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Failure Mode, Effects and Criticality Analysis of Load Haul Dump Vehicles (100t) 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 earlies.

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Strictly as per the compliance and regulations of :

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I. 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.

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In this paper the results of FMECA analysis is published for 100 Ton dumpers working at Open Cast Mines – III, SCCL, Ramagundam.

II. 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.

III. Mil-std-1629a

This standard establishes requirements and procedures for performing a failure mode, effects, and criticality analysis (FMECA) to systematically 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 its effect in order that appropriate corrective actions may be taken to eliminate or control the high risk items

IV. 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

V. 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.

VI. 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.

VII. 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.

VIII. 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 Accoring 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

IX. Conclusions

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

1. For 100 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.
2. For 100 T dumpers as a group, Suspension 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.
3. For dumper CD-302, Gears must be replaced as soon as possible, based on the catastrophic nature of the failure.
4. For dumper CD-303, Radiator must be replaced.
5. For dumper CD-305, Engine must be replaced.
6. For dumper CD-306, Radiator must be replaced.
7. For dumper CD-307, Radiator must be replaced.
8. For dumper CD-308, Suspension must be replaced.
9. For dumper CD-309, Engine must be replaced.
10. For dumper CD-310, Suspension must be replaced.
11. For dumper CD-310, Brakes must be replaced.
12. For dumper CD-312, Suspension must be replaced.
13. For dumper CD-313, Engine must be replaced.

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Appendix

FMECA of all 100 Ton Dumpers

F No	Failure Name	frequency	time	occurrence	severity	detection	RPN
1	Radiator Leak	30	1987	0.1863	0.3447	0.4	0.0257
2	Engine Failures	23	967	0.1429	0.1678	1	0.0240
3	Suspension Failure	21	945	0.1304	0.1639	0.7	0.0150
4	Brake Failures	25	482	0.1553	0.0836	0.9	0.0117
5	Air compressor failures	20	633	0.1242	0.1098	0.6	0.0082
6	Cylinder Failure	12	1188	0.0745	0.2061	0.3	0.0046
7	Steering problems	13	256	0.0807	0.0444	0.8	0.0029
8	Bolts and studs failure	14	666	0.0870	0.1155	0.2	0.0020
9	Bucket & wear plate damage	14	255	0.0870	0.0442	0.5	0.0019
10	Hose failure and hoist failure	19	372	0.1180	0.0645	0.1	0.0008

Table 2 : Calculation of Risk Priority of all 100T Dumpers

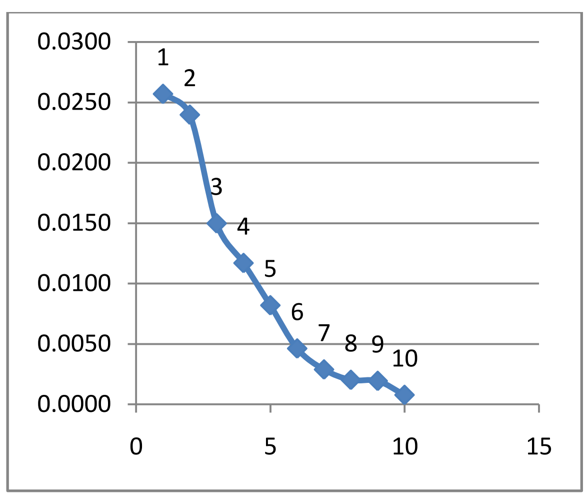

Figure 1 : Failure number Vs RPN of 100 T Dumpers

From 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, suspension, and brake are critical, cylinder failures and steering problems 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 steering system and cylinders. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – CD 302

F No	Failure Name	frequency	time	occurrence	severity	detection	RPN
1	Gears failure	3	936	0.0789	0.4522	0.5	0.0178
2	brake failures	5	202	0.1316	0.0976	0.9	0.0116
3	radiator leaks	7	236	0.1842	0.1140	0.4	0.0084
4	Railings damage	4	96	0.1053	0.0464	1	0.0049
5	steering problems	3	96	0.0789	0.0464	0.8	0.0029
6	pivot, bolts and studs failure	4	270	0.1053	0.1304	0.1	0.0014
7	cylinder failure	3	136	0.0789	0.0657	0.2	0.0010
8	Bucket damage	4	44	0.1053	0.0213	0.3	0.0007
9	tyre problems	3	22	0.0789	0.0106	0.7	0.0006
10	suspension failure	2	32	0.0526	0.0155	0.6	0.0005

Table 3 : Calculation of Risk Priority Number of CD-302 Dumper

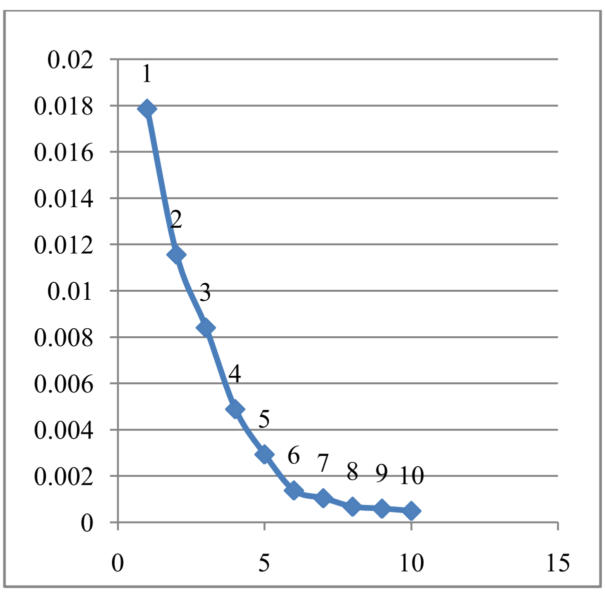

Figure 2 : Failure number Vs RPN of CD – 302 Dumper

From the table 3 and figure 2 it can be concluded that failure 1 i.e. gears failure is of high risk, is catastrophic failure. The failures (2 3 and 4) of brake failure, radiator leaks and railings damage are classified as critical. Steering, pivots bolts and studs failure and cylinder are categorised as marginal failures and the other failures are minor failures. According to Table 1 the gears failures 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 Steering, pivots bolts and studs, cylinders. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – CD 303

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	radiator leaks	8	136	0.2667	0.1276	0.4	0.0136
2	Engine failures	2	195	0.0667	0.1829	1	0.0122
3	water boiling in radiator	4	108	0.1333	0.1013	0.8	0.0108
4	suspension failure	4	243	0.1333	0.2280	0.3	0.0091
5	cylinder failure	2	113	0.0667	0.1060	0.6	0.0042
6	pivot, bolts and studs failure	2	93	0.0667	0.0872	0.5	0.0029
7	clutch failure	2	19	0.0667	0.0178	0.9	0.0011
8	Gears failure	1	47	0.0333	0.0441	0.7	0.0010
9	hose failure and hoist failure	3	90	0.1000	0.0844	0.1	0.0008
10	Bucket damage	2	22	0.0667	0.0206	0.2	0.0003

Table 4 : Calculation of Risk priority of CD-303 Dumper

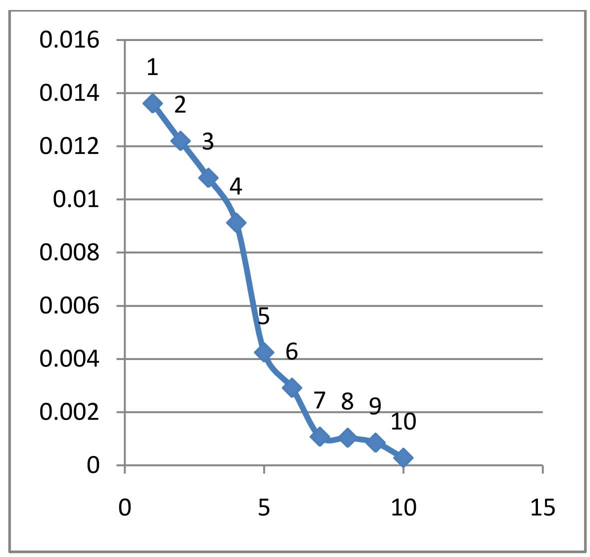

Figure 3 : Failure number Vs RPN of CD – 303 Dumper

From the table 4 and figure 3 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, suspension, and water boiling in radiator are critical. Cylinder failures and pivots, bolts and studs failure, clutch failure 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 pivots, bolts, studs, clutch, and cylinders. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – CD 305

F No	Failure Name	frequency	time	occurrence	severity	detection	RPN
1	Engine failures	3	131	0.1429	0.2323	1	0.0332
2	leaks and liquid change	4	213	0.1905	0.3777	0.2	0.0144
3	air compressor broken	2	67	0.0952	0.1188	0.7	0.0079
4	tyre problems	2	23	0.0952	0.0408	0.8	0.0031
5	Railings damage	2	33	0.0952	0.0585	0.5	0.0028
6	transmission failure	2	26	0.0952	0.0461	0.4	0.0018
7	belt and pulley failure	2	16	0.0952	0.0284	0.6	0.0016
8	rock ejector damaged	2	33	0.0952	0.0585	0.1	0.0006
9	brake failures	1	7	0.0476	0.0124	0.9	0.0005
10	Bucket damage	1	15	0.0476	0.0266	0.3	0.0004

Table 5 : Calculation of Risk priority of CD-305 Dumper

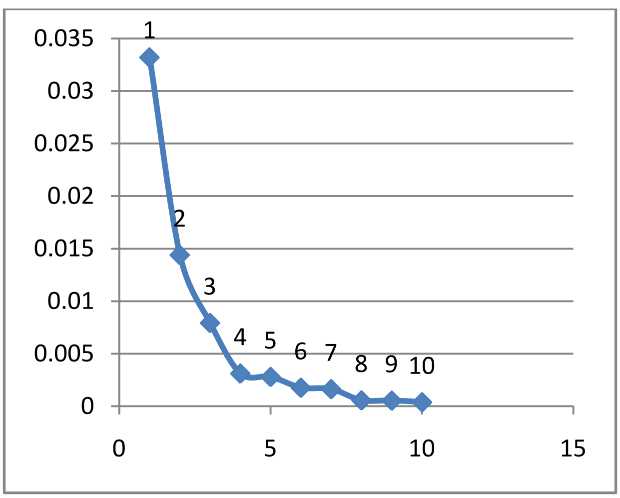

Figure 4 : Failure number Vs RPN of CD – 305 Dumper

From the table 5 and figure 4 it can be concluded that failure 1 i.e. engine failure is of high risk, is catastrophic failure. The failures (2, 3 and 4) of leaks and liquid change, air compressor broken, tyre problems are critical. Railings damage air compression failure, belt and pulley failure are categorised as marginal failures and the other failures are minor failures. According to Table 1 the engine and 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 railings, belt and pulley, air compressor. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

FMECA of Dumper – CD 306

F No	Failure Name	Frequency	time	occurrence	severity	detection	RPN
1	radiator leaks	4	78	0.2222	0.1785	0.3	0.0119
2	Bucket damage	2	58	0.1111	0.1327	0.4	0.0059
3	not taking load	1	51	0.0556	0.1167	0.7	0.0045
4	brake failures	1	31	0.0556	0.0709	0.8	0.0032
5	pivot, bolts and studs failure	2	116	0.1111	0.2654	0.1	0.0029
6	steering box failures	2	16	0.1111	0.0366	0.5	0.0020
7	steering problems	1	15	0.0556	0.0343	0.9	0.0017
8	hose failure and hoist failure	3	45	0.1667	0.1030	0.1	0.0017
9	Engine failures	1	12	0.0556	0.0275	1	0.0015
10	tyre problems	1	15	0.0556	0.0343	0.6	0.0011

Table 6 : Calculation of Risk priority of CD-305 Dumper

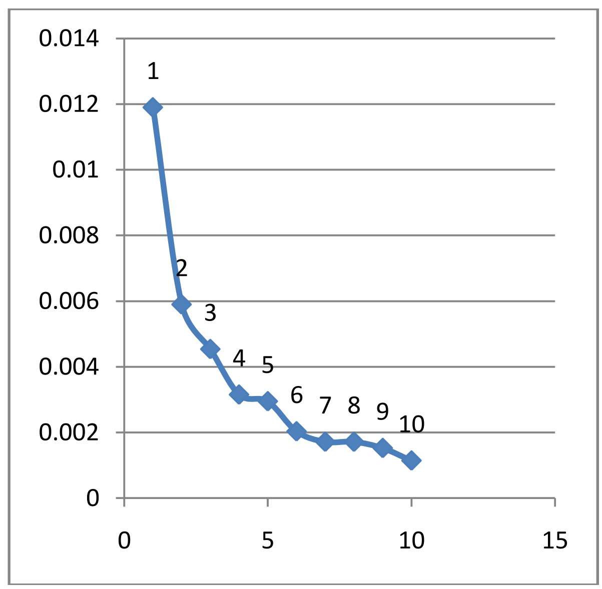

Figure 5 : Failure number Vs RPN of CD – 306 Dumper

From the table 6 and figure 5 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 bucket damage, not taking load, brakes failures are critical. Pivots bolts and studs failures, steering box failures and steering failures 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 pivots, bolts, studs and steering box and steering system. To avoid minor failures daily preliminary inspection of the whole dumper must be done before moving into the coal mine.

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