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Risk Evaluation & Failure Investigation for Reliability Enhancement (A Case Study of Dumpers at OCP, Ramagundam)

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Abstract: -- 6-Sigma is a quality tool that measures how far a given process deviates from the perfection. It is considered as the one of the most efficient quality tool so far on the globe, which produces the product with approximately zero defects. Sigma level determines the quality performance of a product, service delivery or a process and provides an overall framework for continuous improvement in the process of an organization. The sigma level can be calculated using the DPMO (Defects Per Million Opportunities) which is a measure of the number of defects occurring in a process. This paper deals with the application of the 6-Sigma methodology in determining the performance level of various failures that occurred in the Load Hauling Dumpers used in open cast mines. DPMO, RPN can fairly determine the machine behaviour. This paper throws some light on establishing the relation between the 6-sigma quality and risk priority number so as to estimate the behaviour of the equipment.

Keywords: 6-sigma, OCP, Dumpers, DPMO, RPN.

I. INTRODUCTION

In any organization, the quality function involves efforts of all the groups in the organization. Quality is always the result of an intelligent effort. Although many philosophies and tools have been evolved towards quality, six-sigma is one most and primary quality tool in the world. Six-Sigma evolved from management science concepts developed in the United States to Japanese management breakthroughs to "total quality" efforts in 1980s. Six Sigma approach was firstly introduced by Motorola in the late twentieth century after then it has been successfully through many organizations such as Nokia, Texas, LG, Sony, GE and ABB with the aim of reducing quality costs. It is a high- performance data-driven approach for analysing the root causes of business processes/problems and solving them. It brings a link between customers, process improvements, and financial results.

Six-sigma is a customer-oriented, systematic, structured, proactive, and quantitative companywide approach for continuous improvement of manufacturing, services, engineering, suppliers, and other business process. It is a statistical measure of the performance of a process or a product. It measures the degree to which the process deviates from the goals and then takes efforts to improve the process to achieve total customer satisfaction. If a process is at 6-sigma level, such a process yields 3.4 defects per million opportunities (DPMO) products which is almost 100% (more precisely 99.99966%) defect free. In this study DPMO for each failure mode has been calculated in order to know the sigma level. Based on the sigma level, the failure performance can be predicted and whether the failures are in tolerable range or not can be known. It is also customary to know the risk associated with each failure. This can be done using risk priority number, which gives an idea of riskiness associated with a particular failure. Further, the relation between the sigma level and RPN was established using Spearman's rank correlation co-efficient.

II. ORGANIZATION PROFILE

The Singareni Collieries Company Limited (SCCL) is a government owned company. It is one of the Public Sector Undertakings which is jointly owned by the Government of State of Telangana (51%) and the Union Government (49%). The company is administered by the Union Ministry of Coal. SCCL is currently operating 15 opencast and 34 underground mines spread out across 4 districts of Telangana with a manpower of about 62805.

The Company's accredited function is to explore and exploit the coal deposits in the Godavari valley coalfield, which is the only repository of coal in South India. Mining activities of SCCL are presently spread over four districts of Telangana Viz. Mancherial, Peddapalli,

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Badradri and Bhupalpalli. The company is involved in coal extraction in Telangana, in the Pranahita-Godavari Valley region, which has significant coal reserves, with proven geological reserves estimated at 8,791 million tonnes. Ramagundam is one of the important operating areas of singareni collieries. There are three divisions (RG-1, RG-2, RG-3) and Adriyala project area in Ramagundam region. Each division is headed by a general manager.

Objectives of the present study

The analysis on dumpers operated in Singareni Collieries Company Limited (SCCL), Ramagundam are taken up with the following objectives.

1. To identify the machine behavior based on the past failures.
2. To calculate the sigma level for the failure units separately.
3. To calculate the Risk Priority Number for each failure unit.
4. To interpret the relationship between the sigma level and RPN value using Spearman's Rank Co-Relation Coefficient

III. LITERATURE REVIEW

E. V. Gijo et al dealt with the application of the Six Sigma methodology in reducing defects in a fine grinding process of an automotive company in India. The DMAIC (Define–Measure–Analyse–Improve–Control) approach has been followed here to solve the underlying problem of reducing process variation and improving the process yield. This paper explores how a manufacturing process can use a systematic methodology to move towards world-class quality level. The application of the Six Sigma methodology resulted in reduction of defects in the fine grinding process from 16.6 to 1.19%. The DMAIC methodology has had a significant financial impact on the profitability of the company in terms of reduction in scrap cost, man-hour saving on rework and increased output.

Nihal Erginel et al had examined the screwing process as a Six Sigma project. The aim of this project is to reduce the failure rate of screwing process in the white appliance factor in Turkey. Five sequential phases are applied that are Define, Measurement, Analysis, Improvement and Control of the Six Sigma Project. These phases lead the way to carry out to the project. At the end, defective units are decreased and the process capability index is increased. The experimental design and analysis are handled. Finally, the pin shape and the type of handgun are determined as effective factors. Also, the best levels of these factors are found. The failure rate of screwing process is decreased from 30% to 14%. This study proposes the Six-Sigma projects with all phases sequencing and presents the results are originated the deviations from the manufacturing process.

Shashank Soni et al identified the root causes of failure for a welding process at a manufacturing plant and proposes to use Operational Six Sigma technique to eliminate the problem. In contrast to other method which measure and identify the non - conformance through destructive testing, a technique is proposed to use a mathematical model, which is later charted using SPC technique. The paper deals with an application of Six Sigma DMAIC (Define- Measure-Analyse-Improve-Control) methodology in an industry which provides a framework to identify, quantify and eliminate sources of variation in an operational process in question, to optimize the operation variables, improve and quality performance, viz., process yield with well executed control plans.

Abdulaziz A. Bubshait et al had applied lean six sigma methodology to reduce the failure rate of valves at oil field. The objective of this study is to make recommendations to reduce the failure rate of choke valves by applying lean six sigma approach aiming to increase availability of production wells as well as meeting production targets for producing wells. The procedure follows the framework: define, measure, analyze, improve and control DMAIC phases. The project started with problem definition through statistical analysis of the current performance and quantification of failed choke valves for certain period of time. This involves using the supplier-input-process-output-customer SIPOC diagram. The process also involved brainstorming session to identify potential root causes of the problem. Classifying and rating these causes were achieved by use of the several tools: a "fishbone" diagram, cause-and-effect matrix, and failure mode and effect analysis (FMEA).

Adan Valles et al had conducted a Six Sigma project at a semiconductor company dedicated to the manufacture of

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circuit cartridges for inkjet printers. They are tested electrically in the final stage of the process measuring electrical characteristics to accept or reject them. Electrical failures accounted for about 50% of all defects. Therefore, it is crucial to establish the main problems, causes and actions to reduce the level of defects. With the implementation of Six Sigma, it was possible to determine the key factors, identify the optimum levels or tolerances and improvement opportunities. The major factors that were found through a design of experiments 3 factors and 2 levels were: abrasive pressure (90-95 psi), height of the tool (0.06-0.05) and cycle time (7000-8000 msec.). The improvement was a reduction in the electrical failures of around 50%. The results showed that with proper application of this methodology, and support for the team and staff of the organization, a positive impact on the quality and other features critical to customer satisfaction can be achieved

IV. METHODOLOGY

This case study is mainly intended to investigate the failures and to evaluate the risk associated with it. As there are many tools to investigate the failures and its performance, a new approach has been tried out in this direction. Six-sigma is an approach which focuses on process improvement and reduction in variation. This can be achieved by calculating DPMO then by which sigma value can be noted out using statistical tables. The sigma value indicates how often defects are likely to occur.

Here the various failures of 25 dumpers are considered as defects and all these failures have been categorised as eight major defects. Opportunities of these defects have been counted for DPMO calculation. The sigma value for eight defects has been allotted based on DPMO and the ranking was given for each failure depending on sigma value from least to highest.

Failure performance and failure risk are two different entities, so another aspect of this study is evaluating the risk of each failure mode. RPN methodology is used for determining the risk and raking was done based on the RPN value from highest to least. Further, it is necessary to find the relation between sigma level and RPN methodology. This can be achieved by Spearman's rank correlation coefficient approach, which establishes the relation between two sets of data.

V. DEFECTS PER MILLION OPPORTUNITIES ANALYSIS

A defect can be defined as a non-conformance of a quality characteristic (e.g. strength, width, response time) to its specification. DPMO is stated in opportunities per million units for convenience: Processes that are considered highly capable (e.g., processes of Six Sigma quality) are those that experience only a handful of defects per million units produced (or services provided). DPMO is a measure of the number of defects occurring in a process. It simply expresses how process flow, service, or product is performing in relation to quality defects. DPMO is the total number of defects in a population divided by the total number of opportunities, multiplied by a factor of 1 million.

$$DPMO = \frac{Total\ number\ of\ defects\ detected \times 1000000}{Number\ of\ units\ produced \times Opportunities\ of\ defects\ per\ unit}$$

A. Defective

Defective suggests that the value or function of the entire unit or product has been compromised. Defective items will always have at least one defect. Typically however, it takes multiple defects and/or critical defects to cause an item to be defective. To put it simply, defective is "broken", it can't be used or sold.

B. Defect

A defect is an error, mistake, flaw, fault or some type of imperfection that reduces the value of a product or unit. A single defect may or may not render the product or unit "defective" depending on the specifications of the customer.

C. Opportunities

Opportunities are the total number of possible defects. If for example a unit has 6 possible defects then each unit produced is equal to 6 defect opportunities. If we produce 100 of those units then there are 600 defect opportunities.

Steps in DPMO Analysis

1. Declare the area of work and register customer complaint/suggestion/expectation.
2. Identify the CTQCs and translate in terms of name, measure and specification.

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3. Define the defect, unit and opportunity
4. Compute the number of defects per opportunity.
5. Compute the DPMO based on total number of units considered.
6. Convert the DPMO into appropriate sigma level using the sigma conversion chart

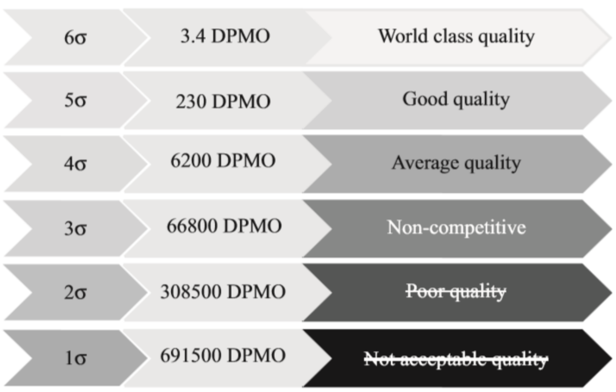

Figure 1 DPMO and quality level on a Six-Sigma scale

Table 1 DPMO and sigma levels for different failures of dumpers

Declaration of area of work:	Dumpers of the SCCL, which are used to transport the coal from mines to load centers.							
Defining unit	Brake	Engine	Suspension	Transmission	Steering	Turbocharger	Radiator	Hoist & Hydraulic
Defects	66	90	62	68	76	41	73	78
Opportunity	35	44	18	32	42	18	34	20
Units Considered	25	25	25	25	25	25	25	25
DPMO	75428.57	81818.18	137777.77	85000	72380.95	91111.111	85882.35	156000
Sigma level	2.9112	2.8729	2.5904	2.8722	2.9583	2.8339	2.8666	2.511
Rank	2	3	7	4	1	6	5	8

I. RISK PRIORITY NUMBER

A risk priority number (RPN) is a numerical and relative "measure of the overall risk" corresponding to a particular failure mechanism and is computed by multiplying the severity, occurrence, and detection numbers.

RPN = Severity × Occurrence × Detection

The RPN is a valuable tool for setting priority. In the conventional approach, higher RPN values represent higher priority. While the conventional approach develops 1,000 cells, there are only 120 different RPN values. Some values can't occur (17, 22, and 925) while others can occur multiple times. There are twenty-four (24) different ways to get 60, 72 and 120.

A. Severity(S)

Severity is an assessment of the seriousness of the effect of the potential failure mode to the next component, subsystem, system or customer if it occurs. Severity applies to the effect only. A reduction in Severity Ranking index can be effected only through a design change. Severity should be estimated on a 1to10 being more severe.

B. Occurrence (O)

Occurrence is how frequent a specific failure cause is estimated to occur. The likelihood of occurrence ranking number has a meaning rather than a value. Removing or controlling one or more of the causes/mechanisms of the failure mode through a design change is the only way a reduction in the occurrence ranking can be effected. Estimate the likelihood of occurrence of potential failure cause/mechanism on a 1 to 10 scale where 10 denotes the highest probability of occurrence. Only occurrences resulting in the failure mode should be considered for this ranking; failure detecting measures are not considered here.

C. Detection (D)

Detection is the ability to detect the cause/mechanism/weakness of actual or potential failure. In Design FMEA, this must occur before the component, subsystem, or system is released for production. In Process/Service FMEA it must occur in time to prevent distribution in case of a product or catastrophe in case of an Asset / Maintainable Unit. In order to achieve a lower ranking, generally the planned control (e.g. preventative activities) has to be improved. In System FMEA it must occur before the scheduled maintenance.

The level of detection is measured on a scale of 1 to 10, where 10 signify virtually no ability to detect the fault.

Table 2 Severity, Occurrence and Detection Ratings for different Failure modes

Sl. No.	Unit	Severity (S)	Occurrence (O)	Detection (D)
1	Engine	10	7	7
2	Brake	6	7	6
3	Suspension	4	7	7
4	Transmission	9	7	7
5	Steering	9	7	8
6	Turbocharger	4	6	9
7	Radiator	10	7	2
8	Hoist cylinder and hydraulic	10	7	6

I. SPEARMAN'S CORRELATION TEST

Spearman's Rank correlation coefficient is used to identify and test the strength of a relationship between two sets of data. It is often used as a statistical method to aid with either proving or disproving a hypothesis. The Spearman correlation between two variables is equal to the Pearson correlation between the rank values of those two variables; while Pearson's correlation assesses linear relationships, Spearman's correlation assesses monotonic relationships (whether linear or not). If there are no repeated data values, a perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. In a sample it is denoted by r_s and is by design constrained as follows

$$-1 \leq r_s \leq 1$$

Spearman's correlation is given by the formula,

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

Where,

d = Difference of ranks

n = Total number of the systems

The closer r_s is to ±1 the stronger the monotonic relationship. Verbally the strength of the correlation can be described by using the following table for the absolute value of r_s

Table 3 Spearman's Rank Correlations Coefficient Strength Table

Sl.No.	Spearman's Coefficient Range	Strength of the relation
1	0.00 – 0.19	Very Weak
2	0.20 – 0.39	Weak
3	0.40 – 0.59	Moderate
4	0.60 – 0.79	Strong
5	0.80 – 1.0	Very Strong

In this study Spearman's Rank correlation coefficient is used to test the relation between the sigma level and RPN Value.

II. RESULTS

Six-sigma approach and RPN methodology has been applied for the failures occurred in dumper working at open cast mines. The evaluation of sigma level is dependent on the number of defects (failures) occurred, opportunities and the units considered. RPN approach is based on severity, occurrence and detection. After the analysis, the values of sigma level and RPN values along with its rankings are shown in the table no.4.

Table 4 Sigma level and RPN rankings

Sl. No.	Failure Unit	Sigma Level	Sigma Rank	RPN	RPN Rank
1	Engine	2.8729	**3**	490	**2**
2	Brake system	2.9112	**2**	252	**5**
3	Suspension system	2.5904	**7**	196	**7**
4	Transmission system	2.8722	**4**	441	**3**
5	Steering system	2.9583	**1**	504	**1**
6	Turbocharger system	2.8339	**6**	216	**6**
7	Radiator	2.8666	**5**	140	**8**
8	Hoist cylinder and hydraulic system	2.511	**8**	420	**4**

From the table it can be observed the highest risk is found with the steering system whereas least sigma level is found for hoist cylinder and hydraulic system. To find out

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the relation between sigma level and RPN, Spearman's Rank Correlation Coefficient was calculated and shown in the table no. 5

Table 5 Spearman's Rank Correlation Coefficient Calculation

Unit	RPN Rank	Sigma Rank	D	d^2
Engine	**2**	**3**	-1	1
Brake	**5**	**2**	3	9
Suspension	**7**	**7**	0	0
Transmission	**3**	**4**	-1	1
Steering	**1**	**1**	0	0
Turbocharger	**6**	**6**	0	0
Radiator	**8**	**5**	3	9
Hoist cylinder & Hydraulic system	**4**	**8**	-4	16

$\sum d^2 = 36$, n = 8.

The value of Spearman's rank correlation coefficient is

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

$$r_s = 1 - \frac{6*36}{8(8^2-1)}$$

$$r_s = 0.5714$$

III. CONCLUSION

In this study failure investigations were carried out using six-sigma and RPN methodology. DPMO and RPN have been calculated for all the eight failures and a rank has been assigned for the same. Based on the DPMO values, sigma value was allotted to know the sigma level of the failures. All the eight failures have the sigma value less than 3σ, which indicates that all the failures are critical. Proper maintenance and service of dumpers are needed to reduce the failures and to enhance the sigma level. RPN reveals that steering system has the highest risk among all the failure in terms of production. Necessary amendments are needed to minimize the risk associated with the steering, engine and transmission failures, where it shows the highest risk. Spearman's correlation test result shows that there is moderate positive strength between the RPN and Sigma, where they are related directed proportional.

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