PERFORMANCE MEASUREMENT THROUGH OVERALL EQUIPMENT EFFECTIVENESS IN AN AGRO BASED PLANT

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Abstract

In the generation of agile manufacturing, the machines and its functions are also becoming complex. OEE of a machine plays an important role in present scenario where delivery and quality are of prime importance to customer. The aim is to illustrate the use of FMEA analysis by discussing a novel case study dedicated to the improvement of Overall Equipment Effectiveness. One of the most widely used performance measures is OEE, a powerful tool for production development if used correctly. It is a three-part analysis tool for equipment performance based on its availability, performance, and the quality rate of the output. It is used to identify for equipment the related losses for the purpose of improving total asset performance and reliability. Failure Modes and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality Analysis (FMECA) are methodologies designed to identify potential failure modes for a product or process before the problems occur, to assess the risk. In the agro based industry a data of downtime of all the machines was collected from November 2012 and it was observed that the highest downtime was in the component 2 and the grinder machine. Hence these machines are selected for the performance measurement through OEE. After calculating the three parameters that is performance, availability and quality, the OEE of component 2 and hammer mill was observed to be 71.70% and 72.60% respectively. Followed by OEE, FMEA analysis was conducted to identify the critical machinery. The risk priority number for each sub equipment was calculated. The RPN number of equipment 1 of the component 2 reduced from 280 to 160 and that of hammer mill reduced from 256 to 180. This improved the availability of the machinery and further suggestions were provided to improve the overall equipment effectiveness of the plant.

Key Words: Overall Equipment Effectiveness, Performance, Failure mode and Effect Analysis, Agro based plant.

INTRODUCTION

One of the most widely used performance measures is OEE, a powerful tool for production development if used correctly. This OEE includes analysis of repair data and failure over a line of process. 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. It is a three-part analysis tool for equipment performance based on its availability, performance, and the quality rate of the output. It is used to identify for equipment the related losses for the purpose of improving total asset performance and reliability. It categorizes major losses or reasons for poor performance and therefore provides the basis for setting improvement priorities and beginning of root cause analysis. In the agro based industry a data of downtime of all the machines was collected from November 2012 and it was observed that the highest downtime was in the component 2 and the grinder machine. Hence these machines are selected for the performance measurement through OEE.

LITERATURE REVIEW

A considerable amount of literature has been published in relation to the definition of OEE and its various applications. Muhammad Abdus Samad, Muhammed Rifat Hossain, Md. Asrafuzzaman(1) wrote a research paper on the calculation of overall equipment effectiveness of a CNC cutting section of the shipbuilding industry. Shipbuilding industry is considered to be a thrust sector in the economy of Bangladesh. In the shipbuilding process, CNC cutting is used to cut steel plates according to the ship design. The objective of this thesis was to measure the performance of the CNC section. To do this, Overall Equipment Effectiveness (OEE) is selected; a tool of Lean Manufacturing widely used to measure the efficiency of a manufacturing plant in terms of availability, performance and quality and also identify the major productivity losses. Data were collected from the CNC shop to calculate the OEE percentage. The amount of three OEE losses i.e. downtime, speed loss and quality loss was measured and the liable factors behind these losses were identified. J. Suresh Kumar, G. Sujatha and D. Thyagarajan (3) research studied the OEE in terms of energy consumed in manufacturing of a breakfast cereal. Nowadays due to raise of electricity price, industries are in a struggle to utilise and pay for the energy which they utilise. So estimation of consumption of energy by each equipment of a plant should be noted for further rectification steps. Energy management is one of the essential steps that should be maintained in industries to make cost benefit. This paper investigates the utilisation of OEE measure for efficient management of improvement in production performance and calculation of efficiency and energy consumption of the equipments used in cereal processing industry. Farhad Anvari and Rodger Edwards(5) tried to evaluate the OEE based on market. In the steel industry, the metal sheets and coils produced by a hot strip mill based on their technical specifications and market requirement could be delivered to external customer or to a cold roll mill for further processing. The principle applies to the output of the cold roll mill. The products could either be sold to external customers or processed in a following machine in order to make galvanized sheets. Galvanized sheets also have two paths to an external customer or to a following machine for making colour coated sheets. The amount of a product for each path depends on the market position of a manufacturing company, product specification and customer requirements. From the past literature survey, it is evident that some research on FMEA have been carried out by previous researchers but still a lot of applied research in the above field is required so as to explore the successful utilizations of the FMEA technique in the area of manufacturing and design. Some of the past research work is discussed as under. Price et al. (1997) identified a Model-based diagnosis as a promising technology because it takes away the effort of building fault trees by hand, and provides a more complete coverage of possible faults. They typically portrayed it as the execution-time generation and ordering of candidate faults. Their approach was very flexible and powerful, but rarely resulted in practical diagnostic systems.
Hughes et al. (1999) stated that traditional quantitative methods for modeling mechanical systems are inappropriate for automated mechanical FMEA production. Functional modeling capitalizes on existing practices of describing components at the functional level when producing FMEA's. They defined a functional model scheme that was tailored to the reasoning requirement imposed by the automation FMEA production for mechanical systems. Their initial work was directed to reduce the amount of engineer intervention required when converting pre-existing information resources such as CAD/ CAM data into the functional model required for FMEA production. The focus of their work was kinematic systems have been the focus of work to date as the majority of the information stored in CAD/CAM produced files is associated with this domain. Rhee and Ishii (2003) demonstrated the systematic use of empirical data in performing Life Cost-Based FMEA and how it can improve the reliability and life cycle cost of complex systems such as a linear particle collider. Life CostBased FMEA aids not only design improvements and concept selection, but it also allows one to improve and plan preventive and scheduled maintenance of components. They concluded that Life CostBased FMEA has three main benefits: estimation of life-cycle cost, FMEA, and Service Mode Analysis (SMA). The method proposed by them inherently captures a system's life-cycle costs related to component failures during design, manufacturing, installation, and operation. Designers can readily incorporate the changes in the model to estimate an improved life cycle cost. The root causes directed designers to focus their efforts on problem systems, components, and processes. Yeh and Hsieh (2007) proposed a FMEA based on fuzzy theory approach and developed a prototype of the risk assessment experts system. They presented the analysis of a sewage treatment system (STS) to demonstrate the proposed fuzzy FMEA method. They concluded that the application of linguistic terms allows experts to provide a more reasonable and meaningful information for these three parameters. Fuzzy rule base could allow experts to construct the more realistic and logical rules. Narayanagounder et al. (2009) addressed the drawbacks in traditional FMEA and proposed a new approach to overcome these shortcomings. The Risk Priority Code (RPC) was used to prioritize failure modes, when two or more failure modes have the same RPN. They proposed a new method to prioritize failure modes, when there is a disagreement in ranking scale for severity, occurrence and detection. An Analysis of Variance (ANOVA) was used to compare means of RPN values. SPSS (Statistical Package for the Social Sciences) statistical analysis package is used to analyze the data. The results presented by them are based on two case studies. It was found that the proposed new methodology/approach resolves the limitations of traditional FMEA approach. Arvanitoyannis and Varzakas (2009) had applied Failure mode and effect analysis (FMEA) model in conjunction with cause-and-effect analysis for the risk assessment of octopus processing. Critical control points were identified and implemented in the cause and-effect diagram (also known as Ishikawa, tree diagram and fishbone diagram). The main emphasis was put on the quantification of risk assessment by determining the risk priority numbers (RPN) per identified processing hazard. Chemicly contaminated product, decomposed raw materials, scombrotxin presence in the final product, incorrectly labelled product, storage in cans (foreign matter) and defective products, were identified as those with the highest RPN (378, 294, 280, 252, 245 and 144 respectively) and corrective actions were undertaken. Following the application of corrective actions, a second calculation of RPN values was carried out, leading to considerably lower values (below the upper acceptable limit of 130). It was concluded that the incorporation of FMEA analysis within the ISO22000 system of an octopus processing industry is imperative.

**PROBLEM IDENTIFICATION & SCOPE OF WORK**

Management of any industry keeps a keen eye on the productivity and its improvement. Before selecting this project a detailed analysis of the process was done in the plant. After collecting the data from November-2012 till date, it was very clearly observed that although the production of the plant has substantially increased with the help of technological improvement, there was a very little change in the hours of breakdown. Also, the downtime was kind of repetitive in nature. Furthermore, the company also intends to bring a significant change in the plant in order to reduce the breakdown. Objectives: To study the existing manufacturing process. To calculate the downtime of all the equipments of the plant. To identify the critical machinery. Determine the present OEE. Investigate parameters affecting the OEE such as downtime performance and quality. To suggest some recommendations to improve the OEE. Overall Equipment Effectiveness (OEE) is a way to monitor and improve the efficiency of a manufacturing process. Developed in the mid1990's, OEE has become an accepted management tool to measure and evaluate plant floor productivity. OEE is broken down into three measuring metrics of Availability, Performance, and Quality. These metrics help gauge plant's efficiency and effectiveness and categorize key productivity losses that occur within the manufacturing process. OEE empowers manufacturing companies to improve their processes and in turn ensure quality, consistency, and productivity measured at the bottom line. By definition, OEE is the multiplication of Availability, Performance, and Quality. The formula to calculate Overall Equipment Effectiveness is as follows: OEE = Availability x Performance x Quality. The formula to calculate Overall Equipment Effectiveness is as follows: OEE = Availability x Performance x Quality.

**METHODOLOGY**

- Determination of OEE of the eprocess.
- Failure data collection for component 2 and grinder machine from shutdown list.
- To identify critical breakdowns through failure mode and effect analysis.
- Suggestions for maintenance planning and production planning from the point of view of improving OEE.

**Data Collection and Analysis**

The breakdown shut down data of component 2 and component 1 in minutes is given below. There are several equipments which have been shown below and the total hours of breakdown is calculated. The breakdown time for this machine as well as for the component 1 and component 2 is individually considered because the failure of any of the equipments can also lead to the stoppage of the component 1 or the component 2. Therefore, all the equipments that lead to the stoppage of the component 1 or component 2 have been considered. Similarly, the OEE of component 2 is calculated to be 71.74%.

FMEA Analysis of Component 1 and Component 2.
<table>
<thead>
<tr>
<th>MONTH</th>
<th>Performance</th>
<th>Quality</th>
<th>Availability of component 1</th>
<th>OEE of component 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov-12</td>
<td>84.96</td>
<td>90</td>
<td>90.26</td>
<td>69.01</td>
</tr>
<tr>
<td>Dec-12</td>
<td>97.65</td>
<td>90</td>
<td>91</td>
<td>80.14</td>
</tr>
<tr>
<td>Jan-13</td>
<td>96.85</td>
<td>90</td>
<td>93</td>
<td>81.20</td>
</tr>
<tr>
<td>Feb-13</td>
<td>73.46</td>
<td>90</td>
<td>95.93</td>
<td>63.42</td>
</tr>
<tr>
<td>Mar-13</td>
<td>77.77</td>
<td>90</td>
<td>94</td>
<td>65.95</td>
</tr>
<tr>
<td>Apr-13</td>
<td>82.31</td>
<td>90</td>
<td>93.53</td>
<td>69.28</td>
</tr>
<tr>
<td>May-13</td>
<td>71.46</td>
<td>90</td>
<td>94.34</td>
<td>60.68</td>
</tr>
<tr>
<td>Jun-13</td>
<td>88.88</td>
<td>90</td>
<td>94.23</td>
<td>75.38</td>
</tr>
<tr>
<td>Jul-13</td>
<td>90.65</td>
<td>90</td>
<td>98</td>
<td>79.55</td>
</tr>
<tr>
<td>Aug-13</td>
<td>96.73</td>
<td>90</td>
<td>92</td>
<td>80.14</td>
</tr>
<tr>
<td>Sep-13</td>
<td>81.81</td>
<td>90</td>
<td>95</td>
<td>70.06</td>
</tr>
<tr>
<td>Oct-13</td>
<td>87.23</td>
<td>90</td>
<td>96</td>
<td>75.25</td>
</tr>
<tr>
<td>Nov-13</td>
<td>74.88</td>
<td>90</td>
<td>95</td>
<td>64.22</td>
</tr>
<tr>
<td>Dec-13</td>
<td>83.31</td>
<td>90</td>
<td>90</td>
<td>67.31</td>
</tr>
<tr>
<td>Jan-14</td>
<td>90.42</td>
<td>90</td>
<td>97</td>
<td>78.97</td>
</tr>
<tr>
<td>Feb-14</td>
<td>62.88</td>
<td>90</td>
<td>99</td>
<td>55.86</td>
</tr>
<tr>
<td>Mar-14</td>
<td>78.50</td>
<td>90</td>
<td>98.21</td>
<td>69.38</td>
</tr>
<tr>
<td>Apr-14</td>
<td>83.12</td>
<td>90</td>
<td>96.41</td>
<td>72.12</td>
</tr>
<tr>
<td>May-14</td>
<td>75.12</td>
<td>90</td>
<td>97.69</td>
<td>66.04</td>
</tr>
<tr>
<td>Jun-14</td>
<td>96.73</td>
<td>90</td>
<td>96.96</td>
<td>84.41</td>
</tr>
<tr>
<td>Jul-14</td>
<td>110.92</td>
<td>90</td>
<td>96.35</td>
<td>96.18</td>
</tr>
</tbody>
</table>

Failure Mode and Effect Analysis (FMEA) was first developed as a formal design methodology in the 1960s by the aerospace industry with their obvious reliability and safety requirements. Later, its use spread to other industries, such as the automotive, oil and natural gas. FMEA aims to identify and prioritize possible imperfections in products and processes. FMEA analyses

- Potential failure modes of product or machine,
- Potential effects of failure,
- Potential causes for failure (like Material defects, Design deficiencies)
- Assesses current process controls, and
- Determines a risk priority factor.

FMEA Procedure

The process for conducting FMEA can be divided into following steps. These steps are briefly explained as follows.

**Step 1** Collect the functions of system and build a hierarchical structure. Divide the system into several subsystems, having number of components.

**Step 2** Determine the failure modes of each component and its effects. Assign the severity rating (S) of each failure mode according to the respective effects on the system.

**Step 3** Determine the causes of failure modes and estimate the likelihood of each failure occurring.

Assign the occurrence rating (O) of each failure mode according to its likelihood of occurrence.

**Step 4** List the approaches to detect the failures and evaluate the ability of system to detect the failures prior to the failures occurring. Assign the detection rating (D) of each failure mode.

**Step 5** Calculate the risk priority number (RPN) and establish the priorities for attention.

**Step 6** Take recommended actions to enhance the performance of system.

**Step 7** Conduct FMEA report in a tabular form.

In the previous section breakdown shutdown data was collected. In order to calculate the RPN number, the rating scale for the three parameters of FMEA that is detection, occurrence, severity is shown in the following table.

<table>
<thead>
<tr>
<th>MACHINE NAME</th>
<th>RPN NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment 1</td>
<td>280</td>
</tr>
<tr>
<td>Equipment 2</td>
<td>256</td>
</tr>
<tr>
<td>Equipment 3</td>
<td>160</td>
</tr>
<tr>
<td>Equipment 4</td>
<td>150</td>
</tr>
<tr>
<td>Equipment 5</td>
<td>108</td>
</tr>
<tr>
<td>Equipment 6</td>
<td>60</td>
</tr>
<tr>
<td>Equipment 7</td>
<td>60</td>
</tr>
</tbody>
</table>

With certain changes in the design and material of construction of sub equipment 1 and sub equipment 2 the RPN number of sub equipment 1 reduced from 280 to 160 and for sub equipment 2 it reduced from 256 to 180.

**RESULTS AND DISCUSSION**

Following recommendations in the component 1 would further improve the overall equipment effectiveness.

1. Component 1 mill hopper, screw feeder, mixer and pelleting chamber must be free from any foreign matters.
2. Check the electric interlocking (cooler, vibrosieve, conveyors elements, intake and measuring).
3. Make sure that all safety devices are connected correctly and operate properly, especially the switch of the equipment 1.
4. Check whether all elements are correctly lubricated and whether the reservoir of the grease pump (if delivered) is full with grease.
5. Check whether the pallet cutting knives are adjusted correctly.
6. The trial of spark welded or hot dip galvanized rollers in the component 2 should be taken which can improve the life of the rollers and hence the change over time would reduce.
7. The trial of new material construction for equipment 1 can be used.

**Maintenance for component 2 equipment**

1. Feeders Lubrication of feeder - check oil level in variable speed drive weekly and oil roller chain sparingly. Grease front feeder bushing daily. Feeder flight bearings grease monthly.
2. Conditioner A clean out panel is located on the side of the conditioner chamber to permit inspection and cleaning of the mixer without removing the mixer shaft. Lubrication Grease...
the bearing at each end of the mixer monthly.

3. Feed Chute The feed chute carries feed from the conditioning mixer to the die cavity by gravity flow. To do this job efficiently, the chute must be kept clean and free of dents. If a magnet is located in the feed chute, clean it after each run to remove metal buildup.

4. Deflector The purpose of the deflector is to maintain a clean surface on the cone and assure uniform distribution of feed to the die. Keep clear of caked on material which will restrict flow to the die.

5. Main shaft and Drive Assembly Most models have the entire drive running in oil and needs only the oil changed twice yearly. On new models the front main shaft bearing needs to be greased each eight (8) hours of operation.

CONCLUSION

1. The overall equipment efficiency of the existing machinery was calculated
2. The critical machinery analysis was done through failure mode and effect analysis.
3. Improvements were done in shear pin of the component 1 and component 2.
4. The RPN number of sub equipment 1 reduced from 280 to 160 and for sub equipment 2 it reduced from 256 to 180.

REFERENCES


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