*	*669,8*	*951*	*70869*	*0,7*	*965*	*96,5%*	*99,4%*	*98,6%*	*94,7%*
5	*625,8*	*603,1*	*842*	*60582*	*0,7*	*636*	*96,4%*	*99,1%*	*99,0%*	*94,5%*
6	*629,0*	*608,2*	*872*	*59634*	*0,7*	*431*	*96,7%*	*99,0%*	*99,3%*	*95,0%*
7	*667,1*	*642,2*	*963*	*31432*	*0,7*	*882*	*96,3%*	*99,8%*	*97,2%*	*93,4%*
8	*626,0*	*599,3*	*882*	*66119*	*0,7*	*800*	*95,7%*	*99,9%*	*98,8%*	*94,4%*
Average OEE										*94,1%*

Machine 11 achieved an average OEE of 94.1%.

Table 13. *OEE average (Machine-12).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*658,8*	*631,7*	*920*	*39137*	*0,7*	*530*	*95,9%*	*99,1%*	*98,6%*	*93,7%*
2	*676,4*	*648,9*	*920*	*36164*	*0,7*	*322*	*95,9%*	*99,2%*	*99,1%*	*94,4%*
3	*766,0*	*739*	*1000*	*35652*	*0,7*	*218*	*96,5%*	*99,5%*	*99,4%*	*95,4%*
4	*694,1*	*663,8*	*1010*	*42202*	*0,7*	*425*	*95,6%*	*99,7%*	*99,0%*	*94,4%*
5	*646,9*	*622,8*	*930*	*38860*	*0,7*	*579*	*96,3%*	*99,3%*	*98,5%*	*94,2%*
6	*597,0*	*560,6*	*895*	*31422*	*0,6*	*319*	*93,9%*	*99,0%*	*99,0%*	*92,0%*
7	*661,4*	*621,1*	*1056*	*28052*	*0,6*	*429*	*93,9%*	*98,6%*	*98,5%*	*91,2%*
8	*593,6*	*554,5*	*827*	*36673*	*0,7*	*465*	*93,4%*	*99,9%*	*98,7%*	*92,1%*
Average OEE										*93,4%*

Machine 12 achieved an average EEE of 93.4% & for 8 months there was no significant increase or decrease.

Table 14. *OEE average (Machine-13).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*635,9*	*609,1*	*822*	*32722*	*0,7*	*704*	*95,8%*	*99,8%*	*97,8%*	*93,5%*
2	*668,0*	*639,9*	*923*	*39330*	*0,7*	*487*	*95,8%*	*99,5%*	*98,8%*	*94,2%*
3	*672,5*	*649,3*	*936*	*48129*	*0,7*	*262*	*96,6%*	*99,4%*	*99,5%*	*95,5%*
4	*679,5*	*646*	*909*	*43640*	*0,7*	*472*	*95,1%*	*99,9%*	*98,9%*	*94,0%*
5	*665,1*	*637,5*	*901*	*39153*	*0,7*	*308*	*95,9%*	*99,7%*	*99,2%*	*94,8%*
6	*609,3*	*581,3*	*779*	*40294*	*0,7*	*319*	*95,4%*	*99,2%*	*99,2%*	*93,9%*
7	*634,1*	*608,9*	*852*	*32534*	*0,7*	*394*	*96,0%*	*99,4%*	*98,8%*	*94,3%*
8	*585,6*	*553,1*	*710*	*40948*	*0,8*	*639*	*94,5%*	*99,9%*	*98,4%*	*92,8%*
Average OEE										*94,1%*

Machine 13 achieved an average of 94.1% and there was no significant increase or decrease.

Table 15. *OEE average (Machine-14).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performance Efficiency	Rate of Quality Product	OEE
1	*643,7*	*614,5*	*954*	*45841*	*0,6*	*518*	*95,5%*	*99,4%*	*98,9%*	*93,8%*
2	*680,4*	*652,1*	*1001*	*49272*	*0,7*	*892*	*95,8%*	*99,7%*	*98,2%*	*93,9%*
3	*702,4*	*679,5*	*1012*	*53755*	*0,7*	*489*	*96,7%*	*99,7%*	*99,1%*	*95,6%*
4	*694,1*	*670,8*	*988*	*48818*	*0,7*	*389*	*96,6%*	*99,7%*	*99,2%*	*95,5%*
5	*663,5*	*643*	*883*	*40172*	*0,7*	*336*	*96,9%*	*99,5%*	*99,2%*	*95,7%*
6	*626,9*	*601,6*	*859*	*35211*	*0,7*	*111*	*96,0%*	*99,9%*	*99,7%*	*95,6%*
7	*666,1*	*638,4*	*982*	*33026*	*0,6*	*57*	*95,8%*	*99,2%*	*99,8%*	*94,9%*
8	*647,2*	*619,7*	*1035*	*50609*	*0,6*	*144*	*95,8%*	*98,5%*	*99,7%*	*94,0%*
Average OEE										*94,9%*

Machine 14 achieved an average of 94.9%, not much different from machine 13.

Table 16. *OEE average (Machine-15).*

Month	Loading Time	Operating Time	Quantity Shot	Processed Amount	Ideal CT	Defect Amount	Availability Ratio	Performanc e Efficiency	Rate of Quality Product	OEE
1	*686,0*	*649,2*	*854*	*46580*	*0,8*	*1370*	*94,6%*	*98,6%*	*97,1%*	*90,6%*
2	*687,7*	*649,5*	*785*	*43701*	*0,8*	*722*	*94,4%*	*99,1%*	*98,3%*	*92,0%*
3	*688,0*	*657,3*	*863*	*49911*	*0,8*	*483*	*95,5%*	*99,7%*	*99,0%*	*94,4%*
4	*684,2*	*644,8*	*901*	*40526*	*0,7*	*285*	*94,2%*	*99,3%*	*99,3%*	*92,9%*
5	*665,0*	*623,8*	*717*	*38571*	*0,9*	*318*	*93,8%*	*98,8%*	*99,2%*	*91,9%*
6	*646,9*	*606,1*	*740*	*33559*	*0,8*	*316*	*93,7%*	*99,5%*	*99,1%*	*92,3%*
7	*679,9*	*634,8*	*877*	*32421*	*0,7*	*319*	*93,4%*	*99,5%*	*99,0%*	*92,0%*
8	*674,4*	*637,3*	*1005*	*49859*	*0,6*	*228*	*94,5%*	*99,7%*	*99,5%*	*93,8%*
Average OEE										*92,5%*

Machine 15 achieved an average of 92.5% and there was no significant decrease or increase for 8 months.

Table 17. *OEE average (Machine-16).*

Month	**Loading Time**	**Operating Time**	**Quantity Shot**	**Processed Amount**	**Ideal CT**	**Defect Amount**	**Availability Ratio**	**Performance Efficiency**	**Rate of Quality Product**	**OEE**
1	*636,3*	*592,3*	*849*	*35514*	*0,7*	*426*	*93,1%*	*100,3%*	*98,8%*	*92,3%*
2	*601,4*	*564,8*	*805*	*38462*	*0,7*	*675*	*93,9%*	*99,8%*	*98,2%*	*92,0%*
3	*661,8*	*629,5*	*861*	*43108*	*0,7*	*313*	*95,1%*	*99,8%*	*99,3%*	*94,3%*
4	*697,3*	*665,6*	*894*	*43531*	*0,7*	*287*	*95,5%*	*99,9%*	*99,3%*	*94,8%*
5	*634,6*	*606,3*	*807*	*37734*	*0,7*	*303*	*95,5%*	*93,2%*	*99,2%*	*88,3%*
6	*635,5*	*593*	*776*	*37205*	*0,8*	*669*	*93,3%*	*98,8%*	*98,2%*	*90,5%*
7	*674,4*	*620,6*	*853*	*32421*	*0,7*	*566*	*92,0%*	*98,9%*	*98,3%*	*89,4%*
8	*672,8*	*604,8*	*825*	*40822*	*0,7*	*529*	*89,9%*	*99,5%*	*98,7%*	*88,3%*
Average OEE										*91,2%*

Machine 16 achieved an average OEE of 91.2%, in June and August OEE achieved below 90% each of 88.3%.

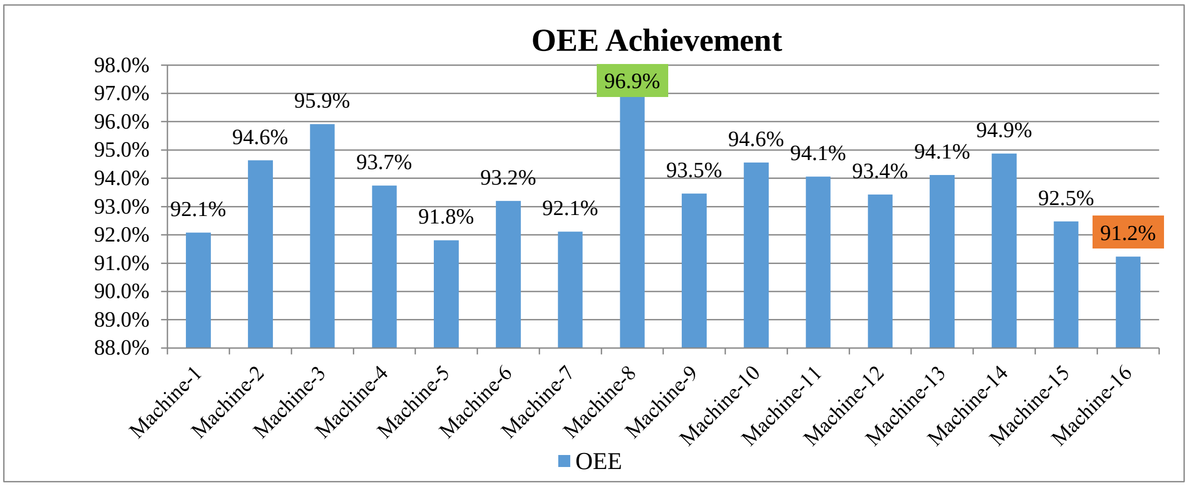

Fig. 4. *OEE achievement of 16 injection machine.*

Achievement of OEE 16 machines can be seen from the graph, machine number 16 reached 91.2% the lowest compared to other 15 machines., Some constraints caused low machine efficiency. The biggest cause of losses affecting low OEE.

– Dandori

Installation of Locating Ring for molds that Increase Tonnage with different sizes causes loss, thereby affecting the efficiency of machine.

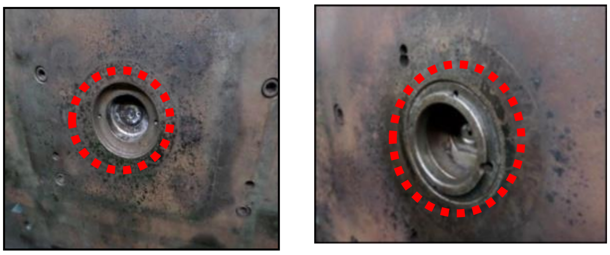

Fig. 5. *Different ring mold sizes.*

- Mold repair

Some problems arise in the mold, installation of the manifold in anti-operation side area to facilitate installation of cooling system. These conditions cause the production process must be hampered because the repair and installation process take a long time so it inhibits production.

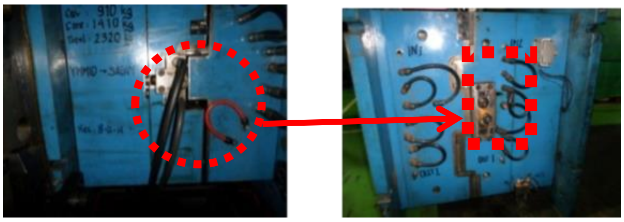

Fig.6. *Installation of manifold in area anti-operation side.*

- Breakdown Machine

Motor machine in the hydraulic machine overheating causes damage so it needs to be repaired.

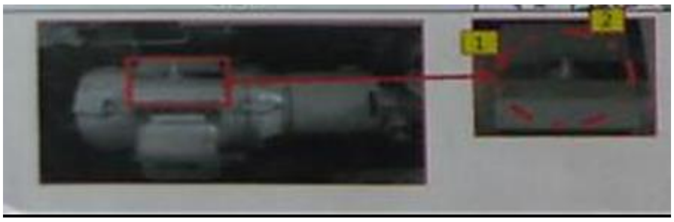

Fig.7. *Ooverheating hydraulic motor machine.*

- Re-setting

Variations and colors of different products require time for resetting due to different processes and cycle times.

- Material Loss

Machine maintenance including components in the machine need to be done intensively so as not to cause problems with the product.

- Robot Breakdown

One of the supports in the injection production process is a robot, when damage occurs the robot will affect the performance of the machine.

Fig. 8. *The robot filter is dirty and causes damage.*

– Cleaning mold

The cleaning mold activity has been scheduled, but at the time of the production process there will still be several positions on the mold that need to be cleaned so that during the injection process the product is produced according to customer specifications.

Fig. 9. *Cleaning on several sides of mold.*

5. Conclusion

Measure of machine performance with the OEE approach has become a culture in Japanese PMA companies. Injection company with a capacity of 16 machines with different efficiency produces output products with different ratios as well. Based on data obtained and data processing for machine efficiency values, the average OEE is still above 90%. The age of machine affects the OEE value, Machine 8 has highest OEE value of 96.9% but there is 1 machine out of 16 machines that have the lowest efficiency value. Several constraints cause a low OEE value, from the analysis there are 7 biggest losses that cause low efficiency of 91.2%.

Suggestion

More in-depth analysis needs to be done for machines 16 with the lowest OEE. Several factors have been identified then it is necessary to do an analysis with 5M and 1E in order to find root of problem

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