Evaluation of Overall Equipment Effectiveness in a Continuous Process Production System of Condensate Stabilization Plant in Assalooyeh

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Abstract
One of the most Important and critical matter in the field of continuous improving of manufacturing systems, is performance evaluation. Overall Equipment Effectiveness is one of the performance evaluation methods that are most common and popular in the production industries. This research tries to evaluate the Overall Equipment Effectiveness index on Stabilization units in a refinery located in Assaluyeh. Identifying the main loss elements of the process was another aim of research. Also result will be compared with world class level. Result of the research demonstrates that although the Overall Equipment Effectiveness coefficients of the investigated process are not at the world class level, but if try to improvement continuously, their performance are acceptable.

Keyword: Overall Equipment Effectiveness, Total Effectiveness Equipment Performance, Condensate Stabilization Process, World Class Level

1. Introduction

Contents of the gas extracted from wells, are separated and refined trough the processes of gas refineries. Equipments that are arranged in a sequence of these processes such as lines, valves, drums, filters, exchangers, pumps and compressors and etc refine the extracted gas and produce valuable products. Condensate is the most valuable products of gas refineries in Assaluyeh. Thus efficient and effective use of the capital intensive facilities established to stabilize Condensate is necessary. In order to achieve and maintain this target performance measurement is a key tool. For several decades researchers study on the subject of definition an appropriate metrics performance measurement for manufacturing facilities. Undoubtedly Overall Equipment Effectiveness (OEE) is one of the most accepted metrics in this field which is applied to many manufacturing industries. OEE is a performance measurement method that indicates the relationship between the availability factor, performance factor and quality rate factor. In this way, OEE can be considered to combine the operation, maintenance and management of manufacturing equipment and resources (Dal et al 2000). The OEE metric that originally described by Nakajima (1988), can measure level of equipment effectiveness, and also identify loss elements which are classified into six major groups. These six big losses are breakdown losses, setup and adjustment losses, minor stoppage, reduced speed losses, defect/rework and yield losses. The first and second groups of losses are known as downtime losses which used to determine availability factor of machine. The third and fourth losses are known as speed losses and used to determine performance factor of machine. Finally two last groups of losses are known as quality losses and used to determine quality rate of machine. The OEE includes some weak points for example it can be used as an index of performance evaluation of individual equipment in a production system and do not observe relationship the target machine with its downstream and upstream machine of manufacturing line production. The other weak point pertains to the losses that occur into excluded time which are times scheduled for not producing. These weak points require further modification in order to meet wider requirement. So recently are developed modified OEE models. TEEP, proposed by
Ivancic (1998), is very similar to OEE. The main difference lies in the inclusion of planned downtime in the total planned time horizon. In order to show clearly how maintenance contributes to improve the productivity of the plant, TEEP metric distinct between planned downtime and unplanned downtime. The TEEP measure, as well as OEE, is limited to equipment level performance. The overall line effectiveness (OLE) is proposed by Nachiappan and Anantharaman (2006) to measure productivity of product line involving machines in series which arranged in continuous line manufacturing effectiveness of a manufacturing line (OEEML). Anvari and et al (2010) proposed a new method, overall equipment effectiveness system. In 2009 Braglia and et al according to their alternative structure of losses, proposed overall equipment based on market (OEE-MB), which monitors production and measures the equipment effectiveness for full process cycle in order to meet the market. Muthiah and Haung (2007) offered overall throughput effectiveness (OTE) metric for factory level performance monitoring and bottleneck detection. In the field of application of OEE in oil and gas industries, Nadernejad and Nilipour Tabatabaei (2011) compare the overall equipment effectiveness in Continuous Production Line of Isomax unit of Esfahan Oil Refining Company with World Class Manufacturing.

This paper measures Overall Equipment Effectiveness in a Continuous Process Production System of Condensate Stabilization Plant in Assaloooyeh, compares their effectiveness with world class level and determines effectiveness losses elements in these processes.

2. Background

According Hansen (2001) performance evaluation is one of the key tools to determine world class companies. The OEE metric launched by Nakajima (1988), in order to measures productivity of individual production equipment, in a factory. The OEE is defined as a measure of total equipment performance, that is, the degree to which the equipment is doing what it is supposed to do (Williamson). OEE metric identifies and measures main production losses such as availability, performance and quality. Therefore OEE can be used as a key tool to improve equipments effectiveness and consequently increase productivity. According to the presentation at the 1999 Society maintenance reliability professional conference, Rohm and Haas corporation determined that developing hidden capacity of existing factories was ten times less expensive than building new capacity (Hansen 2001). On the other hands if the OEE is 50%, means half the factory is not contributing, but still consumes resource (shiresystem 2011).

2.1. Notation of the OEE elements

Availability (A): Comparison between amount of time that the machine is working and the amount of time that it was scheduled to work.

Performance (P): Comparison between amount of the product that actually was produced and amount of the product that theoretically should be produced.

Quality (Q): Comparison between number of the good (specified) product and number of the product that actually was produced.

Calendar time (CT): Total time of the observed period.

Excluded time: The time in which machine was planned to not produce

Loading time (LT): The time in which machine was planned to produce.

Operating time (OT): The time in which machine was actually produce.

Net Operating time (NOT): Theoretical cycle time multiply by number of produced unit.

Valuable Operating time (VOT): Theoretical cycle time multiply by number of produced unit which fits specification.

These elements are calculated by the following formula:

\[ LT = CT - \text{Excluded time} \]  
\[ OP = LT - (\text{Breakdown time} + \text{Setup & Adjustment time}) \]  
\[ NOP = OT - (\text{Speed loss time} + \text{Minor Stoppages time}) \]
The raw condensate from the slug catchers is preheated then flashed before going through a desalter drum. The condensate light components are then removed in the condensate stabiliser. The off-gas is then compressed before being sent to storage. The stabilised condensate is then sent to storage for export. The unit contains four main sections:

- Raw Condensate Preflash and Desalting
- Condensate Stabilisation
- Off gas Compression Section
- Stabilised Condensate to Storage

The purpose of the Condensate stabilization unit is to separate hydrocarbon condensate from a mixture of aqueous and hydrocarbon phases and then to stabilize it for export. The unit contains four main sections:

2.2 Condensate stabilization unit

The factors of OEE and TEEP are calculated as follow:

\[
OEE = \frac{Available}{Total} \times \frac{Performance}{Desired} \times \frac{Quality}{Acceptable} \\
TEEP = \frac{Available}{Total} \times \frac{Performance}{Desired} \times \frac{Quality}{Acceptable}
\]

The factors of OEE and TEEP are calculated as follow:

\[
Available (LT) = \frac{OT}{LT-DT} \quad \text{(8)}
\]

\[
Available (CT) = \frac{OT}{CT-DT} \quad \text{(9)}
\]

\[
P = \frac{Actual \ Output}{Thruput \ Cycle \ Time} \quad \text{(10)}
\]

\[
Q = \frac{Total \ production}{Total \ production} - D \quad \text{(11)}
\]

\[
Q = \frac{Total \ production}{Total \ production} - D \times 10D \quad \text{(12)}
\]
compressed and returned to the HP separators Unit, and the stabilised condensate is cooled, mixed with C5s from NGL extraction Unit and sent to storage ready for export.

3. Methodology
In order to calculate time elements and factors used for calculation the OEE and TEEP metrics for processes with gas and liquid fluid as raw material and product, a losses structure was proposed. It is helpful to mention that the gas refineries of Assalooyeh are working all the times without any holidays. According to the maintenance planning, the refineries units would be out of service for several period of time among the year. The losses structure is described as follow:

Time losses before loading time are involved:
- Overhaul activities
- Requested modification activities

Time losses after loading time are involved:
- Failure occurrence in launcher equipment such as pumps and compressors
- Failure occurrence in downstream of the process that cause not to receive feed from downstream (starvation)
- Failure occurrence in upstream of the process that cause not to send product to upstream (blocking)
- Failure occurrence in utility facilities which support the process such as power, water, steam and etc
- Time which is spend for start-up

Reduced speed losses are involved two branches:
- Internal unit losses
  - Decreasing feed flow from downstream
  - Decreasing demand of users
- External unit losses
  - Chronic problem of equipment which are as result of bad manufacturing or bad installation or bad operation
  - Leakage toxic or flammable gas that activate several detectors and lead to local or total shutdown

Quality losses are involved:
- Quality losses during start-up
- Rework (getting feed from off spec)
- Defect (sending product which do not fit specification)

It is necessary to mention that in this paper, ‘Emergency downtime’, ‘Setup and Adjustment’, ‘Reduced speed caused by customer demand’, ‘Defect’, ‘Rework’ and ‘Quality loss of start-up time’ are used as six big losses. Since ‘Minor stoppage’ is not a common loss in the refinery was omitted and instead Quality losses divided to three branches which are mentioned above.

4. Result
Calculations of measuring the OEE and TEEP metrics for two parallel Condensate stabilization units in studied refinery are done according to proposed losses structured. Result is shown in table 1. In order to evaluate availability factor in TEEP metric, calendar time is used and in OEE metric, loading time is
used. Result proposed in table 1 is about the Study that is done for a period of 9 month. Trend of OEE during the period of study are shown in figure 2 and 3.

Insert table 1 here: OEE and TEEP result during study period

In the table 1, the first column shows quantities of availability factor which are achieved according to loading time and are used for OEE calculation. The second column shows quantities of availability factor which are achieved according to calendar time and are used for OEE calculation. In the other columns are respectively proposed quantities of performance factor, quality rate factor, OEE index and TEEP index.

Insert figure 2 here: daily trend of OEE in unit A among study period
Insert figure 3 here: daily trend of OEE in unit B among study period

Trend of OEE in the unit A and B among study time are shown in figures 2 and 3. In these trends wherever occur a gap, point to a planned downtime. So from 251th day up to 263th day of study period, there is a planned downtime in unit A and from 94th day up to 108th day of study period, there is a planned downtime in unit B.

In the following, losses item Pareto chart of unit A and B are shown in figure 4 and 5. These Pareto chart also involve losses before loading time which are planned downtime. The mentioned numbers above each column indicate to the percentage share of each kind of losses from total loss of relevant unit. For instance in figure 4, reduced speed caused by customer demand is about 79% of total loss of unit A.

Insert figure 4 here: Losses Item Pareto chart of TEEP in Unit A
Insert figure 5 here: Losses Item Pareto chart of TEEP in Unit B

Decreasing of entranced feed to refinery as the result of decreasing in users demand for refinery products is considered as ‘Reduced speed caused by customer demand’.

In figures 4 and 5, items which reduce effectiveness of unit A and B are shown in detail. It is obvious that, respectively ‘Reduced speed caused by customer demand’, ‘planned downtime’ and ‘emergency downtime’ are most important losses of these units.

5. Discussion and Conclusion

According to performed studies on OEE factors in the unit A, the main weak points in the Availability factor trend are as follow:

1) From 122th up to 124th day of the studied period, because of well platform was made out of service
2) From 250th up to 263th day of the studied period, because of planned downtime (overhaul)
3) From 263th up to 265th day of the studied period, because of delay to finish overhaul

The main weak points in the Quality rate factor trend are as follow:

1) On 124th day of the studied period, because of quality losses in start-up time
2) On 166th day of the studied period, because of quality losses in start-up time
3) From 196th up to 199th day of the studied period, because of quality losses in start-up time and rework
4) From 224th up to 226th day of the studied period, because of rework
After all, the Performance factor trend in this unit is fluctuated between 40% and 100%. Reason of the high fluctuation in the performance level is high fluctuation in the amount of gas demand by the customers (other oil and gas refineries). Fluctuation in demand of gas, because of no possibility of saving gas, causes fluctuation in entranced feed to refinery which in turn causes fluctuation in the amount of produced Condensate.

Similarly, about unit B, results are shown that the main weak points in the Availability factor trend are as follow:

1) From 75th up to 77th day of the studied period, there is downtime because of low quality
2) From 93rd up to 109th day of the studied period, because of planned downtime
3) From 123rd day of the studied period, there is downtime because of well platform is making out of service
4) From 196th up to 197th day of the studied period, because of power failure as result of trip in power plant

The main weak points in the Quality rate factor trend are as follow:

1) On 2nd day of the studied period, reboiler trip and causes produced Condensate could not fit specification that lead to send final product to off spec tank (defect).
2) From 117th up to 119th day of the studied period, because of rework
3) On 197ed day of the studied period, because of quality losses in start-up time

After all, the Performance factor trend in this unit is fluctuated between 30% and 100%. Reason of the high fluctuation in the performance level is as the same as its reason in the unit A.

The achieved result show distance between overall effectiveness in these process and world class level. According Hansen (2001), world class level for continuous production process is 95%. The major reason for the distance is low performance factors level of these units. Considering current level of Availability and Quality rate factors of each unit is found amount of lack to exceed world class level.

In order to reach to world class level, unit A Performance level has to enhance to 96.13%. On the other hand current level is 21.63% lower than what is necessary to reach to world class level.

Similarly, unit B Performance level has to enhance to 96.25%. It means the current Performance level of unit B is now 25.96% lower than what is necessary to reach to world class level.

Identify and measure six big losses of industries in these units and compassion them with each other, was other aim of the research. As mentioned ‘reduced speed caused by customer demand’ and ‘emergency downtime’ respectively with around 92% and 7% are most important losses of unit A. Similarly ‘reduced speed caused by customer demand’ and ‘emergency downtime’ respectively with around 96% and 4% are most important losses of unit B. Better planning and coordination with customers will lead to reduce main loss of the units.
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Fig1. OEE measurement tool and the perspectives of performance integrated in the tool (Muchiri & Pintelon, 2008)

Fig2. Daily OEE trend of unit A

Fig3. Daily OEE trend of unit B
Pareto Chart of TEEP for unit A

Fig 4. Losses Item Pareto chart of TEEP in Unit A

Pareto Chart of TEEP for unit B

Fig 5. Losses Item Pareto chart of TEEP in Unit