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Failure mode effective analysis of diesel engines used in dumpers

Mining industry in India occupies a popular position in the world league table. Mechanization on a large scale has made major breakthrough in this industry. In open pit mines, dump trucks are used for transporting ore. Failures of dumper subsystems affect production in mines. The most critical subsystem of a dumper is its prime mover, the diesel engine. It provides mobile propulsion to the dumper. Failure of engine will lead to stoppage of dumpers. To reduce the downtime of the engine, failure analysis of its subsystem is important. For this purpose the engine is divided into its different subsystems. Failure analysis is carried out for each subsystem using statistical tools empirical Failure Mode Effective Analysis (FMEA) and Risk Priority Number (RPN). The goal is to find out the most critical subsystem.

Keywords: *Diesel engines; reliability of engine; statistical tools; failure mode effective analysis (FMEA); risk priority number (RPN).*

1.0 Introduction

With the increase in mechanization in mining industry, more and more efficient and reliable equipment are required. To increase the availability of dumpers, there is a need to assess the reliability of its prime mover – the diesel engine. Dillon et al [1] used reliability block diagram and Markov chain method for reliability analysis of transmission system of the general service type of vehicle. The shape parameters and reliability were determined using Weibull distribution. Amit et al [2] analyzed reliability of the piston manufacturing system using fault tree analysis. Barnabas et al [3] had carried out failure rate analysis of IC engine subsystems. In this paper interval between two failures has been found out by using chi-square test. Using Markov chain the exact failure probabilities of all IC engine subsystems were determined. Rodrigo et al [4] has used tools FMEA (Failure modes and effects analysis) and FTA (Fault Tree Analysis) to support the study of failures of hydraulic turbine. Behera et.al [6] carried out reliability investigations in load haul dump machine using Weibull, Exponential and Lognormal probability distribution plots. In this study the status of criticality of different subsystems of diesel engine

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TABLE 1: TIME BETWEEN FAILURES FOR VARIOUS ENGINE PARTS

	Defective part	TBF (hours)
1	Turbocharger	2655
		633
		4112
2	Air compressor head	2036
		13
		479
		77
		3585
		1673
3	Alternator	1246
		44
		856
		1595
		2328
4	Hose	5220
		2494
		76
		608
5	Fan blade	2389
		1
		1585
		832
		8
6	Self-starter	3950
		3913
		538
7	SCCC pump	6220
		716
		337
8	Water pump	3827
		2356
		3856
9	Oil sump gasket	2066
		2278
		1114

have been found out using empirical method, FMEA and RPN. Finally the results have been compared. The Mean Time Between Failures (MTBF) was calculated to set a limited time period to check for every failed subsystem. This check assists in reducing sudden failure of subsystems.

In FMEA method, the subsystem failure analysis is carried out based on their function, mode, effect, cause and frequency. The subsystems are assigned the risk priority number (RPN) depending on their severity, occurrences and detection of failures.

2.0 Data collection

The engine failure data were collected from the workshop maintenance record book of a leading open pit mine. For this analysis, the time between failures (TBFs) of different subsystems of engines has been considered. The engines are turbocharged engine fitted in 85 tonne dumpers. The engines are 12 cylinders, V-type engines, with a power rating 805 H.P.

3.0 Methodology

The engines under study are the diesel engines used in 85 tonne dumpers deployed in an open pit coal mines. The failure of different engine subsystems and their subparts are considered for reliability analysis. As it can be seen from Table 1 that the number of failure for each subsystems is very small due to which the probabilistic nature of the underlying failure process cannot be found out therefore parametric failure analysis could not be applied for reliability analysis.

FMEA is one of the most efficient tools used for prevention of problems and for identification of more worthwhile solutions, in terms of cost, in order to prevent such problems. Initially survey was done on the function of each subsystem as well as its failure modes and effect. On the basis of severity, occurrence and detection of the failures, the risk priority number (RPN) has been designated to the engine subsystems. At last the results obtained shows the subsystem which is more susceptible to failure.

TABLE 2: TABLE OF DIFFERENT FAILURE MODE AND THEIR EFFECT ALONG WITH THEIR OCCURRENCE FREQUENCY

Engine system

Function: to provide the mobile propulsion to the engine

	Subsystem	Subsystem function	Functional failure	Failure mode	Failure cause	Failure effect	Failure frequency
1.	Turbo charger	To propel air compressor	Excessive white smoke	Turbocharger defective	Turbocharger impeller shaft broken	Engine running stop (8 hrs)	3 failures in 4 years
2.	Air compressor	To compress the air	Coolant in air tank	Air compressor head defective	Replaced the air compressor head	Engine running stop (27hrs)	6 failures in 4 yrs.
3.	Alternator failed	Charge the battery	Alternator not giving charge	Alternator defective	Alternator replaced	Engine running stop (4hrs)	5 failures in 4 yrs.
4.	Hose	To transfer oil, water and coolant	Water leakage from transmission oil cooler hose	Poor hose quality	Replaced the hose by new one	0 hrs	4 failures in 4 yrs.
5.	Fan blade	Cool the radiator	Fan blade and radiator damage	Fan blade broken	Fitted new fan blade and radiator	Engine running stop (40 hrs)	6 failures in 4 yrs.
6.	Self-starter	To start the engine	Starting problem	Self-starter failed	Replaced the self-starter	Engine running stop (4hrs)	3 failures in 4 yrs
7.	SCCC pump	To inject the fuel	Coolant leakage	SCCC pump to thermostat by pass tube gasket defective	Replaced the gasket by new one	0 hrs	3 failures in 4 yrs.
8.	Water pump	Use to circulate the water	Coolant leakage	Water pump seal defective	Replaced the pump by new one	0 hrs	3 failures in 4 yrs.
9.	Oil sump gasket	To prevent engine oil leakage	Engine oil leakage	Upper oil sump gasket defective sump gasket	Replaced upper and lower oil	0 hrs	3 failures in 4 yrs.

Table 3: Ordering of Indexes for severity occurrence and detection

Rank	Severity (S)	Occurrence (O)	Detection (D)
1	None	Almost never	Almost certain
2	Very minor	Remote	Very high
3	Minor	Very slight	High
4	Very low	Slight	Moderately high
5	Low	Low	Moderate
6	Moderate	Medium	Low
7	High	Moderately high	Very low
8	Very high	High	Remote
9	Serious	Very high	Very remote
10	Hazardous	Almost certain	Almost impossible

Table 4: Table of risk priority number (RPN) for different engine failed parts

Engine system				
Function: to provide the mobile propulsion to the engine				
Name of failed subsystem	Severity (S)	Occurrence (O)	Detection (D)	RPN (Risk priority number) = S×O×D
1. Turbo charger	6	4	5	120
2. Air compressor	7	6	6	252
3. Alternator	5	5	5	125
4. Hose	2	4	3	24
5. Fan blade	9	6	5	270
6. Self-starter	5	4	3	60
7. SCCC pump	1	4	3	12
8. Water pump	1	4	3	12
9. Oil sump gasket	1	4	5	20

4.0 Data analysis

The FMEA of the engine subsystems has been carried out based on the failure mode, failure reason and its effect. Accordingly the problem associated with the engine subsystems has been ranked according to the severity, occurrence and detection. By taking the product of these ranked numbers risk priority number has been found out. Table 2 shows different failure mode and their effect along with their occurrence frequency. The Table 4 shows the RPN for different subsystems. The radiator fan blade failure is having the highest value of RPN i.e.270.

5.0 Results and discussions

Using FMEA analysis the air compressor head is having the highest value of RPN i.e.270 as shown in Table 4. The results show that the radiator fan has undergone much more damage as compared to other subassemblies and is highest prone to failure.

6.0 Conclusion

In this paper an attempt has been made to find out most failure vulnerable part of engine using FMEA (RPN) analysis.

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