International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:12, No:8, 2018

Providing a Practical Model to Reduce Maintenance Costs: A Case Study in GeG Company

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***Abstract*—**In the past, we could increase profit by increasing product prices. But in the new decade, a competitive market does not let us to increase profit with increased prices. Therefore, the only way to increase profit will be to reduce costs. A significant percentage of production costs are the maintenance costs, and analysis of these costs could achieve more profit. Most maintenance strategies such as RCM (Reliability-Center-Maintenance), TPM (Total Productivity Maintenance), PM (Preventive Maintenance) and etc., are trying to reduce maintenance costs. In this paper, decreasing the maintenance costs of Concentration Plant of Golgohar Iron Ore Mining & Industrial Company (GeG) was examined by using of MTBF (Mean Time Between Failures) and MTTR (Mean Time To Repair) analyses. These analyses showed that instead of buying new machines and increasing costs in order to promote capacity, the improving of MTBF and MTTR indexes would solve capacity problems in the best way and decrease costs.

***Keywords*—**GeG Company, maintainability, maintenance costs, reliability-center-maintenance.

I. Introduction

IN traditional management, maintenance has been considered as support tools and non-productive with little advantages for organizations. In the new approach, maintenance is considered as an essential part of organizational functions and applying effective maintenance strategies, causes significant added value in productive activities. Because of this, maintenance (as a main principle) is used as a distinctive competence in manufacturing companies. Increasing the reliability and maintainability factors in many production systems by using of optimization methods and management of operations resulted in costs reduction and productivity improvement [6], [9].

There is vast literature on reliability and maintainability factors with a high number of books and articles. References [3], [11], [24] described concurrent engineering in detail and presented applicable examples in different kinds of industries. Reference [7] studied the models and evaluated reliability as a function of time and usage. Reference [4] reported on 26 cases on reliability and maintainability, and the statistical techniques illustrated included modeling. In the mentioned study, the comprehensive examination consists of experiment and its simulation, failure investigation and FMEA analysis, as well the application of preventive maintenance and other effective tools were applied. Reference [21] reported that the impact of unplanned machine breakdowns leading to low production rate, bad scheduling and low productivity of the entire manufacturing operations. Reference [17] identified a link between quality improvement and productivity. The relationship between machine reliability and system productivity was also investigated by [15] who determined the productivity throughput based on different states of the same system. Reference [2] highlighted the relationship between maintenance and quality, stressed its importance, and proposed a broad framework for modeling the maintenance–quality relationship.

An investigation of the literature showed that there is a scarcity of field failure data of production circuits. Reference [10] showed four weeks' actual production data from two automotive body-welding lines. His aim was to reveal the nature of randomness in realistic problems and to assess the validity of exponential and independent assumptions for service times, inter-arrival times, cycles between failures, and times to repair. Reference [25] described the failure analysis of computerized numerical control (CNC) lathes; the field failure data was collected over a period of two years on approximately 80 CNC lathes. Reference [16] published a statistical analysis of failure data for an automated pizza production line. References [22], [23] developed the reliability and maintainability analysis of strudel and feta cheese production lines at the machine, workstation and entire line level; statistical approach was used to study the failure and repair data and finally the best fitness index parameters were concluded, and the reliability and hazard rate modes for all workstations and both production lines (strudel and feta cheese) were calculated.

Reference [20] conducted reliability and maintainability analysis for the juice bottling industry by applying statistical techniques on field failure data. In this paper, the subject that instead of increasing the number of machines (in order to solve the bottleneck problem), solve bottleneck problems by improving reliability and maintainability factors was investigated by using the industrial data set. On the other hand, in this study, we have tried to fix the bottleneck problem of production lines with calculating the ratio of mean time

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between failures (MTBF) to mean time to repair (MTTR) in the beginning, and if that was acceptable, the bottleneck problem will be solved with another methodology. Otherwise, the first action for overcoming of the bottleneck problem is improving the reliability and maintainability factors. It was shown that the mentioned approach could assist organizations in decreasing the costs.

II. Process of Iron Concentration Plant and Problem Description

GEG is one of the biggest companies in Iran. GEG has six factories now and one of these factories is the Concentration Plant. In this factory, iron ore with 50% grades (as Fe percent) is converted to iron concentrate with more than 67% grades. The iron concentrate production line consists of five workstations (Fig. 1). In this circuit, at first iron ore with maximum size of 150 centimeters is converted to iron ore with dimensions of 20 centimeters in gyratory crushing area. Then iron ore entered the sag-mills and is converted to iron ore with dimensions of 600 microns. The next step is the dry magnetic separators area. This area has eight set separators and every set consists of three separators as rougher, cleaner and scavenger; their layout is shown in Fig. 2.

In the first separator, magnetic materials are separated by magnet and the remaining materials are tale. Both the magnetic materials and tale materials go to the next separator. If the magnetic materials at this stage are separated by the magnet angle of the drum separator again, these materials are known as dry concentrate. If tale materials at this step are not separated by the magnet again, these materials are known as tale material. The materials that in the first step were separated as magnetic materials or in the next step were separated as tale materials or vice versa are known as middle materials. Therefore, the outputs of this stage (dry separation) are divided into three parts: dry concentrate, middle materials and dry tale. Dry concentrate is known as one type of final product. Tale materials go to another factory and middle materials go to the next area of the plant (wet separation).

In the wet separation area, the middle materials are milled again in ball mills. These materials after grinding go to the wet magnetic separators (LIMS) step. In this step, there is one separator with an arrangement of rougher, cleaner and recleaner drums. Therefore, the output of this step is divided into two parts: wet concentrate and wet tale. After dewatering of wet concentrate (in disk filters), the wet concentrate will mix with dry concentrate (derived from pervious section) and the product will be ready for sale. According to the stations capacities, a section of bottleneck is related to the dry magnetic separator area. For the mentioned problem, the first solution is purchasing new separator sets. In this paper, it has been shown that instead of increasing the number of separators sets in order to solve the bottleneck problem, the bottleneck problem can be solved by improving reliability and maintainability factors.

III. Calculate MTBF and MTTR for Bottleneck

There are eight separator sets in the plant and each set of separators consists of three separators and if a separator stops working, then the set will stop. Therefore, life cycle of every set equals with a minimum life cycle of three separators. Based on the pervious data, the life cycle of each separator follows exponential function with μ=24 hours = $\frac{1}{\lambda}$ and the life cycle of each set separators is obtained as follows [8], [12], [14]:

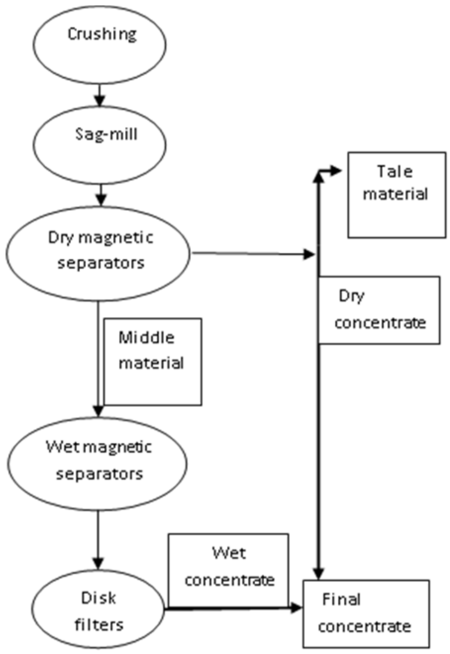

Fig. 1 Schematic presentation of iron Concentration Plant

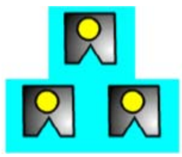

Fig. 2 Arrangement of each set separator

Definition: Exponential distribution with parameter λ:

$$f(t) = \lambda e^{-\lambda t} \quad t \geq 0 \quad (1)$$

Exponential cumulative distribution function:

$$F(t) = 1 - e^{-\lambda t} \quad t \geq 0 \quad (2)$$

Reliability distribution function:

$$R(t) = \exp(-\lambda t) \quad t \geq 0 \quad (3)$$

$$F(t)=p(T\leq t)=p(\min(x_1,x_2,x_3)\leq t)=1-p(\min(x_1,x_2,x_3)> t)=1-P(x_1>t).P(x_2>t).P(x_3>t)=1-R(t_1).R(t_2).R(t_3)=1-\text{Exp}(-\lambda_1 t).\text{Exp}(-\lambda_2 t).\text{Exp}(-\lambda_3 t)=1-\exp(-t(\lambda_1+\lambda_2+\lambda_3)) \quad (4)$$

International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
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$f(t)=\frac{dF(t)}{dt} \rightarrow f(t)=(\lambda_1+\lambda_2+\lambda_3)\exp(-t(\lambda_1+\lambda_2+\lambda_3))$ (5)

Therefore, the density function of set is an exponential function with $\mu = \mu_1 + \mu_2 + \mu_3$:

$$\lambda 1 = \frac{1}{24}\ \lambda 2 = \frac{1}{24}\ \lambda 3 = \frac{1}{24}$$

$$\lambda_1 + \lambda_2 + \lambda_3 = \frac{3}{24}$$

$$MTBF = T_a = \frac{1}{\lambda} = 8 T_a = MTBF = \frac{1}{\lambda} = \frac{24}{3} = 8 \quad (6)$$

Based on the previous data, MTTR is obtained as follows:

$$t_e = MTTR = \frac{\text{total maintenance time}}{\text{number of repairs}} = 117\text{min or about 2 hours} \quad (7)$$

IV. Calculating the Number of Available Machines

According to the Fig. 3, the number of available machines can be calculated based on the ratio of T_a to t_e and the total number of machines (k). These values are calculated and equal to T_a=8 and t_e=2 hours in section three (based on (6) and (7)) for each set separator and k is equal to eight. Therefore, $\frac{Ta}{te}$ = four and the number of available machines equal to five. At first, the managers wanted to have bought three set separators (k=11) and solve the bottleneck problem, but this is not an acceptable solution and would increase costs, because if you buy even eight sets (k=16) instead of three sets, the number of available machines is equal to five and other machines will go to repair or queue for repair (Fig. 3).

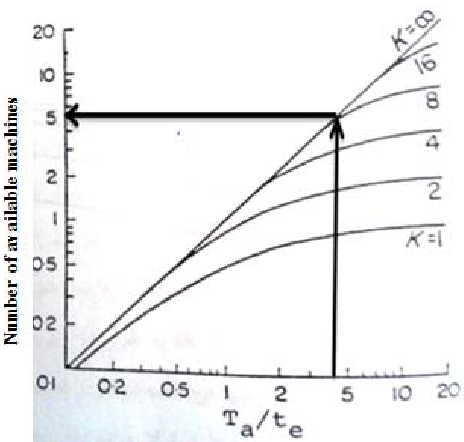

Fig. 3 Number of available machines based on rate T_a to t_e [18]

V. Failures Analysis and Improve Reliability and Maintainability

To increase the rate of Ta(reliability) to t_e(maintainability) should be increased T_a and should be reduced t_e. T_a is the mean time between failures of a system during operation. A good example of the significance of T_a can be found in the mining industry, where proper lubrication of equipment, cleaning, education, and very good condition base monitoring etc., can increase the T_a of crushers, separators, and sag mills [19], [5], [1].

While T_a measures the time between failures, t_e measures the time between the service interruption and service restoration. t_e includes problem diagnosis and problem repair. When changes are uncontrolled and unmanaged, te is dominated by problem diagnosis. Most of te is spent in the diagnosis phase, therefore, troubleshooting charts and tables can reduce te [13], [5], [1].

According to the Pareto chart, the most important problem of separators (more than 70%) was gearbox and chain breakage.

A technical team was formed to solve the problems. The roots of failure were poor quality parts and dust. The team proposed two solutions: Changing of suppliers and removing the sources of pollution. By using of these solutions Ta increased from eight to 12 hours. In addition, the following actions were taken to reduce t_e and improve maintainability:

- Changes in connections from screw to pins, USB wires and other connections,
- Increasing the space around the separator for repairing,
- Increasing the safety stock for commonly used parts, and
- Training of technicians and operators and preparing troubleshooting charts.

With these solutions, t_e decreased from two hours to 1.5 hours. Now, with these parameters: K=8, T_a=12, t_e=1.5, the number of available set separators is equal to seven (Fig. 4).

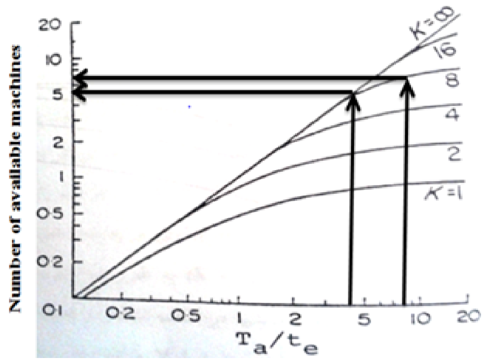

Fig. 4 Number of available machines based on rate T_a to t_e [18]

VI. Conclusions

- It was pointed out that the number of available set separators increased from five to seven due to the improved rate of T_a to t_e from four to eight (Figs. 3 and 4).
- This paper shows the importance of reliability and maintainability factors as one of the best ways to reduce costs, increase production and improve productivity.
- Improvement of the maintenance conditions of dry magnetic separators reduced their energy consumption.
- Given the current competitive market, there is no possibility of increasing profit by increasing prices, and the only way to increase profit is to reduce costs and an analysis of maintenance costs resulted in lower costs.

There is a future research scope for using lognormal distribution, Weibull distribution or other distribution functions in machine reliability analysis or investigating of improve rate of T_a to t_e with other equipment layouts.

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