Overall Equipment Effectiveness (OEE) analysis and Failure Mode and Effect Analysis (FMEA) on Packer Machines for minimizing the Six Big Losses - A cement industry case

I S. Muthalib, M Rusman and G L Griseldis

Industrial Engineering Department, Universitas Hasanuddin, Makassar - Indonesia

E-mail: irwan@tiunhas.net

Abstract. Bosowa Maros Cement Company (BMC) is a company engaged in the production of cement. There are seven packer machines for the packaging process to fulfill the demand in BMC. The most problems are many breakdowns that occur on packer machines, and the amount of production, which not maximum, causes a lack of Overall Equipment Effectiveness (OEE) value. The research aimed to identify the performance of packers based on production data using OEE and Failure Mode Effect Analysis values. The results of the six big losses and the Pareto diagram show that the most affect losses in causing the low achievement of OEE values on both machines are reduced speed loss, idling and minor stoppages, equipment failure (breakdown loss) for Packer 3 is 94.27% and Packer 7 is 90.41%. The average OEE value of the Packer 3 machine is 53%, and the Packer 7 machine is 36%. OEE values on the two machines have not reached the OEE ideal standard by the Japan Institute of Plant Maintenance (JIPM), which is 85%.

1. Background
The strict competition in the era of globalization requires industries to be more productive with the best quality for each product produced. Bosowa Maros Cement Company (BMC) is an industry located in Maros Regency, South Sulawesi, Indonesia. BMC itself has 7 Packer machines that are operated for the cement packaging process, but not all packer machines are able to perform optimally.

Based on company data for the period January 2018 to July 2019 Packer 1 operated for 442 days, Packer 2 operated for 483 days, Packer 3 operated for 521 days, Packer 4 operated for 516 days, Packer 7 operated for 374 days, Packer 8 operated for 385 days day, and Packer 9 operated for 401 days. There was no Packer that could operate 100% during that period due to some failures or damages on the equipment, or the packer was only idle [1]. Based on the results of interviews in the Production Planning and Inventory Control (PPIC) and Production Engineering (PE) sections, the packer has experienced to some of the same types of failures, including the spout not functioning or being clogged by cement solids, the machine dies due to various equipment malfunctions, bag filling which exceeds the maximum time from the target, and so on that those will result in unplanned downtime on the machine.

In the world of engine maintenance, there are six type of losses that must be avoided by every company that can reduce the level of effectiveness of a machine, known as the Six Big Losses [2]. As mention in Almeanazel [3], the six big losses are usually categorized into 3 main categories based on...
aspects of loss: downtime, speed losses and defects. A comprehensive calculation method to identify the level of productivity and machine performance is called Overall Equipment Effectiveness (OEE). The purpose of this research were to find out how much the achievement of the packer’s OEE values includes availability rate, performance efficiency, and quality rate at BMC, identify the losses that most affect the Packer engine's evectivity, and provide suggestions for improving engine performance from the measured OEE values, which will be proposed as consideration for improvements to the Packer engine.

2. Literature Review

2.1. Overall Equipment Effectiveness (OEE)
Overall Equipment Effectiveness (OEE) is a calculation carried out to determine the extent of the effectiveness of an existing machine or equipment [3]. OEE is one of the methods available in Total Productive Maintenance (TPM) according to [4]. Generally, OEE is used as an indicator of the performance of a machine or equipment. The purpose of OEE is as a measure of the performance of a maintenance system, by using this method it can be seen the availability of machines or equipment (availability), production efficiency (performance), and the quality of the output of the machine/equipment (quality) [5].

2.2. Six Big Losses
There are six equipment losses that cause low performance of machines and equipment. the six losses are known as six big losses which are divided into 3 categories of losses: downtime losses (breakdown, set up and adjustment) speed losses (idling and minor stoppages losses, reduce speed), and quality losses (rework and quality defects, start up reject) [6].

2.3. Failure Mode and Effect Analysis (FMEA)
Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent possible failure modes [7] and [4]. The factors are defined are: Severity, Occurance, and Detection. The Risk Priority Number (RPN) is get by multiplying Severity, Occurance, and Detection.

3. Research Methodology
Data is taken from PPIC department of BMC. By used the OEE method as written in [2], there were three stages of the process, including the calculation of availability ratio (down time losses), performance ratio (speed losses), and quality ratio (quality losses).

Also mentioned in [8] and [9], after the effectiveness of the engine was known, the calculation of the magnitude of the ratio of the six components of the six big losses was equipment failure, set up and adjustments, idling and minor stoppages, reduced speed, scrap and rework and startup losses to find out what categories of losses are causing low OEE value of the machine.

Then the research continued by filling in the FMEA questionnaire as a method of identifying problems. FMEA questionnaire data was obtained from one respondent namely Production Engineering employees who were responsible for managing the activities of the Packer machine. How to calculate FMEA questionnaire data by using RPN, i.e. multiplying severity, occurance and detection [4]. The results to be obtained were expected to be a reference for decision making to achieve a good maintenance management system. The data processed was the downtime of packer 3 and packer 7 machines from January 2018 to June 2019 where later the processing results are compared with international OEE standards.

4. Results

4.1. Calculation of OEE.
The ABC inventory management system is a technique for managing inventory control by dividing inventory systems that need to be controlled more. [10][11] mention that the ABC category is based on the price of the type of inventory and the amount of company demand. From the results of data processing obtained spare parts grouping as in Table 1.
4.2. Calculation of Packer Machine Losses
This calculation is to identify the six components of six big losses, which component has the highest ratio or influence on the low OEE value that has been obtained.

| Group Losses | Six Big Losses | Time Losses (hour) | Time Losses (%) | Cumulative |
|--------------|----------------|--------------------|-----------------|------------|
|              |                | Packer 3 | Packer 7 | Packer 3 | Packer 7 | Packer 3 | Packer 7 |
| Downtime Losses | Equipment Failure | 2,112.58 | 1,620.76 | 17.71 | 22.55 | 18 | 23 |
|                | Set Up & Adjustment | 560.71 | 660.05 | 4.76 | 8.84 | 22 | 31 |
| Speed Losses | Idle & Minor Stoppages | 2,673.29 | 2,280.81 | 22.47 | 31.39 | 45 | 63 |
|                | Reduce Speed | 6,491.00 | 3,049.00 | 54.09 | 36.47 | 99 | 99 |
| Quality Losses | Scrap & Rework | 59.28 | 25.16 | 0.00 | 0.00 | 100 | 100 |
4.3. Failure Mode and Effect Analysis (FMEA)

From the results of the total time loss on the Packer 3 engine and the Packer 7 engine, there was three losses factors, namely Reduced Speed Loss, Idling and Minor Stoppages, and Equipment Failure. These three losses factors analyzed using Failure Mode and Effect Analysis. The FMEA analysis was made based on the results of interviews and discussions with the head of production and Production Engineering of the Packer machinery section at BMC.

| Factor Losses | Failure Mode | Failure Cause | Failure Effect | Initial Conditions |
|---------------|--------------|---------------|---------------|--------------------|
| Equipment Failure (breakdown) | Breaker motor trip | Dust conceded contactor | The spout does not work during the cement filling process | 7 5 4 140 |
| | Trouble instrument | Slip ring encountered a problem (carbon brush was used up / worn out) | The engine is off for a moment, and repair is needed | 8 4 5 160 |
| Idling and Minor Stoppages | Flow attempt failed | The spout is blocked by solid cement | The spout lights up but does not release material (cement) | 6 5 6 180 |
| | Bag can’t released | Rubber Bufferaus | Couldn't remove bag | 4 5 4 80 |
| | Lost work time | Power Blackout | Working time is reduced, production targets may not achieve than targeted | 6 4 4 96 |
| | | Workers (laborers / operators) are not available | Work is pending to wait | 6 3 3 54 |
| Reduced Speed Loss | Beyond maximum filling time | Material discharge is not optimal | Bag filling exceeds the maximum amount of time targeted | 7 5 6 210 |
| | | Aerasi Cylinder Bag Holder leaking out | Cannot remove the bag according to the filling limit and release towards the irregular conveyor belt | 3 5 4 60 |
| Actual and Ideal production time doesn’t match | Workshop takes too long, workers tend to chat while working | Work completion time sometimes does not match the target | 4 3 3 36 |

From three losses factors, the reduced speed loss factor, which is the failure mode beyond the maximum
filling time, is the largest RPN, which means that these losses must get more attention to be overcome.

5. Discussion
In Packer 3 it appears that in the 9th and 18th periods the OEE value of the machine was very low by 44%. In packer 7 it appears that in the 13th period the OEE value of the machine was very low by 17%. This is due to the low level of engine performance ratio in that period. Overall, the OEE value on Packer 3 machines was 56% and in Packer 7 it was 36% below the Japan Institute of Plant Maintenance (JIPM) standard of 85%. Of the three components, the value that affects OEE is the value of a very low performance ratio. Those were stated in [12] and [13]. So, it can be stated that the overall performance or productivity of the two Packer machines is not maximal, still far below ideal conditions.

From the OEE result, it can be seen that in Packer 3, the value of the biggest loss ratio is caused by reducing speed losses by 54.09%, idle & minor stoppages losses by 22.47%, and Equipment Failure Losses by 17.71% which is 94.27% so it becomes a major factor in the low level of effectiveness of the Packer 3 engine. Based on the cumulative recapitulation of six big losses packer 7, it can be seen that the value of the largest loss ratio is caused by reducing speed losses by 36.47%, idle & minor stoppages losses by 31.39%, and Equipment Failure Losses by 22.55% which amounts to 90, 41% so it becomes a major factor in the low level of effectiveness of the Packer 7 engine. The three other factors: set up & adjustment losses, scarp & rework and start up losses as a whole only affect 4.76% for Packer 3 and 8.84% for Packer 7 so that they do not significantly influence the low OEE value on the machine, then the three factors are not a priority for improvement.

Based on the RPN from the Worksheet FMEA of the Packer 3 and Packer 7 machines before, the biggest cause of failure was known to affect the low OEE value in the reduced speed loss factor, the same emotion in [6], which is beyond the maximum filling time with an RPN of 210 due to the material discharge from the Packer machine which is not optimal which results in the bag filling exceeding the limit maximum time than targeted. The next biggest cause of failure is the idling and minor stoppages factor, namely the flow attempt failed with an RPN of 180 caused by a blockage in the spout so that the bag is not filled with material. In the equipment failure factor (breakdown loss) the biggest cause of failure was trouble instrument with an RPN of 160 because the engine was running and then turns itself off. The three losses factors based for the reduced speed loss factor, which is the failure mode beyond the maximum filling time, was the largest RPN, which means that these losses must get more attention to be overcome.

6. Conclusion
The OEE value on the Packer 3 machine were 53%, and Packer 7, which was 36%, and still far from the world standard OEE standard set by the Japan Institute of Plant Maintenance (JIPM) by 85%. So, it can be stated that the effectiveness of the two machines, namely Packer 3 and Packer 7 during low production. This was due to the large amount of loading time that absorbed due to Reduce Speed, Idle and Minor Stoppages, and Equipment Failure (Breakdown Loss) that occured on the engine.

It was known that the biggest factors that cause the low achievement of OEE values on Packer 3 and Packer 7 machines were Reduced Speed Loss, Idling and Minor Stoppages, and Equipment Failure (Breakdown Loss). On the Packer 3 engine, the Reduce Speed Loss factor results in an inefficient time of 54.09% or 6491 hours, Idling and Minor Stoppages results in an inefficient time of 22.47% or 2,673.29 hours, and Equipment Failure (Breakdown Loss) resulting in inefficient time of 17.71% or 2,112.58 hours during January 2018 - June 2019.

On the Packer 7 engine the Reduce Speed Loss factor results in an inefficient time of 36.47% or 3049 hours, Idling and Minor Stoppages results in an inefficient time of 31.39% or 2280.81 hours, and Equipment Failure (Breakdown Loss) results inefficient time of 22.55% or 1620.76 hours during January 2018 - June 2019. Therefore, the higher the total time loss, the less the effectiveness of the Packer engine in producing products.

Proposed design improvements proposed by researchers to the company in minimizing the Six Big Losses that occur were to make changes in preventive parts and determine the life of the parts life,
perform routine scheduled cleaning every month so that no more blockages occur in the spout during the filling process, and preventive maintenance measures taken before the machine operates and can prevent damage to the machine while operating for the sake of smooth production.

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