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Reliability Analysis of Dumpers through FMEA-TOPSIS Integration

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ABSTRACT

Failure modes and effects analysis is an effective and most common traditional method to find and eradicate the failure modes in the system. In the FMEA method ranks are assigned based on risk priority number and are calculated by simply multiplying Severity(S), Occurrence(O), and Detection(D). FMEA doesn't consider subjectivity and vagueness in the decision-maker judgement and this method has been criticized due to its limitations. This project work aims to overcome the shortcomings of FMEA by integrating with the Multi-Criterion Decision Making (MCDM) model by Shannon Entropy weight method with Technique for Order of Preference by Similarity to Ideal Solutions (TOPSIS). The entropy method is used to calculate weights of the risk factors and TOPSIS is to examine the priority of ranking of failure modes or causes identified by the FMEA Study. In the Present work, FMEA and TOPSIS Hybridization method was performed to analyze potential failure modes of a group of dumpers in open cast mining at Singareni Collieries Company Limited (SCCL) in Ramagundam. The results obtained from this hybridization can be used to take the corrective actions in time so that the system reliability is improved.

KEYWORDS: Dumpers, FMEA, Entropy method, and TOPSIS.

INTRODUCTION

In India, coal is the most abundant fossil fuel. It provides maximum energy needed by our country. India is highly dependent on coal for meeting commercial energy requirements because of this reason production of coal is important. The mining process is used to extract coal from the earth's surface and underground. There is various equipment are used to extract and transport coal include excavators, walking draglines, roof bolters, drills, continuous miners, longwall miners, railcars and chairlifts, shuttle cars, scoops, rock dusters, dumpers, dozers, scrapers, shovels. A dumper is a vehicle used to transport coal from one place to another place.

Coal mining is the process of extracting coal from the earth's surface and underground. Today extraction of coal is a highly productive and mechanized operation. The value of coal is very high for its use. coal is used to produce heat and electricity and it can also be used as fuel for steel and cement industries. For time being the developments in the coal mining process enhances. At First, the men dug the tunnel to obtain coal but today's situation is different most of the work can be done by machinery.

1.1 Importance of dumpersin Open Cast Mines

Various equipment and tools are used in open cast mines.A dumper is a heavy-duty vehicle containing a steel body container open at the top to receive material loaded by tractor shovels or draglines. All dumpers have a hydraulic pressure force to ram out to lift the loaded body.In this work, the failure diagnosis has been carried out on the dumpers because of from analysis of failure data, dumpers gave the more trouble than any other. Dumpers (figure1) are diesel-powered vehicles.It is used to carry coal and topsoil in open cast mining. Dumpers generally travel from mining site to the coal plant this is the main reason for getting more repairs in dumpers.

Figure 1Dumper

1.2Reliability

"Reliability is elaborated as the probability of a product, system, or process performing its intended function satisfactorily in a specified period of timeand will operate in specified environmental conditions without failure". Reliability is measured in Mean time between failure (MTBF), Mean time to failure (MTTF), and Mean time to repair (MTTR).

A.1.3 Objectives of the present work

This project is focused to identify the failures modes and the

The primary objectives of the project study are as follows

1.Analyze the available failure data of dumpers at SCCL, Ramagundam coal mine.

2.Identify the system failures based on failure data

3.Finding out the failure modes, their effects and causes and recommend corrective actions.

4.Perform failure modes and effects analysis (FMEA) through the RPN method on available failure data to predict the failure or risk before it reaches the end.

5.Perform TOPSIS method to prioritize the risks or failure modes.

2. LITERATURE REVIEW

Zh]ang, X et. al [1] This paper presents, hybrid multilevel FTA-FMEA method to overcome the drawbacks of individual methods. Widely used failure analysis methods failure tree analysis and failure modes and effects analysis, but these methods are time-consuming and expensive when they are fully implemented. In this method three-layer analysis is used, in the first layer, FTA is performed to find the failure modes and then FMEA is conducted to examine them and to find the key functional modes for the criticality analysis. For the second layer, the same steps are followed as in the first layer, the FTA performs to find meta-action/component failure modes from the results obtained from the first layer that is key functional fault modes. FMEA is performed subsequently and key meta-action/component failure modes are determined by using criticality analysis. In the third layer, failure causes are determined by using criticality analysis key failure causes are determined.

Pancholi, N., & Bhatt, M [2] In this paper presents, Reliability improvement of Al wire rolling mill and to investigate performance reliability of continuous process industry. Multi attribute decision making methods are used to overcome the limitations of traditional FMECA. Criticality analysis is performed based on downtime and frequency of failure. The limitations of FMECA assign equal weightage to all attributes, small variation in the valves of severity, occurrence and detection shows large variation in the RPN value. In this paper, MADM based non-traditional FMECA models like TOPSIS and PSI are used for major critical components obtained from criticality analysis. FMEA is prepared based on available past data and discussion with the operators, managers and maintenance personnel and assign the scores for different failure causes. In this study Shannon entropy method is used for calculation of attribute weights. From the different failure models, it is concluded that bearings, gears and shafts are most critical components it needs special care.

Başhan, V., Demirel, H., & Gul, M [3] In this paper, twenty-three fundamental failures are considered and examined by FMEA and TOPSIS approach single-valued neutrosophic sets. Here, they have taken experts' opinions for risk data due to the lack of available data. The single-valued neutrosophic set is a special version of neutrosophic sets of fuzzy and intuitionistic fuzzy sets, it deals with the real-world problem by considering three aspects those are truthiness, indeterminacy, and falsity. This study helps to overcome the limitations of FMEA based approach. First, a team finds the objective and scope of FMEA and assigns scores for failure modes according to the risk factor in a neutrosophic environment after that sensitivity analysis has been done.

Ahmadi, M. et al [4].This paper presents, FMEA and TOPSIS models are deal with risk factors, only the FMEA model gives the way but does not guarantee good results because of high dependency on the prediction of experts in evaluating risk. The objective of this study is to eliminate the influence of expert emotion in the process of risk evaluation, out of three parameters of FMEA methods two parameters (severity and detection) are purely dependent on expert opinion. TOPSIS method is used to assess the severity and detection based on eight attributes and occurrence is calculated differently based on factual data that is counting the number of failures in a year and average failures and normalize them on a zero to ten scale. This is successfully implemented in a steel company, given the riskiest (adherence of box in box annealing line) failures out of 645 failure modes and in 21 production lines.

Kolios et.al [5] In this study First, potential failure modes are identified by the expert's opinion and followed by an FMEA study to identify the most critical failure modes of SCM. A fussy TOPSIS model is used to analyze and prioritize the most critical failure modes obtained from FMEA.In this case study, thirty (30) potential failure modes are identified by the experts, and failures due to external factors like installation errors, testing, and transportation of equipment are not considered. For the FMEA study, three parameters are considered such as occurrence, severity, and detection and in the fussy TOPSIS model the occurrence is divided into three parts, severity into five parts, and detection is divided into two parts for improving the reliability. The results obtained from the study are validated by using the OREDA baseline database in the oil and gas industry.

M. Pradeep Kumar, N. V. S. Raju, and M. V. Satish Kumar [9] In this paper, FMECA and Criticality index methods are used. FMECA method is used to identify the critical failure modes and criticality index to analyze the criticality of failure mode. For the simplification of the analysis process fishbone diagram of the dumper is drawn. The total system is divided into seven subsystems and failure modes are identified for the subsystems, cause and effect are studied for failure modes. FMECA analysis has been done by using RPN and it is used to prioritize the failure modes so that the risk can be minimized. The ranks are obtained by using RPN and the criticality index is analyzed and compared by using spearman's rank correlation coefficient. This shows positive correction, indicates both methods are suitable for the determination of criticality analysis.

N. Lakshmi Narayana, Dr. N.V.S. Raju and M. Pradeep Kumar [8] In this study, FMECA is performed on dumpers to identify the potential failure modes. In the mining industry, much different equipment is used but dumper is travel from one place to another. From the available data, dumpers gave more trouble than the all-other equipment's that is the reason why they have taken the dumper to analyze the failures. This study is performed on 100 tons and 85 tons dumpers. FMECA study performed on dumpers in SSCL, Ramagundam. Total 31 dumpers are taken into consideration for a two years period and from the available data 12 major potential failures are taken to perform the FMECA. Scales are established to obtain the severity, occurrence, and detection scores from these data RPN values are calculated to prioritize the failures according to more production loss to low.

K. Maheswaran, T. Loganathan [9]In this paper, the author used the FMEA and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) to overcome the drawbacks of FMEA. The analytic hierarchy process (AHP) method is used to compute the weights to attributes. This Proposed model consists of Four steps for the process of risk evaluation, first step includes the identification of failure modes by the expert's opinion. In the second step identification of risk associated with failure modes. In the third step, the identification of weights corresponding to the risk factors, and the last step for the process is ranking of each failure mode, this process is used for identification highest potential risk. The multi-criteria decision-making model PROMETHEE is used to prioritize the failure modes. In this model, four attributes are taken are severity, occurrence, detection, and protection, and assign the scores for them based on the expert's opinion.

B.3. DATA COLLECTION

Data collection is the most predominant step in reliability analysis. If improper data or incorrect data leads to wrong results or improper results. Some of the companies record or maintain the data and some may not record. It is very burdensome to handle and understand the large production data in the industries. For the smooth running of the industry, the data should be maintained. The reliability analysis is dependent totally on a collection of data. The data is obtained in two ways, one is from the field surveying, other is obtain the sample from the laboratory. Field surveying is a very expensive and time-consuming method. From Table 1, The ratings are allotted to the three criteria, which include severity, occurrence, and detection.

Table 1 Refined failure dataof dumpers for failure analysis

Failure modes	Failure code	TTR	Frequency of failure
Brake fluid leak	1a	25	6
Brake jam	1b	20	5
Brake wear	1c	50	5
Brake anchor leak	1d	12	9
Brake relay valve leak	1e	7	2
Engine abnormal sound	2a	55	3
Engine replaced	2b	355	2
Cylinder exhaust bolts broken	2c	79	6
cylinder head replaced	2d	738	1
Engine blow by	2e	6	3
Engine not carrying load	2f	35	8
Oil leak from suspension	3a	23	19
Suspension seal leak	3b	22	9
Suspension(box) failure	3c	24	5
Suspension preventive repair and maintenance	3d	9	5
Suspension seal failure	3e	118	3
Transmission oil leak	4a	15	9
Tyres toe in and out	4b	12	6
Clutch and gear slipping problem	4c	18	7
Torque converter failed	4d	128	2
Throttle sensor failure	4e	35	3
Hydraulic cylinder oil leak	5a	54	22
Hoist cylinder leak	5b	18	14
Hoist pump leak	5c	15	2
Hoist seal leak	5d	14	5
Bucket not working	5e	9	1
Radiator water pump leak	6a	47	4
water boil in radiator and air leak	6b	21	4
Radiator fan damaged	6c	38	2
Radiator hose problem	6d	9	2
oil leak from steering cylinder	7a	15	3
steering hard	7b	15	1
steering lock	7c	11	1
steering hose leak	7d	14	2
steering box failed	7e	29	3
Compressor burnt	8a	16	3
Air compressor broken	8b	15	4
Air tank vibration	8c	29	1
Air drier leak and replaced	8d	10	3
Turbo charger failed	9a	29	3
turbo oil leak	9b	25	2
Turbo gas leak	9c	8	1

4. METHODOLOGY FOR THE PROJECT

Firstly, the FMEA technique is used to identify the failure modes to corresponding failure classes of dumpers.It is also determining the failure effects and causes of dumpers. Then after the obtained results from FMEA are examined by MCDM model TOPSIS. In the TOPSIS method weights are calculated by the Shannon entropy weight method. At finally Rank is assigned to the risks based on the relative closeness ratio. This FMEA-TOPSIS Integration method is used to overcome the shortcomings of FMEA.

5. SEVERITY(S)

Severity is the measurement of the seriousness or effect of the failure mode on the sub-system, downstream operation, customer, and subsequent components. These severity rankings were given on a normalization scale of 1 to 10. The ranking of severity should not be changed except in case of a change in the design of the product. Here 1 indicating the lower effect and 10 indicates a very high effect on product/ item.

Table 2 Scaling table for Severity ranking

Rank	Severity ranking criteria
1	Interruption is less than 3 hours
2	Interruption is more than 3 hours and less than 5 hours
3	Interruption is more than 5 hours and less than 10 hours
4	Interruption is more than 10 hours and less than 20 hours

5	Interruption is more than 20 hours and less than 35 hours
6	Interruption is more than 35 hours and less than 55 hours
7	Interruption is more than 55 hours and less than 80 hours
8	Interruption is more than 80 hours and less than 110 hours
9	Interruption is more than 110 hours and less than 150 hours
10	Interruption more than 150

6. OCCURRENCE

Occurrence measures the frequency of failure in a system. Assign the ranking score for each cause or failure mechanism. The removal and reduction of occurrence ranking will happen with the change of design of product or process. Assign the 1 to 10 scales for the causes of failure of mechanisms in the system. Here 1 indicates the low chance of occurrence failure and 10 indicates a very high chance of occurrence of failure. Here the scaling data is for only 2 years.

Table 4 Occurrence of failure ranking

Probability of failure	Occurrence ranking criteria	Rank
Almost never	Once in 2 years	1
Very rare	Once in 18 years	2
Rare	Once in 1 year	3
Very Low	Once in 6 months	4
Low	Once in 3 months	5
Medium	Once in 2 months	6
Moderate High	Once in a month	7
High	Once in fortnight (2 weeks)	8
Very High	Once in a week	9
Extremely high	Once in a day	10

7. DETECTION

Detection is the measurement of failure cause or mechanism before it reaches the end-user. For to get the minimum ranking of detection, design control should be improved. Scales for the detection same as the severity and occurrence. Here, 1 indicates failure can easily be detected and 10 indicates it's impossible to detect the failure.

Table 5 Detection of failure and corresponding ranking

Probability of detection	Detection ranking criteria	Rank
Extremely high chances of detection	Sound	1
Very high chance of detection	Vibration/hardness/ feeling different from actual	2
High chance of detection	Visualinspection/Smell inspection	3
Moderately high chance of detection	Driver physical inspection	4
Moderate chance of detection	Instruments to detect	5
Low chance of detection	Maintenance and repairs	6
Remote chance of detection	Internal damage	7
Very remote chance of detection	Internal damage	8
almost impossible to detect	Sudden failures	9
Impossible to detect	No chance of detection	10

8. RISK PRIORITY NUMBER (RPN)

RPN measures the risk of design by simply multiplying the severity, occurrence, and detection rankings. RPN values in the range of 1 to 1000. RPN is used to prioritize the failure causes in the process of design. Here 1 indicates the smallest risk and a higher value of RPN indicates more risk. If the RPN value is less than 50 then that risk is ignored and if the RPN is more than 50 then that risk is supposed to take corrective actions to minimize that cause. The team members of FMEA are search for each and every method to reduce the RPN value.

RPN = Severity (S) x Occurrence (O) x Detection (D)

9.SHANNON ENTROPY WEIGHT METHOD

This method is used to calculate the weights for the different attributes in the TOPSIS method. This method is invented by Claude Shannon, which measures the uncertainty of randomness in the information data. The expected value of the information data contained message is quantified using this method. Shannon entropy uses a mathematical model for explaining the expected value of alternatives of a variable. The entropy function always has a positive value. Because of the many attributes, the entropy concept is accepted as an objective criterion that can be used in measuring the information content of any statistical process.

9.1 steps to perform the entropy method

Step1: Normalization of a decision matrix to get project outcomes Pij

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (1).$$

The normalization process has been done with the help of equation (1). Each and every element in the decision matrix is divided by the sum of elements in the column or criteria.

Step2**:** Calculation of entropy measure of project outcomes determine with the help ofequation (2). Consider the probability distribution of random variables with finite limits. Here quantifies the uncertainty of total probability distribution is measured by using this method.

$$E_j = -k\sum_{i=1}^{m} p_{ij}\, ln p_{ij} \qquad (2).$$

Where k = 1/ln(m) here, m = number of alternatives

Step3: Calculation of weights by using entropy concept

$$w_j = \frac{1-Ej}{\sum_{j=1}^{n}(1-E_j)} \qquad (3).$$

From equation (3) weights are calculated by substituting entropy (Ej) valve.

10.TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION(TOPSIS)

Technique for order preference by similarity to an ideal solution is simply shortly to call it as TOPSIS. This method is a mathematical technique to examine the ranking priority of failure modes or failure cause. TOPSIS is a multi-criteria decision-making method that was discovered by Hwang in 1981. TOPSIS is used to obtain the critical failures modes from the list of failures, this will save the time and cost for analysis. The key point of this method is choosing of best alternative from the group of alternatives. TOPSIS method is used to overcome the drawbacks of traditional FMEA [1,2]. The main purpose of TOPSIS is to obtain the best solution, one which is having minimum distance from the ideal solution and more distance from the anti-ideal solution.

10.1 Steps followed to perform the TOPSIS method

There are seven different steps in the construction of TOPSIS method

Step 1: Preparation of a decision matrix

Form the decision matrix by giving a number of alternatives and criteria or attribute values. The decision matrix is represented byxij, where i representcriteria and j representalternatives. An alternative is on the n rows and criteria shown on m columns. The rank of the decision matrix is n x m.

Representation decision matrix

$$X_{ij} = \begin{vmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{vmatrix}$$

Step 2: Normalization of decision matrix

The normalization process has been done to equalize the units. There are two different ways to normalize the decision matrix

(1) Distributive normalization method

Here, each element is divided by the square root of the sum of each squared element in a column or criteria.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \text{ i = 1,2,3---,m j =1,2,3,---n (4).}$$

(2) Ideal normalization method

If the criteria for the problem is maximized then each element is divided by the highest value in a particular or column.

$$r_{ij} = \frac{x_{ij}}{\max\, x_{ij}} \text{i=1,2,3---m} \qquad (5).$$

(3) For the minimization of criteria, each element is divided by the minimum value in each column or criteria. from the normalization method, we get the values in the range of 0 to 1.

$$r_{ij} = \frac{x_{ij}}{\min\, x_{ij}} \qquad \text{i =1,2,3---m (6).}$$

Representation of normalization decision matrix is

$$r_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

step 3: Construction of weighted normalized decision matrix

The weights for this step are measured by two different methods those are Analytical Hierarchy Process (AHP), theShannon entropy weight method simply call it as entropy method. These weights are assigned to each and every criterion in the decision matrix. Obtain the weighted normalized decision matrix by multiplying each column element to the corresponding weight of criteria.

$V_{ij} = W_j r_{ij}$ j = 1,2,3, -----, n i = 1,2, ----, m (7).

Step 4: Determination of Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

There are three ways are present to determine the positive ideal and negative ideal solutions

Comparison of each alternative with the virtual ideal alternative and virtual negative ideal alternative.

(1) For maximization criteria, the best alternative is the maximum value of that particular column and for minimization criteria, the best alternative is the minimum value of that column. Maximization criteria are the benefit attribute and minimization criteria are the cost attribute. An example of a benefit attribute is the performance of an engine, reliability of the bolt.

(2) Standard positive ideal and negative ideal points are defined. The positive ideal point is one (1) and the Negative ideal point is Zero (1).

(3) The positive and negative ideal alternatives are identified or specified by the decision-maker. It must lie in the range of 0 to 1.

A+ = {V1+, V2+, V3+ }--------- Positive Ideal Solution

A-= {V1-, V2-, V3- } ------------Negative Ideal Solution

V+ = {max Vij (Benefit attribute), min Vij (cost attribute)}

V- = {min Vij (Benefit attribute), max Vij (cost attribute)}

Step 5: Calculation of Separation or Euclidean distance

Determination of distance from each alternative to the ideal alternative

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^+\right)^2} \qquad i = 1,2,3\text{-----},m \qquad (8).$$

Determination of Euclidean distance from the negative ideal alternative.

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^-\right)^2} \quad i = 1,2,3,\text{------},m \ \ (9)$$

Step 6: Computing the relative closeness ratio or relative proximity index

$$C_i = \frac{S_i^+}{S_i^+ + S_i^-} \qquad (10)$$

Ci values lie between 0 and 1. When Ci value approaching 1 indicates the preferred or favorable alternative.

Step 7: Prioritization of ranks in descending order of C_i Ranks are obtained by the closeness ratio.

11. RESULTS AND DISCUSSIONS

Table 6 Results from FMEA and TOPSIS methods

Failure code	Severity	Occurrence	Detection	RPN	Rank	S_i^+	S_i^-	C_i	Rank
1a	5	4	3	60	22	0.0207	0.0632	0.7535	23
1b	5	4	4	80	12	0.0211	0.0595	0.7381	25
1c	6	4	2	48	27	0.0301	0.0613	0.6704	33
1d	4	6	3	72	16	0.0123	0.0657	0.8418	16
1e	3	3	5	45	28	0.0018	0.0786	0.9777	3
2a	7	4	1	28	34	0.0398	0.0625	0.6107	36
2b	10	4	3	120	4	0.0694	0.0401	0.3664	41
2c	7	5	2	70	20	0.0405	0.0514	0.5594	37
2d	10	3	3	90	10	0.0690	0.0473	0.4069	40
2e	3	4	5	60	23	0.0022	0.0745	0.9708	4
2f	5	5	5	125	3	0.0224	0.0531	0.7038	30
3a	5	7	2	70	21	0.0228	0.0617	0.7301	27
3b	5	6	4	120	5	0.0225	0.0531	0.7021	31
3c	5	5	4	100	8	0.0217	0.0556	0.7190	29
3d	4	5	6	120	6	0.0134	0.0615	0.8208	19
3e	9	4	6	216	1	0.0615	0.0300	0.3278	42
4a	4	6	3	72	17	0.0123	0.0657	0.8418	17
4b	4	5	4	80	13	0.0120	0.0643	0.8429	14

4c	4	5	4	80	14	0.0120	0.0643	0.8429	15
4d	9	3	4	108	7	0.0597	0.0434	0.4213	39
4e	4	4	2	32	33	0.0106	0.0752	0.8760	10
5a	6	7	5	210	2	0.0339	0.0401	0.5420	38
5b	4	7	3	84	11	0.0133	0.0650	0.8299	18
5c	4	3	3	36	30	0.0105	0.0752	0.8779	7
5d	4	5	3	60	24	0.0115	0.0677	0.8544	13
5e	4	1	4	16	39	0.0106	0.0837	0.8880	5
6a	6	4	3	72	18	0.0304	0.0560	0.6479	34
6b	5	4	5	125	9	0.0217	0.0572	0.7246	28
6c	6	3	3	54	26	0.0300	0.0613	0.6717	32
6d	4	3	3	48	31	0.0105	0.0752	0.8779	8
7a	5	4	3	60	25	0.0207	0.0632	0.7535	24
7b	4	1	6	24	36	0.0120	0.0815	0.8718	11
7c	4	1	6	24	37	0.0120	0.0815	0.8718	12
7d	4	3	3	36	32	0.0105	0.0752	0.8779	9
7e	6	4	3	72	19	0.0304	0.0560	0.6479	35
8a	5	4	1	20	38	0.0203	0.0736	0.7838	20
8b	4	4	1	16	40	0.0106	0.0804	0.8840	6
8c	5	1	5	25	35	0.0209	0.0754	0.7828	21
8d	3	4	1	12	42	0.0008	0.0878	0.9909	1
9a	5	4	4	80	15	0.0211	0.0595	0.7381	26
9b	5	3	3	45	29	0.0202	0.0679	0.7707	22
9c	3	1	5	15	41	0.0014	0.0893	0.9842	2

11.1 Results from FMEA

In this study, past failure data of twelve dumpers are collected and analyzed to identify, reduce or eliminate the risk associated with failure modes. RPN value is calculated based on the severity(S), occurrence(O), and Detection(D) ratings. From Table 6 it is concluded that suspension seal failure mode(3e) has the highest priority in the RPN method. so, this should be corrected in time to reduce the risk of failure and the next highest priority risk is a hydraulic cylinder oil leak. Based on this RPN method effective maintenance methodology has been suggested. From the FMEA result, the RPN value of more than 150 is considered as the most critical failures needs to perform predictive maintenance, RPN value 150 to 50 considered as critical failures and needs to perform preventive maintenance and if RPN is less than 50 is considered as normal failures needs to perform corrective maintenance

11.2 Results from MCDM TOPSIS based FMEA

From the observation of table 6, Air drier leak and replaced (8d), Turbo gas leak (9c) are the best failure modes and suspension seal failure mode(3e), Engine replaced (2b) are the worst failure modes that should be corrected in time to reduce the risk of failure. In the TOPSIS method ranks are given from best alternative to worst alternative. According to the rankings, maintenance plans are suggested. The limitation of TOPSIS is reversal ranking if one alternative is eliminated or added then the total ranking order will be inverted which means the best alternative becomes worst.

11.3 Achievements from the Shannon entropy weight method

The Shannon entropy method is mostly used in TOPSIS and other MCDM methods to calculate the weights corresponding to the attributes. There are various weight calculating methods are available is SAW, analytical hierarchy

Process (AHP).

Weights Obtained from the shannon entropy method are

W1 = 0.34, W2 = 0.33, W3 = 0.33.

12. CONCLUSION

This project has been done to identify Failure classes and failure modes of a dumper truck and it also finds the failure effects, causes, and current controls by the FMEA method and it suggests corrective actions to minimize or eradicate the risk. First, FMEA through RPN analysis is performed then FMEA through multi-criteria decision model TOPSIS is performed. A combination of multi-criteria decision-making methods with the FMEA provides the most effective or most accurate results. Shortcomings of traditional FMEA can be overcome by combining FMEA with the MCDM model. In this project, a Hybrid analysis of FMEA and TOPSIS has been done on the failure data of dump trucks to prioritize the failures.

According to the ranks, the corrective actions are taken in time.From this analysis the highest prioritized failure mode is suspension seal failure and the lowest risk failure mode is Air compressor broken. There is a little variation of prioritized rankings of failure modes obtained from both methods.

The five most priority rankings from the TOPSIS analysis are suspension seal failure, engine replacement, cylinder head replaced, Torque converter failed and Hydraulic cylinder oil leak. The five riskiest failure Rankings by RPN method are suspension seal oil leak, Hydraulic cylinder oil leak, Engine not carrying a load, Engine replaced, and Hoist cylinder leak. Table 6 shows the priority of all failure modes from traditional FMEA and FMEA based TOPSIS methods.

13. FUTURE SCOPE

A similar procedure is extended to other industries like textile and chemical plants. Different MCDM methods like Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), measuring attractiveness by a categorical-based evaluation technique (MACBETH), ELECTRE, and qualitative flexible multi-criterion (QUALIFLEX) with analytical hierarchy process (AHP) or simple additive weighting method (SAW), etc. Results can be validated with another process to prove the competency of MCDM

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