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PERFORMANCE IMPROVEMENT OF INJECTION PUMP MACHINES BASED ON OVERALL EQUIPMENT EFFECTIVENESS: CASE STUDY IN OIL COMPANY

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Abstract. Although the water injection pump system produced is not the main system in oil and gas production, but this system becomes very important because failures occur in the injection pump can cause pollution and loss of production opportunity-LPO. The Pertamina Exploration and Production-PEP field Bunyu injection pump system often fails. Maintenance performance is measured by the availability that has low amount and impact on increasing LPO (as an undesirable condition). This study aims to optimize the effectiveness of PEP field Bunyu injection pump by implementing measurements of overall equipment effectiveness (OEE) and analysis of six big losses. The analysis results show that the proposed problem components that need to be improved are suction and discharge pump piping, pump characteristics, power supply characteristic, setting of suction or discharge valve and quality of pump spare part. The results of the study show that there are two big losses affecting the effectiveness of water injection pump system produced, namely breakdown losses and reduced speed losses. As a result of improvements, it shows increased OEE value.

Introduction

The performance of the water injection plant system is one of the determinants in the smoothness and achievement of oil and gas production. If the water injection produced is stopped or interrupted, it will close one or several production wells to prevent the excess gross fluid in the tank from being accommodated, thus it can result in loss of production opportunity-LPO from crude oil. The field Bunyu is one of the fields in the Pertamina Exploration & Production (PEP) working area which has the smallest working area and highly enough LPO crude oil data. Based on a study of the monthly reports on PEP Field Bunyu maintenance activities during 2016, the performance of production facilities for injection pumps (types of centrifugal pumps) and power sources in their electric motors had the greatest number of hours of damage compared to other production equipment. The effect of damage to the injection pump on LPO is shown in Figure 1 where the injection pump performance indicator shown by the availability value with average value of 86.77% in 2016. The achievement of this value is still below the target of the PEP Field Bunyu set at 90%. The other main equipments which are the tank and separator have high reliability, hence there is no breakdown or damage during 2016. Transfer pumps, gas compressors and pipelines can be considered as good enough because the frequency of failures is quite low and handling problems that are not too complicated.

Increasing maintenance effectiveness level requires an approach method that involves all business factors, input-output, expertise, technology, and other resources in an integrated manner. One approach is to measure overall equipment effectiveness-OEE as a product of total productive maintenance-TPM which the concept was introduced in 1971 by Japanese scientist Seiichi

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Nakajima. Total productive maintenance is one of the methods developed in Japan that can be used to improve the productivity and efficiency of company production by using machine and equipment effectively [1,2,3].

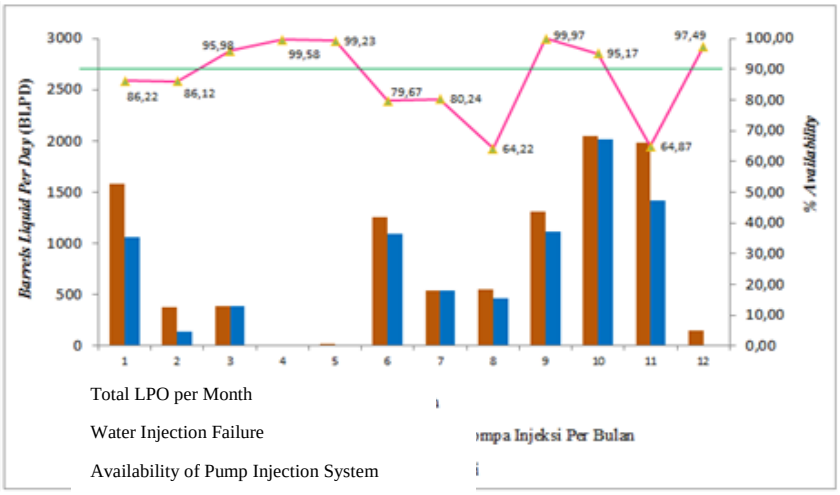

Figure 1 Availability value of Injection Pumps and LPO in 2016

Overall equipment effectiveness can identify hidden losses which are a big waste which not been aware of [4]. OEE value is a multiplication of availability rate, performance rate and rate of quality factors as a measure of the overall effectiveness of the equipment [5]. The research of [4] confirmed that OEE is a very useful measuring tool in monitoring production performance and as an indicator of performance sustainability. OEE implementation can identify and overcome various obstacles. Research conducted by [6] was evaluating rig performance to produce more efficient rig operations. OEE monitors the actual performance of relative workover to performance capabilities under optimal workover conditions. Increased efficiency can be achieved through effective management efforts to increase productivity. According to [7], OEE is one of the most popular methods of performance evaluation in manufacturing processes to identify and eliminate the causes of production losses.

Research [8] studied the measurement of OEE and six big losses analysis in gas refinery companies in Assaluyeh-Iran. The results of the study show that better planning and coordination with customers can reduce large losses at the refinery unit. Refer to research [5] reported case study on the Turbo-Gas Compressor (ENI Oil Co.) engine, with the assumption of a quality rate of 100%, successfully obtained an OEE value 66.3%. This value can still be considered as competent but still considering to improve its performance and availability. Reserch [9] in his study obtained an OEE value of 33% with an assumption of a quality rate of 100% in the Genset Cat G3512 PEP Field Sangatta. Through the analysis of the six big losses, it can be seen that the performance rate component is the cause of the low OEE value, this is based on the high value of idling and minor stoppages due to the less effective implementation of preventive maintenance [10]. Research [11] measured the performance of the water discharge process in Narmada Water Supply Plant-NWSP where the plant had an OEE value of 59.59%. This value was 25.41% lower than the world-class OEE reaching 85%. These disadvantages are mainly downtime losses, speed losses, quality losses that affect OEE values.

Method and Materials

In this study, the authors conducted several techniques for collecting data, namely:

a. Documentation; data/information obtained consist of company profile, company organizational structure, injection process data (flowrate) and pump operation data.
b. Interview; the parties interviewed were: (i) Technicians and Supervisors to perceive the cause of the pump breakdown and how to solve it, (ii) Production operators to know more about the

injection process and how coordination was carried out with Maintenance officers, (iii) RAM Assistant Manager (as head of Maintenance) of Field Bunyu to learn about the management efforts of maintenance activities.

c. Observation (field visit); data retrieval using eyes without other standard tools (as a checklist of documentation and interview methods)
d. Literature/library studies; in the form of collecting data and information from various literature such as handbooks and journals related to the issues discussed.
e. Presentation of data; in the form of tables, diagrams, graphs and descriptions of the results of the analysis used.

1. The data analysis techniques are as follows:
2. Calculation of Availability Rate

$$Availibility\ Ratio = \frac{Loading\ time - Downtime}{Loading\ time} \times 100\%$$

Where

(Loading time – Downtime) is Operation time

3. Calculation of Performance Rate

$$Performance = \frac{Flowrate\ \text{aktual}}{Flowrate\ \text{target}\ (ideal\ design\ capacity)} \times 100\%$$

4. Calculation of Quality Rate

Produced water is a waste that is definitely programmed to be injected so there is no term for yield or defect losses (quality value of 100%).

5. Calculation of OEE

$$Overall\ Equipment\ Effectiveness\ (OEE) = Availibility \times Performance \times Quality$$

6. Calculation of Six Big Losses
   a. Breakdown losses

$$Breakdown\ Losses = \frac{\text{Lamanya kerusakan hingga perbaikan}}{Loading\ time} \times 100\%$$

   b. Setup and Adjustment losses

$$Setup\ \&\ Adjustment\ Losses = \frac{\text{Lamanya persiapan dan penyesuaian}}{Loading\ time} \times 100\%$$

   c. Idle & mino stoppage losses

$$Idle\ \&\ Minor\ Stoppage\ losses = \frac{Non\ Productive\ time}{Loading\ time} \times 100\%$$

   d. Reduced speed losses

$$Reduced\ Speed\ losses = \frac{Target\ Output - Actual\ Output}{Target\ Output\ (design\ capacity)} \times 100\%$$

   e. Reduced Yield losses and Defect losses; there is no yield and defect losses.

7. Pareto Diagram for Losses and causal analysis with Fishbone Diagram
8. Failure Mode and Effect Analysis (FMEA) & Risk Priority Number (RPN)
9. Analysis of 5W + 1H and improvement implementation.

Result and Discussion

Produced water from the Field Bunyu in the water injection plant in MGS (Main Gathering Station) ranges from 26,000-45,000 barrel water/day (BWPD) during 2016 to April, 2017. The installed

injection pump consists of four units in parallel with three operating units and one standby unit. If needed urgently, all four pumps can be operated simultaneously. The schematic is shown in (Fig. 2). The pump capacity of each manufacturer is 66.3 m^3 per hour which is equivalent to 10,000 BWPD and electric motor driven with 134 kWh of electricity.

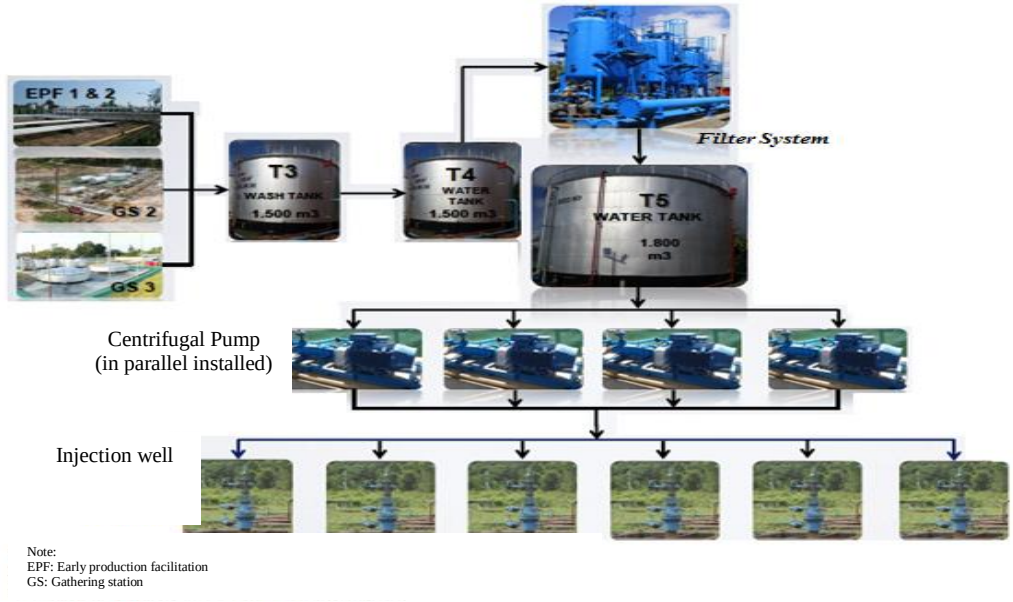

Figure 2 Injection Schematic System of Field Bunyu

Because it has a factor of 1.1 for optimum operation, the ideal operating conditions for the total pump system capacity are 33,000 BWPD for three units and 44,000 BWPD for four units. The injection process lasts 24 hours continuously by adjusting the utilization of the four pumps. The data that has been collected for this study are shown in Table 1 and Table 2.

Table 1 Data of injection pump down time in 2016

Month	Loading time (hours)	Setting time (hours)	Down time (hours)	Operating time (hours)
January	647.00	0	89.17	557.83
February	558.17	0	77.50	480.67
March	563.83	0	22.67	541.17
April	522.00	0	2.17	519.83
May	505.71	0	3.88	501.83
June	582.13	0	118.38	463.75
July	568.00	0	112.25	455.75
August	628.50	0	224.88	403.63
September	578.00	0	0.17	577.83
October	531.33	0	25.67	505.67
November	636.13	0	223.50	412.63
December	596.67	0	15.00	581.67
Total	6,917.46	0	915.21	6,002.25

Table 2 Data of injection system flow rate in 2016

Month	Minor Stoppages (hours)	Flow rate target (BWPD)	Actual flow rate (BWPD)
January	0	33,000	29,136
February	0	33,000	29,418
March	0	33,000	32,228
April	0	33,000	31,051
May	0	33,000	30,219
June	0	44,000	35,118
July	0	44,000	30,258
August	0	44,000	27,913
September	0	33,000	31,824
October	0	33,000	29,822
November	0	44,000	29,733
December	0	33,000	30,232
Total	0	440,000	366,952

The results of availability, performance and OEE calculations are shown in Table 3.

Table 3 Calculation of OEE in 2016

Month	Availability (%)	Performance (%)	Quality (%)	OEE (%)
January	86.22	88.29	100.00	76.12
February	86.12	89.15	100.00	76.78
March	95.98	97.66	100.00	93.73
April	99.58	94.09	100.00	93.70
May	99.23	91.57	100.00	90.87
June	79.67	79.81	100.00	63.58
July	80.24	68.77	100.00	55.18
August	64.22	63.44	100.00	40.74
September	99.97	96.44	100.00	96.41
October	95.17	90.37	100.00	86.00
November	64.87	67.58	100.00	43.83
December	97.49	91.61	100.00	89.31
Average	86.77	83.40	100.00	72.36

As for the analysis of six big losses (become four big losses due to yield and defect do not exist), it has been found that there is no set up/adjusment and minor stoppages, breakdown losses were 13,23% and reduced speed losses were 16.6% as shown in Table 4 and Table 5.

Table 4 Calculation of % four big losses

Losses type	% value	% cummulative
Down time	13.23	44.35
Reduced speed	0.00	0.00
Minor stoppages	16.60	55.65
Total	29.00	100.00

Table 5 The rank of four big losses

Losses type	% value	% cummulative
Down time	55.65	55.65
Reduced speed	44.35	100.00
Minor stoppages	0.00	100.00
Total	100.00	100.00

The results of the problem analysis (losses) with fishbone diagrams are shown in (Fig. 3) for reduced speed losses and (Fig. 4) for breakdown losses, through FMEA analysis, it was determined that the proposed improvements were based on the causes and implementation of improvements using the 5W and 1H methods (starting with the value of the Risk Priority Number (RPN) of more than 100 based on the FGD focus discussion group). Based on this analysis, the problematic components with more than 100 RPN values to be proposed to receive improvement are suction and discharge piping of pump, pump characteristics, power source characteristics, suction and discharge valve settings as well as pump spare part quality.

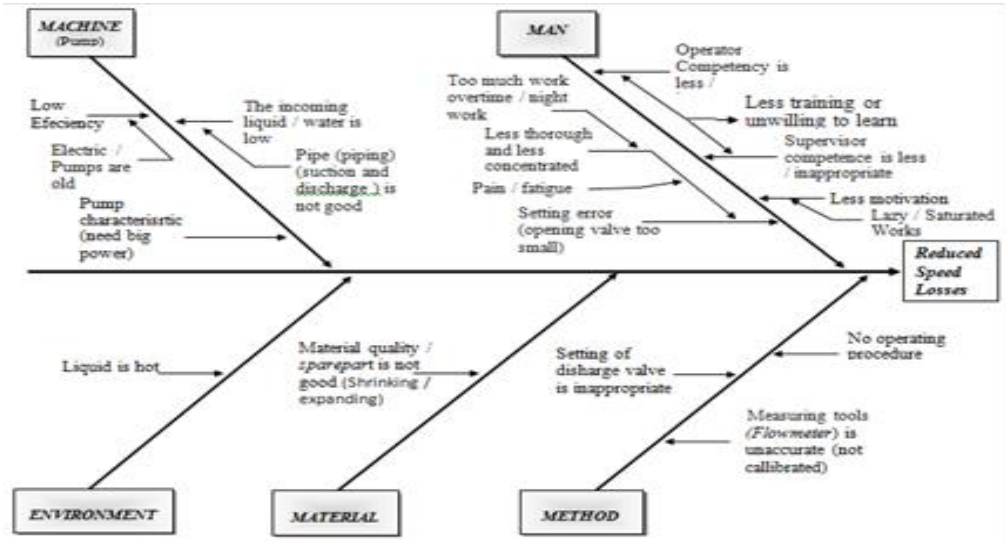

Figure 3 Fishbone Diagram for Analysis of Reduced Speed Losses

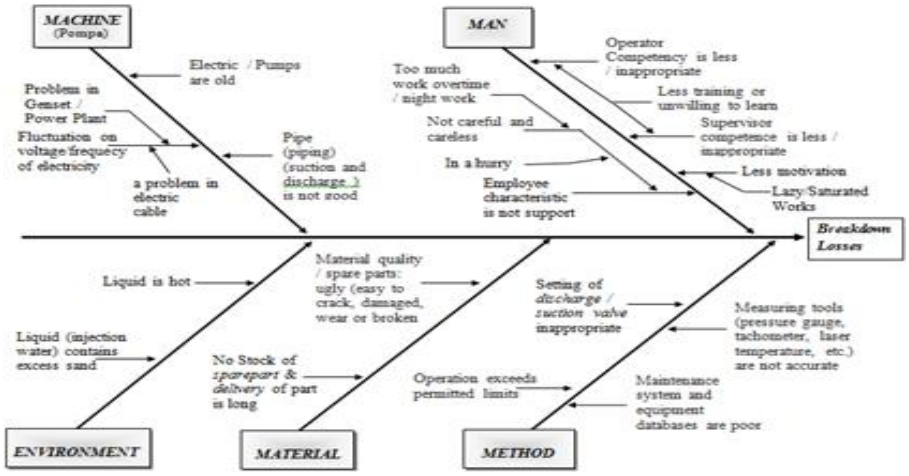

Figure 4 Fishbone Diagram for Analysis of Breakdown Losses

The results of calculation of availability, performance and OEE in 2017 (after repairs) are shown in Table 6, Table 7, and Table 8.

Table 6 Calculation of Availability, 2017

Month	Loading time (hours)	Down time (hours)	Operation time (hours)	Availability (%)
January	582.17	65.33	516.83	88.78
February	630.90	66.15	564.75	89.51
March	697.83	28.00	574.50	95.99
April	567.67	22.67	623.80	96.01
Total	2,478.57	182.15	2,296.42	92.65

Table 7 Calculation of Performance, 2017

Month	Flow rate target (BWPD)	Actual Flow rate (BWPD)	Performance rate (%)
January	33,000	29,055	88.04
February	33,000	31,144	94.38
March	33,000	32,077	97.20
April	33,000	31,974	96.89
Total	132,000	124,250	94.13

Table 8 Determination of OEE in 2017

Month	Availability	Performance (%)	Quality (%)	OEE (%)
January	88.78	88.84	100.00	78.14
February	89.51	94.38	100.00	84.47
March	95.99	97.20	100.00	93.30
April	96.01	96.89	100.00	93.02
Average	92.65	94.13	100.00	87.21

With the same principle, the analysis of six big losses determines the breakdown losses of 7.35% and reduced speed losses of 5.87% as shown in Table 9.

Table 9 Determination of six big losses percentage (%) in 2017

Losses type	Value (%)	% of losses value	% of Losses value cumulative
Break down	7.35	55.59	55.59
Reduced speed	5.87	44.41	44.41
Set up	0.00	0.00	0.00
Minor stoppages	0.00	0.00	0.00
Total	13.38	100.00	100.00

The achievement of the overall equipment effectiveness (OEE) value after repairs has increased initially from 72.36 to 87.21%, which has also passed the world-class OEE. Comparison of achievements between 2016 (before repairs) and 2017 (after repairs) is shown in (Fig. 5).

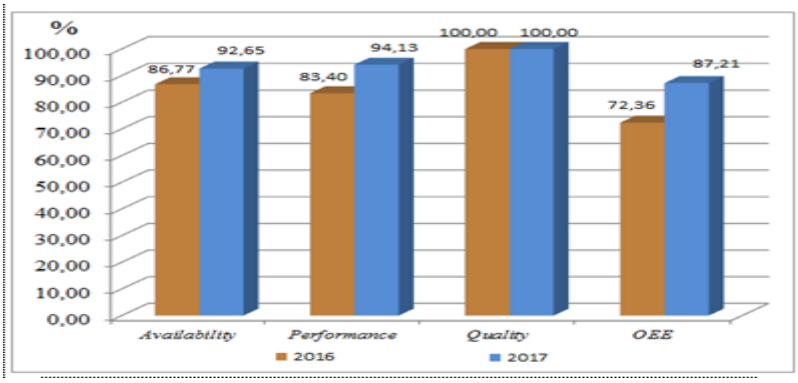

Figure 5 Comparison Graphic of OEE values

The analysis results of six big losses indicate that there are two big losses that have a dominant effect on OEE values, namely breakdown losses and reduced speed losses. It is proven that the decrease in losses in the process of injection of produced water gives an increase in OEE value.

Conclusion

The value of Overall Equipment Effectiveness (OEE) in the injection process at Field Bunyu's water injection plant was 72.36% during 2016. This OEE value is still below the world-class OEE manufacturing industry (minimum 85%) and continuous process industry (minimum 95%). The availability value has also not reached the company's target due to frequent breakdown of the pump caused by frequent damage to bearings, wearing and mechanical seals. After the injection process was improved, the OEE value rose to 87.21% in 2017. Even though it is still lower than the continuous process industry standard, this value has exceeded the OEE of manufacturing companies. The dominant cause that influences the achievement of OEE values is reduced speed losses of 16.6% and breakdown losses (pump availability factor) of 13.23%. Increasing OEE value can be achieved by making several improvements include: (i) adding electricity so that the four pumps operate more effectively, using Genset Cat G 3516 from Field Tarakan, (ii) modifying gland packing and wear rings as part of fast moving pump and installation variable speed drive (inverter) for pump motor purposes. This improvement reduced speed losses from 16.6% to 5.87% and breakdown losses from 13.23% to 7.35%.

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