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Failure Mode, Effects And Criticality Analysis Of 85 T Dumpers In Open Cast Mines

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Abstract:

Failure mode, effects and criticality analysis (FMECA) is an extension of failure mode and effects analysis (FMEA). FMEA is a bottom-up, inductive analytical method which may be performed at either the functional or piece-part level. FMECA extends FMEA by including a criticality analysis, which is used to chart the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

The objective of FMECA is to identify all failure modes in a system design. Its purpose is to find all critical and catastrophic failures that can be minimised at the earliest.

Keywords: *Criticality Analysis, failure mode, failure effects, risk priority number, etc.*

Introduction

Every machinery, equipment, buildings undergo deterioration due to their use and exposure to environmental conditions. This deterioration must be detected well in advance so as to forestall loss and damage. Industries, therefore, address such issues time to time through repairs, renovations, rejuvenations, reconditioning, etc., so as to enlarge their useful life to a maximum possible extent. In this context, the maintenance assumes importance as an engineering function and is made responsible for provision of the condition of these machines, equipments, buildings and services that will permit uninterrupted implementation of plans requiring their use. This means that estimation of the failure mode, failure effect, and the failure criticality to maintain the machine in good condition is necessary.

The objective of FMECA is to identify all failure modes in a system design. Its purpose is to find all critical and catastrophic failures that can be minimised at the earliest. Hence, FMECA must be started as soon as the preliminary information is available and investigation is extended as more information is available in suspected problem areas.

In this paper the results of FMECA analysis is published for 85 Ton dumpers working at Open Cast Mines – III, SCCL, Ramagundam.

Procedure

Failure Mode, Effects and Criticality Analysis (FMECA) is an analysis technique which facilitates the identification of potential problems in the design or process by examining the effects of lower level failures. Recommended actions or compensating provisions are made to reduce the likelihood of the problem occurring, and mitigate the risk.

MIL-STD-1629A

This standard establishes requirements and procedures for performing a failure mode, effects, and criticality analysis (FMECA) tosystematically evaluate and document, by item failure mode analysis, the potential impact of each functional or hardware failure on mission success, personnel and system safety, system performance, maintainability, and maintenance requirements. Each potential failure is ranked by the severity of itseffect in order that appropriate corrective actions may be taken to eliminate orcontrol the high risk items

Criticality Analysis

To perform criticality analysis of the failures identified Risk Priority Number (RPN) for each failure must be calculated. To calculate the RPN the failures are listed along with the failure times and their severity and occurrence are calculated.

The key inputs used in failure modeling using FMECA are as follows:

Severity (S)

Severity (S) is a numerical measure of how serious is the effect of the failure to the customer. It is to assess the failure result on an assumed scale with questioning, if the component or system failure results in a mere nuisance or can it result in serious injury. The degree of severity is generally measured on a scale of 1 to 10 where 10 is the most severe.

Occurrence (O)

Occurrence (O) is a measure of probability that a particular mode will actually happen. The degree of occurrence is measured on a scale of 1 to 10, where 10 signify the highest probability of occurrence.

Detection (D)

Detection (D) is a measure of probability that a particular mode would be detected in the manufacturer's own operation before reaching the customer. The level of detection is measured on a scale of 0.1 to 1, where 0.1 signifies virtually no ability to detect the fault.

Risk Priority Number (RPN)

Provides an alternate evaluation approach to Criticality Analysis. The risk priority number provides a qualitative numerical estimate of design risk. RPN is defined as the product of three independently assessed factors: Severity(S), Occurrence (O) and Detection (D).

RPN = (S) * (O) * (D)

Criticality Ranking According To RPN

Criticalities of the failures are given ranking according to the RPN they are given according to the following table (Table 1).

Failure Number	Failure Classification	Maintenance Policy
1	Catastrophic	Replace the equipment
2, 3 & 4	Critical Failure	Complete overhaul
5, 6 & 7	Marginal	Repair the component
8, 9 & 10	Minor	Inspect daily

Table 1: Classification of failures according to failure number.

Conclusion

The analysis of each dumper has given the most critical failure that is causing major production losses. The each failure that is classified as catastrophic, critical, marginal and minor are prioritised and analysed. Thus, each catastrophic failure must be considered first in maintenance of each dumper as discussed. It is suggested that every failure that is classified as catastrophic, the component must be replaced and new component must be placed as risk of the failure is more important.

From the analysis done by risk priority number it can be concluded that

- For 85 T dumpers as a group, Radiator leaks and Engine failures are frequent failures that are hampering the production, based on the catastrophic nature of the failure and risky nature of failure, the radiator and engine must be replaced whenever the next failure occurs.
- For 85 T dumpers as a group, operator seat failures and brake failures are critical failures that are the other obstacles, for such failures they must be checked for every trip so that any inconvenience can be avoided.
- For dumper C-354, Engine must be replaced.
- For dumper C-357, Engine must be replaced.
- For dumper C-362, Brakes must be replaced.
- For dumper C-364, Steering box must be replaced.
- For dumper C-366, Engine and crank must be replaced.
- For dumper C-367, Brakes must be replaced.
- For dumper C-368, Engine must be replaced.
- For dumper C-369, Operator seat must be replaced.
- For dumper C-373, Cylinder must be replaced.
- For dumper C-374, Engine must be replaced.
- For dumper C-376, Radiator must be replaced.

- For dumper C-377, Radiator must be replaced.
- For dumper C-379, Radiator must be replaced.
- For dumper C-380, Radiator must be replaced.
- For dumper C-381, Radiator must be replaced.
- For dumper C-382, Engine must be replaced.
- For dumper C-383, Engine must be replaced.
- For dumper C-384, Brakes must be replaced.

Appendix

FMECA of Dumper – C 353

F No	Reason for failure	frequency	time	Occurrence	Severity	detection	RPN
1	Radiator leaks	45	7102	0.1573	0.2550	0.6	0.0241
2	Engine failures	24	6652	0.0839	0.2388	0.9	0.0180
3	brake failures	46	2160	0.1608	0.0775	0.7	0.0087
4	operator seat damaged	26	1537	0.0909	0.0552	1	0.0050
5	not taking load	17	2390	0.0594	0.0858	0.8	0.0041
6	steering failures	28	1590	0.0979	0.0571	0.5	0.0028
7	Gear & clutch failure	20	927	0.0699	0.0333	0.4	0.0009
8	suspension failure	25	823	0.0874	0.0295	0.3	0.0008
9	hose failure and hoist failure	31	1350	0.1084	0.0485	0.1	0.0005
10	Bucket & wear plate failure	17	796	0.0594	0.0286	0.2	0.0003

Table 2: Calculation of Risk Priority Number of CD – 353 Dumper

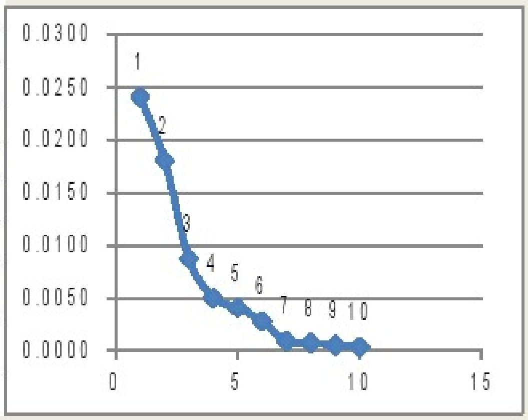

Figure 1: Failure number Vs RPN of CD – 353 Dumper

Form the table 2 and figure 1 it can be concluded that failure 1 i.e. Radiator leaks is of high risk, is catastrophic failure. The failures (2 3 and 4) of engine, brake, operator seat damage are critical. not taking load, steering failures, gear and clutch are categorised as marginal failures and the other failures are minor failures. According to Table 1 the radiator must be replaced when the failure occurs again and again. Similarly the critical failures can be avoided by complete overhaul of the dumper. Marginal failures can be avoided by repairing of not steering failures, gear and clutch. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – C 354

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	Engine failures	2	576	0.1053	0.3366	0.8	0.0283
2	not taking load	1	483	0.0526	0.2823	0.9	0.0134
3	clutch failure	2	124	0.1053	0.0725	0.6	0.0046
4	air compressor failure	2	96	0.1053	0.0561	0.5	0.0030
5	Gears failure	1	120	0.0526	0.0701	0.7	0.0026
6	uj cross failure	2	96	0.1053	0.0561	0.4	0.0024
7	radiator leaks	5	128	0.2632	0.0748	0.1	0.0020
8	operator seat damaged	2	16	0.1053	0.0094	1	0.0010
9	Bucket damage	1	48	0.0526	0.0281	0.3	0.0004
10	belt and pulley failure	1	24	0.0526	0.0140	0.2	0.0001

Table 3: Calculation of Risk Priority Number of CD – 354 Dumper

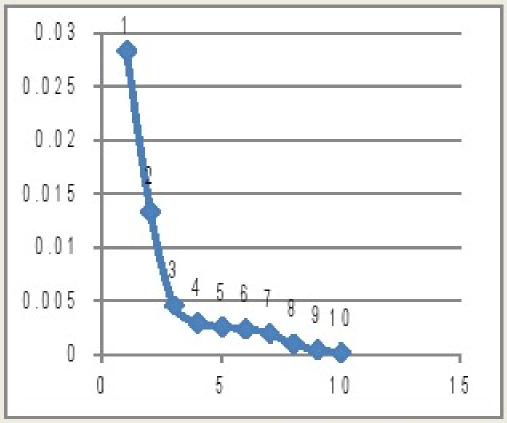

Figure 2: Failure number Vs RPN of CD – 354 Dumper

Form the table 3 and figure 2 it can be concluded that failure 1 i.e. engine failures is of high risk, is catastrophic failure. The failures (2 3 and 4) of not taking load, clutch, air compression failure are critical. Gears, uj cross failure and radiators leaks are categorised as marginal failures and the other failures are minor failures. According to Table 1 the engine and radiator must be replaced when the failure occurs again and again. Similarly the critical failures can be avoided by complete overhaul of the dumper. Marginal failures can be avoided by repairing of Gears, uj cross failure and radiators leaks. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – C 357

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	not taking load	2	279	0.0833	0.1970	1	0.0164
2	radiator leaks	8	520	0.3333	0.3672	0.1	0.0122
3	Gears failure	2	243	0.0833	0.1716	0.7	0.0100
4	hose failure and hoist failure	5	175	0.2083	0.1236	0.2	0.0051
5	steering box failure	2	132	0.0833	0.0932	0.5	0.0039
6	clutch failure	1	26	0.0417	0.0184	0.8	0.0006
7	brake failures	1	11	0.0417	0.0078	0.9	0.0003
8	Engine and crank failures	1	9	0.0417	0.0064	0.6	0.0002
9	cylinder failure	1	11	0.0417	0.0078	0.4	0.0001
10	uj cross failure	1	10	0.0417	0.0071	0.3	0.0001

Table 4: Calculation of Risk Priority Number of CD – 357 Dumper

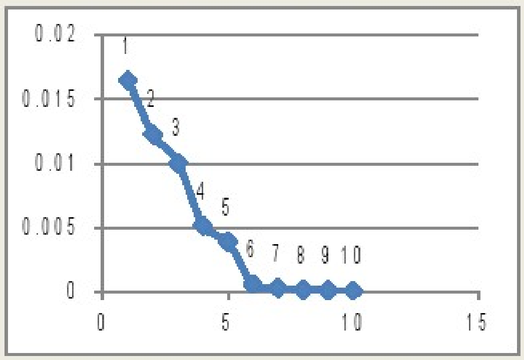

Figure 3: Failure number Vs RPN of CD – 357 Dumper

Failure number Form the table 4 and figure 3 it can be concluded that failure 1 i.e. not taking load is of high risk, is catastrophic failure. The failures (2 3 and 4) of radiators leaks, hose steering box failures are critical. Steering box, clutch and brake failure are categorised as marginal failures and the other failures are minor failures. According to Table 1 the radiator must be replaced when the failure occurs again and again. Similarly the critical failures can be avoided by complete overhaul of the dumper. Marginal failures can be avoided by repairing of Steering box, clutch and brake. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – C 362

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	brake failures	2	460	0.1176	0.2771	0.7	0.0228
2	Engine and crank failures	1	632	0.0588	0.3807	0.9	0.0202
3	radiator leaks	5	135	0.2941	0.0813	0.5	0.0120
4	not taking load	1	264	0.0588	0.1590	1	0.0094
5	suspension failure	2	42	0.1176	0.0253	0.6	0.0018
6	Gears failure	1	15	0.0588	0.0090	0.8	0.0004
7	steering box failure	1	23	0.0588	0.0139	0.4	0.0003
8	uj cross failure	1	43	0.0588	0.0259	0.2	0.0003
9	rock ejector damaged	2	36	0.1176	0.0217	0.1	0.0003
10	valve failures	1	10	0.0588	0.0060	0.3	0.0001

Table 5: Calculation of Risk Priority Number of CD – 362 Dumper

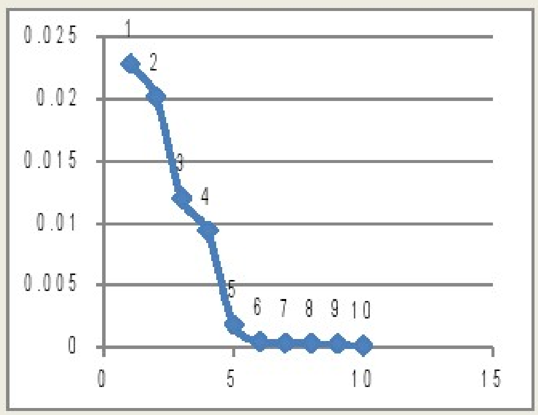

Figure 4: Failure number Vs RPN of CD – 362 Dumper

Form the table 5 and figure 4 it can be concluded that failure 1 i.e. Brakes failure is of high risk, is catastrophic failure. The failures (2 3 and 4) of engine, crank and radiators leaks are critical. Suspension, gears and steering box are categorised as marginal failures and the other failures are minor failures. According to Table 1 the brakes must be replaced when the failure occurs again and again. Similarly the critical failures can be avoided by complete overhaul of the dumper. Marginal failures can be avoided by repairing of Suspension, gears and steering box. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – C 364

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	steering box failure	3	240	0.1500	0.3204	0.4	0.0192
2	clutch failure	2	115	0.1000	0.1535	1	0.0154
3	radiator leaks	7	129	0.3500	0.1722	0.1	0.0060
4	steering problems	1	69	0.0500	0.0921	0.8	0.0037
5	brake failures	2	22	0.1000	0.0294	0.9	0.0026
6	pivot, bolts and studs failure	1	41	0.0500	0.0547	0.6	0.0016
7	suspension failure	1	44	0.0500	0.0587	0.5	0.0015
8	hose failure and hoist failure	1	70	0.0500	0.0935	0.2	0.0009
9	tyre problems	1	10	0.0500	0.0134	0.7	0.0005
10	Bucket damage	1	9	0.0500	0.0120	0.3	0.0002

Table 6: Calculation of Risk Priority Number of CD – 364 Dumper

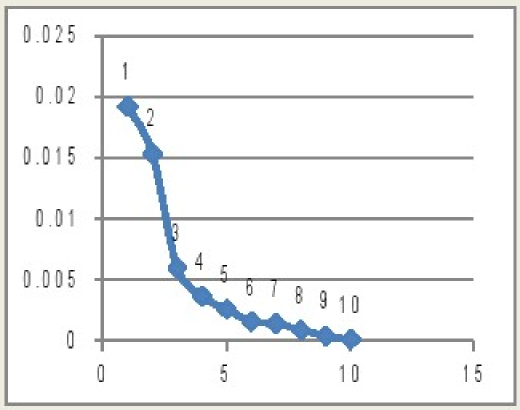

Figure 5: Failure number Vs RPN of CD – 364 Dumper

Form the table 6 and figure 5 it can be concluded that failure 1 i.e. steering box is of high risk, is catastrophic failure. The failures (2 3 and 4) of clutch radiators and steering problems are critical. Suspension, brakes and steering box are categorised as marginal failures and the other failures are minor failures. According to Table 1 the steering box must be replaced when the failure occurs again and again. Similarly the critical failures can be avoided by complete overhaul of the dumper. Marginal failures can be avoided by repairing of Suspension, brakes and steering box. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

MECA of Dumper – C 366

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	Engine and crank failures	1	690	0.0526	0.4752	0.9	0.0225
2	radiator leaks	5	356	0.2632	0.2452	0.3	0.0194
3	pivot, bolts and studs failure	3	215	0.1579	0.1481	0.6	0.0140
4	operator seat damaged	3	78	0.1579	0.0537	1	0.0085
5	clutch failure	2	46	0.1053	0.0317	0.8	0.0027
6	pump failures	1	18	0.0526	0.0124	0.5	0.0003
7	steering box failure	1	12	0.0526	0.0083	0.7	0.0003
8	suspension failure	1	11	0.0526	0.0076	0.4	0.0002
9	air compressor failure	1	15	0.0526	0.0103	0.2	0.0001
10	hose failure and hoist failure	1	11	0.0526	0.0076	0.1	0.0000

Table 7: Calculation of Risk Priority Number of CD – 366 Dumper

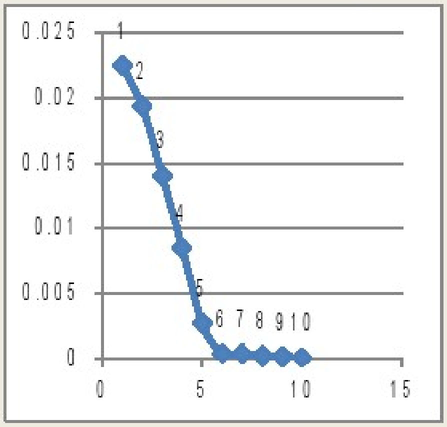

Figure 6: Failure number Vs RPN of CD – 366 Dumper

Form the table 7 and figure 6 it can be concluded that failure 1 i.e. engine and crank failure is of high risk, is catastrophic failure. The failures (2 3 and 4) of radiators leaks, pivots, bolts and studs are critical. Clutch, pump and steering box failure are categorised as marginal failures and the other failures are minor failures. According to Table 1 the engine and crank must be replaced when the failure occurs again and again. Similarly the critical failures can be avoided by complete overhaul of the dumper. Marginal failures can be avoided by repairing of Clutch, pump and steering box. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

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