FAILURE MODE CRITICALITY ANALYSIS USING SAW METHOD: A CASE STUDY

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Abstract:Nowadays, there is lots of pressure on service and manufacturing firms to keep its good place in market and provide quick delivery of products**.**Therefore, firms useddifferentmaintenance techniques to reduce breakdowns in machines so that delivery of products at right time.Most often used technique is FMECA i.e. Failure Mode Effect and Criticality Analysis, but it takes into account only three parameters i.e. asperity, happening and disclosure. Based on literature review these attributes (risk of failure, spare parts, non-observation, maintainability, economic price and economic safety) are recognized. In this present work, an integrated model is proposed for improving the maintenance policies. In this model, method of Shannon's entropy is used to computing the weight of criterion then using these weights maintenance criticality ranking is generated with the help of multi criteria decision making (MCDM) technique i.e.Simple Additive Weighing (SAW). The application of the planned approach has been verified with real life case study on Ring Frame machine in a textile industry. Results from ranking shows "20T spur gear cut (D6)" at topmost position and requires highest attention when policy decisions for maintenance of ring frame machine are made.

***Index Terms* - Maintenance, FMECA, Shannon's Entropy, SAW.**

I. INTRODUCTION

India is on the second number for making of garments and textile in the world. It is supposed that the Indian clothing and textiles business is increased to a capability of 223 billion US$ in 2021, via a statement. This business contributes around 8% of worldwide rotor capability and 24% of the world's spindle capability. The option of raw materials like cotton, wool, silk, expertlabour force and jute have made the India as a sourcecentre. Textiles industry increasefinancial system of India in language of foreign exchange incomes and indirect and direct employment creation. This sector givesin relation to 4% to the GDP, 27% to the country's foreign exchange incursion and 14% to industrial production. Therefore, enlargement and improvement of textile industry has a directly impact on the improvement of the Indian economy. Punjab is the house for well-known textile industries in the country like Trident, Nahar Vardhman. The South Western area of the State, consist of the districts of Muktsar, Mansa and Bathinda etc. is the major cotton producing area in Punjab. Competitive costs of production, good road and rail network, supportive regulatory scheme, simple market access, and Government support create a strong case for deal in the textile sector in Punjab

In the favour ofcontinuousproduction, maintenance of machines and equipments is very essential. In current times, many maintenance strategies (such as corrective maintenance, planned maintenance, breakdown maintenance, predictive maintenance, preventive maintenance and condition-based maintenance,) are used by textile factories. For making of maintenance activities for industrial units, a range of approaches has been recommended in the literature. The most generally used approaches to weigh up the maintenance importance of the modes of failure / items, and classify these in various risk-based categories are fixed on the application of Failure Mode Effect and Criticality Analysis FMECA. This approach has been recommended in other possible forms, regarding risk priority number formulation and/or relevant criteria taken into account. The preference of a maintenance approach is achieved through the examination of the gathered priority risk number, utilizing this method.

II. SHANNON ENTROPY CONCEPT

Shannon's Entropy's technique for evaluateweights for decision-matrix norm that imply to be a major concept in the information theory and also in physical and social sciences where it determine the anticipated information size of a particular message, i.e. in theory of information, Entropy is characteristic for resolve of the degree of inconsistency of a distinct probability dispersion in a way that this inconsistency in biased distributions is extra than sharper distributions P_i. computation of the weight for every correlation criterion on base of the calculation of entropy value and next on shifting it into the attribute weight is categorized in these three steps:

(i) Normalize the evaluation index as:

$$p_{ij}=\frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \qquad i=1, 2,\ldots n \quad (1)$$

(ii) To calculate the entropy value of each criterion $C_1, C_2, \ldots, C_n$

For each criterion, weight is computed by proposing the concept for entropy. Let e_j denotes the entropy of the j^{th} criterion.

$$e_j= -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij} \ln p_{ij} \qquad j=1,2,\ldots,m \qquad (2)$$

while 1/ln n is consistent term it holds the value of e_j between 0 and 1.

(iii) Calculation of the weights of each criterion.

For each criterion the objective weight is given by,

$$w_j=\frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)} j=1,2,\ldots\ldots,m \qquad (3)$$

III. SIMPLE ADDITIVE WEIGHTING METHOD

Simple Additive Weighting (SAW) that is also name as scoring or weighted linear combination method is a simple and extensively used applied multi attribute decision approach. This method is base on the weighted average. Adecision score is computed for each alternative by multiplying the scaled value given to the alternative of that characteristic with the weights of relative significance directly assigned by decision maker pursue by summing of the products for all criteria. The benefit of this technique is that it is a proportional linear transformation of the raw data which means that the relative order of magnitude of the standardized scores remains equal. The SAW procedure has the following steps:

Compute the normalized decision matrix concerning positive attributes:

$x_{ij} = r_{ij}/r_j^*$ i=1,.....m, j=1,....n (4)

and concerning negative attributes:

$x_{ij} = r_j^{min}/r_{ij}$i=1,.....m, j=1,....n (5)

r_j^* is a maximum number of r in the column of j.

Evaluate every alternative, A_i by the following formula

$A_i = \sum w_j x_{ij}$ (6)

Where x_{ij} is the normalized score of the i^{th}alternative in respect of the j^{th} criteria, w_j is the weight of criteria.

Rank the preference order.

IV. IDENTIFICATION OF CRITERIA

In traditional FMECA (Failure Mode Effect and Criticality Analysis) technique only three parameters i.e., asperity, failure happening and non-observation are utilized for computing maintenance criticality. But in this case study total six criteria are taken into account for evaluation of maintenance importance of mode of failure. These are failure happening, chance of non- observation, maintainability, time for spare part and economic safety and economic price.

After recognition of critical factors, their evaluation is carried out by describing a logical approach to compute the distinct criterion for all modes of failure, on the basis of series of tables. Especially, all factors are grouped into various categories that are given a separate range of score from 1 to 9 to consider the separate levels of importance. The scores have then been characterized according to the knowledge of the maintenance employees of a textile industry manufacturing 80 ton of yarn per day. The short definition of this approach and technical information used to give the different scores is explained in the forthcoming sections.

4.1Possibility of failure (O)

This is attached with the repetition with which a mode of failure happens; greater amount represents greater importance of the item. Chance of happening of the failure was assessed as an action of median time between failures (MTBF). The input obtained for MTBF of parts from logbooks, past historical records and is then unified with the experience of maintenance staff.

Table 1 Scores for Possibility of Failure

Happening	MTBF	Score
Almost never	More than 3 years	1
Rare	2 to 3 years	2
Very less	1 to 2 years	3
Less	¾ to 1 years	4
Medium	6 to 9 months	5
Slightly huge	4 to 6 months	6
Huge	2 to 4 months	7
Very huge	1 to 2 months	8
Intensely huge	Less than 30 days	9

4.1.1 Non-observation of Failures (D)

The possibility of observing a mechanism or matter of failure rely upon different factors, e.g. capability of maintenance personnel or machine operator to observe failure, with the help of machine demonstrative aids such as sensors, automated controls and alarms, or by periodical inspection or by naked eye.

Table 2 Non-observation Failures Scores

455200Possibility of Non-observation (%)	Attributes for non-observation of failures	Score
Less than 10	Intensively less	1
10 to 20	Very less	2
21 to 30	Less	3
31 to 40	Fair	4
41 to 50	Medium	5
51 to 60	Slightly huge	6
61 to 70	Huge	7
71 to 80	Very huge	8
More than 80	Intensively huge	9

V. Maintainability (M)

Maintainability means the easiness at which specific component is returned back to its functional condition. Lesser value represents that it is difficult to put the item back to the operational state within assigned time frame, so greater possibility of higher down time. Thus, criticality for maintenance increased with lowering the value of maintainability. As a result, various scores for maintainability index are discovered with separate criticality degree of maintenance.

Table 3 Maintainability Scores

Attribute	Maintainability	Score
M_t more than 0.8	Approximately certain	1
$0.7< M_t \leq 0.8$	Very huge	2
$0.6< M_t \leq 0.7$	Huge	3
$0.5< M_t \leq 0.6$	Slightly huge	4
$0.4< M_t \leq 0.5$	Medium	5
$0.3< M_t \leq 0.4$	Less	6
$0.2< M_t \leq 0.3$	Very less	7
$0.1< M_t \leq 0.2$	Moderate	8
$M_t<0.1$	Intensively less	9

5.1 Spare Parts (SP)

Many unused parts are needed for maintenance of machines. The chance or non availability of these spare parts will have significant impact to define maintenance importance of various parts of machines. After taking into account the significance of spare parts of machine, an arrangement is evolved for giving the priority scores. For this, parts are categorized as desirable, essential and vital, that are additionally grouped as scarce, difficult, and easily available. The scores given to their bilateral consolidation are given in Table 4.

Table 4 Scoring Criteria for Spare Parts

Criticality	Availability		
	Easy	Difficult	Scarce
Desirable	1	4	7
Essential	2	5	8
Vital	3	6	9

5.1.1 Economic Safety (ES)

This term is mentioned to equipment, safety and personnel of structure in the matter of a mode of failure. Scores are given, regarding the performance of the parts. High scores are assigned to the mechanisms with greater number of movable parts, because movable parts are more liable to mis-happenings. Table 3.5 shows the arrangement for giving the scores for economic safety loss.

Table 5 Scores for Economic Safety Loss

Attribute for economic price	Score
Intensively less	1
Very less	2
Less	3
Fair	4
Medium	5
Slightly huge	6
Huge	7
Very huge	8
Intensively huge	9

5.1.2 Economic Price (EP)

The calculation of economic price of a mode of failure in machine is a difficult task. Therefore, scores are given regarding the subjective judgment of maintenance personnel. The various features taken into account for attaining a table of scores on the basis of linguistic assessment are maintenance staff, price of spare parts and manufacturing loss etc. The scoring method for economic cost is given in Table 6.

Table 6 Scores of Economic Price

Attribute for economic price	Score
Intensively less	1
Very less	2
Less	3
Fair	4
Medium	5
Slightly huge	6
Huge	7
Very huge	8
Intensively huge	9

This suggested approach is shown here with a case study performed in a textile industry (Nahar Fibres, Jitwal Kalan,

Table 7 Scores Given to Modes of Failure of Ring Frame Machine

Main Parts	Probable modes of Failure	Probable Effect of Failure	Probable reasons of failure	O	D	M	SP	ES	EP
Delay	Quality	High twist/	Clutch shaft miss (D1)	1	9	3	5	3	5
Drafting	Effected	Production loss	Bearing broken 6206 (D2)	2	5	9	1	3	4
			S-4 solenoid valve miss (D3)	9	9	2	2	2	5
Additional	Ratchet free	Yarn thin or thick	Ratchet free (D4)	1	3	1	1	3	8 7
Drive			Piston air leak (D5)	3	3	5	4	3	8 9
			20T spur gear cut (D6)	1	7	3	1	5	
			35T gear cut (D7)	1	4	6	2	5	
Motor	Speed low	Machine stop/production loss	Mechanical failure (D8)	4	4	3	5	9	3
Variator			Motor variator piston leakage (D9)	5	8	3	2	3	2

Sangrur). There are many stages for producing yarn in the case company such as blow room, carding, preparatory, ring frame, winding and packing of yarn. The present analysis is established on the maintenance study of a ring frame machine, which is one of the major and highest significant operational stage of the textile industry. The function of the ring frame machine is to make yarn from spinning fibers, such as cotton, flax or wool. The probable modes of failure of the ring frame, their reasons and impact on performance of the system are discovered through the root cause analysis (RCA). The assigning of numeral scores to different identified reasons of failures is done as per the scoring method deliberate in the previous portion (Table 7).

VI. CALCULATION OF CRITERIA WEIGHTS BY SHANNON'S ENTROPY METHOD

In this section, criteria weights are computed with the help of Shannon's entropy method. All calculations were performed in MS Excel spreadsheet. In the first step, scores given to factors are normalized by Equation 1. The Normalized matrix is displayed below as in Table 8.

Table 8 Normalized Decision Matrix

Failure Cause	O	D	M	SP	ES	EP
D1	0.0370	0.0192	0.0286	0.0435	0.0278	0.0196
D2	0.0741	0.0962	0.2571	0.0435	0.0833	0.0784
D3	0.3333	0.1731	0.0571	0.0870	0.0556	0.0980
D4	0.0370	0.0577	0.0286	0.0435	0.0833	0.1569
D5	0.1111	0.0577	0.1429	0.1739	0.0833	0.1373
D6	0.0370	0.1346	0.0857	0.0435	0.1389	0.1569
D7	0.0370	0.0769	0.1714	0.0870	0.1389	0.1765
D8	0.1481	0.0769	0.0857	0.2174	0.2500	0.0588
D9	0.1852	0.1538	0.0857	0.0870	0.0833	0.0392

Then in the second step, entropy values for each criterion are computed using Eq.2, that are shown in Table 9.

Table 9 Entropy Values for Each Criterion

e_1	e_2	e_3	e_4	e_5	e_6
0.8586	0.8585	0.8774	0.8275	0.9026	0.8910

In the third step, objective weights $w_j$is determined using Equ. 3 and displayed below in table 10.

Table 10 Criteria Weights

	w_2	w_3	w_4	w_5	w_6
0.1803	0.1804	0.1562	0.2199	0.1241	0.1389

The alternative ranking is generated using Eq. 6 and shown below in Table 11.

Table 11 SAW Scores and Final Ranking

Failure Cause	Score	Rank
D1	0.5538	5
D2	0.6775	2
D3	0.4283	8
D4	0.5538	4
D5	0.3431	9
D6	0.6964	1
D7	0.5745	3
D8	0.4381	7
D9	0.53879	6

In accordance with SAW scores as shown in Table 11, most critical cause of failure is D6.

VII. CONCLUSION

SAW score and ranking of various causes of failure for ring frame machine, used in textile industry for making yarn from spinning fibers. From above calculation D6 (20 T spur gear cut) is on one rank and most critical cause of failure of machine.

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