

Risk Analysis of a Process Plant Using Fuzzy Decision Making Tool

Saurabh Jha P¹, Mohd Salman Khan¹M.Tech Scholar, Department of Mechanical and Automation Engineering, Amity University, Noida, U.P, India¹

ABSTRACT: This paper attempts to analyse the risk involved in the components of an industrial system. Risk is a factor that affects the system performance, operations, cycle time, availability and also the reputation and demand of the product. The study has employed various methods to identify the potential failure causes in the system such as root cause analysis (RCA), risk priority number (RPN) and failure mode effect analysis (FMEA). These methods establish obscure failures which provides a scope for further work. Hence, fuzzy decision making tool technique is applied to interpret the risky component that calls for thorough attention of the sub systems in a process plant

KEYWORDS: Root Cause Analysis, Risk Priority Number, Failure Mode Effect Analysis, IF-THEN Rule

I. INTRODUCTION

Every organization's prime motive is to achieve higher productivity with regard to profit. Hence, periodical assessment of all its components are required to be done on a regular basis. Risk analysis is a broad term which deals with analysing the behaviour of the system and their sustainability in future. In order to develop this, Risk priority number of each component is determined and analysed with fuzzy decision tool of if-then rules. These two combined provide a better understanding and provides us with an estimation so that the critical areas can be focused upon which acts as retardation in the way of production. This, in turn will minimize the maintenance cost that occurs from time to time. The root cause analysis provides a platform to define the risk involved and RPN putforths values to these situations. The FMEA charts clearly summarizes the whole scenario of failures and subsequently, fuzzy tool authenticates it by predicting the appropriate amount of failure and the area which needs to be handles immediately.

II. LITERATURE REVIEW

A detailed study has been done on the risk analysis of the system to improve the availability and maintainability on the system using the if-then tool of MATLAB. This area has found its focus in recent years and has gained importance because of its accurate prediction in all the fields. In 2008, Sodiya et.al, analyzed software security risk using fuzzy expert system. The linguistic variables were set for input and output functions in the form of triangular membership functions. Confidentiality, availability and integrity are three most important parameters for a security system. The fuzzy inference editor summaries the whole process and the results are deduced. Knowing the advantage of this, this technique was now being tried on industrial systems. In 2011, Golmohammadi et al., investigated the noise exposure in an industrial area using fuzzy logic approach. Accordingly, the linguistic variables are set at different fuzzy intervals and are shown on graphs. The rules are then evaluated by different sets of input and the output decides the level of noise. This method became so common that even for the prediction for election results this approach was researched as in 2012 by Singh et al. nine inputs in the form of years, popularity, preferences etc. were subjected to one output. Different membership functions were used for input so that the results could be accurate. Mahashwari and Asthana in 2013 utilized this tool to test image enhancement. The pixel intensity of the image was varied and in order to determine the output that is being showcased. From the results, the enhanced image was better when compared to the original. This shows the authenticity of this fuzzy tool. This tool was then used to analyze the risk possesses by patient it was applied to determine the various problems and its severity by Mayilvagan and Rajeshwari in 2014. The triangular

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membership function of blood pressure is applied by sugeno fuzzy model. Logic gate also clearly defined the relation between the parameters and defuzzification is performed. The 250 rules plotted as far as the patient's life is considered are deduced and the surface plot is generated which processed the risk factor. khalegi et al., in 2014 assessed the risk management of a pipelines. A schematic overview represented the damage and its potential problems. Three different types of general structures for fuzzification and defuzzification were sketched to understand the process flow. Later on, in 2015 Khalifa et al., did a risk assessment of mined areas using fuzzy if then rule by varying the signal strength and location in that area. This rule based system was not only research upon industrial systems but also the workers related to it in 2015 by Jariwala and Christian. Various personal factors of the workers working in a solid waste are taken in triangular membership function and defuzification was performed. These data were collected by questionnaire to have the appropriate prediction. In 2016, Dorskocil evaluated the total project risk by using triangular, trapezoidal and Gaussian membership function in his research. Results revealed the areas of shortcomings, the areas of warning and the supportive areas to focus upon. Recently, in 2016, Panchal and Kumar established a framework for risk analysis using FMEA and fuzzy decision making tool. This is assessed with help of root cause analysis in order to improve system's availability and maintainability characteristics which acts as an elaborate qualitative analysis for listing the various failures. Severity, occurrence and non-detection are assessed as far as the machine's risk is concerned and the results revealed the most critical components in its own category.

Thus, after having a brief knowledge about fuzzy decision making tool using if-the analysis, this I applied to the components of a centrifugal pump industry to determine the critical machines and its risk in the near future.

III.METHODOLOGY

A. ROOT CAUSE ANALYSIS: -

Root cause analysis is an analysis which identifies factors that are responsible for fault or low productivity using a structured approach that helps to focus on the problems underlying as stated by Mahto and Kumar in 2008. Uncertainties or odd factors are always attached to any of the working unit and we cannot deny or eliminate it from the system but its effect on the systems parameters can be reduced by analyzing the causes or failures and its effect in the system.

According to Kiran et al., in 2013, RCA is a four-step process

1. Data collection
2. Cause charting
3. Root cause identification
4. Recommendation

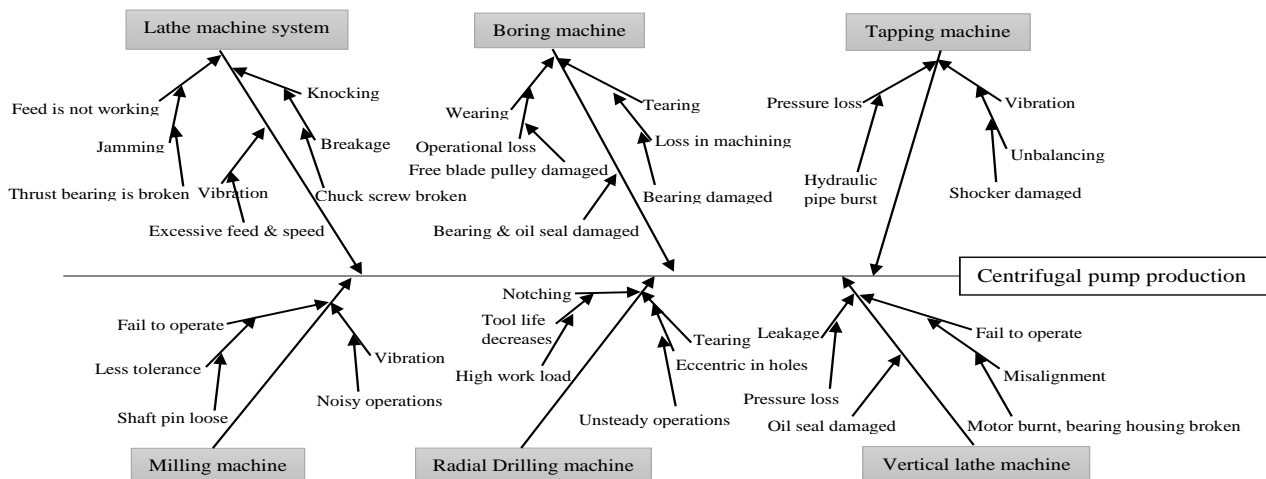


Fig.1.Root cause Analysis

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In the figure 1, the horizontal lines represent the sequential order to evaluate the root cause effect on the production of centrifugal pump system. Whereas the vertical lines represent the various machines in the production system, and sub branch line shows the potential cause of the problem or failure in the system.

B. RISK PRIORITY NUMBER: -

Risk priority number (RPN) is a method to assess the failure which are crucial in a process. Three important parameters namely severity, occurrences and detection are evaluated based on the rating scale. The rating scale can be varied according to the desirable conditions likely to occur for the particular component.

1. Severity (S) is a term which estimates how severe the effect of failure will be to client.
2. Occurrence (O) deals with the failure that is likely to occur during production or in a process.
3. Detection (D) is used to detect or prevent the cause of failure that has happened.

In 2014, sahuo et al., said that RPN is a term which is used for comparing problems within the analysis and subsequently prioritize the problems which will need further action. Linguistic terms are used for ranking and a scale factor from 1 to 10 is employed.

- Severity (S) is measured on a scale from 1 to 10 of each machine to assign the cause effect due to failure. Where 1= Low severity and 10 will be highly severe.
- Occurrence (O) is also calculated on a scale from 1 to 10 and defines the probability at which the defects occur in the root cause of the machine where 1= Not to take in consideration and 10= 100% chance of happening
- Detectability (D) is an approach for indicating the errors or loopholes in the system where 1= Scale defining that attention needs to be paid immediately towards the detected cause and 10= Low detectability means very little errors are detected.
- $RPN = Severity \times Occurrences \times Detection$

High RPN means that attention needs to be diverted towards the detection of error signal. This is done by arranging the RPN in sequential order. It is very important to detect such defects as it might cause severe harms to the system on which we are working.

C.FMEA: -

It is a tool for assessing risk associated with the different ways (modes) in which a part or system can fail, identifies the effect of the system failures, and provide a structure for revising the design or the processing work to mitigate risk where necessary. It provides a method for quantitative analysis of the risk

In 2013, rakesh et al., studied about FMEA analysis and stated that it is a systematic tool for identifying and preventing the problems that occur in a system, thereby increasing its productivity. The factors that are identified by FMEA sheet are potential failure mode, potential effect of failure, potential cause of failure and determines risk priority number. Suresh et al., in 2014, assessed the risk of blast furnace by constructing a flowchart to process FMEA. The review team plays an important role in determining the potential causes of failure and ranking them according to the present situation.

D. FDMS: -

Fuzzy decision making tool provides a platform for analyzing the risks using computer based software that assess the priorities of component which are at a greater risk. In this study, fuzzy If-Then rules are used in which the required set of inputs and outputs are provided and accordingly the fuzzy number are generated for each machine that determines its status of vulnerability. Novak and lehmeck in 2006, studied briefly on the logical structure of If-Then and explained the

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math behind this decision tool. In 201, this tool was applied on a power station by sai and reddy. The results were deduced and subsequently, modification was suggested.

IV. CASE STUDY

The research focuses on the different machines required to manufacture centrifugal pump converts the kinetic energy to hydrodynamic energy. It enables liquid to flow from low pressure to high pressure and a faster rate. It consists of casing (volute, circular), bearing, shaft rod and an impeller. Hence table 1 represents the machines specification of centrifugal plant with all working parameters.

Table.1. Machines specification

Machine	Process	Quantity	Dimensions	Symbol
Lathe machine	Turning, Knurling	3	12inch,12inch,20inch	LM1, LM2, LM3
Vertical boring machine	Boring	2	1200*1200mm,1200*1600mm	VBM4,VBM5
Tapping machine	Threading	1	1 inch	T6
Radial drilling machine	Holes	4	50mm,60mm,60mm,70mm	RDM7,RDM8, RDM9, RDM10
Slotter machine	Facing and threading	1	24inch	SM11
Vertical lathe machine	Keyways	2	6ft,10ft	VLM12, VLM13

V. RISK ANALYSIS

After collecting the data from the company, risk analysis is performed. Risk analysis defines a system's behaviour and how it will function in the near future. These are very much essential to the industry so that they keep up with all the components and know about the status which I turn will be helpful in their overall progress of production.

Table 2. Scale used for the probability of failure

Linguistic terms	Scale/Rank	Occurrence of Failures	Severity	Non-Detection
Very low	1/2	Unlikely	Minimal interference	No chance
Low	3/4	Relatively few	Significant degradation	Remote chance
Moderate	5/6	Occasional	Minor damage	Moderate chance
High	7/8	Repeated	Equipment damage	High chance
Very high	9/10	Unavoidable	Destructive failure	Almost certain

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Table 2 represents the scale determined for each linguistic variable. The parameters associated with machines that are likely to happen in the categories of occurrences, severity and non-detection are defined and accordingly the scale is set. This Table provides an overall view as to how is the variation that is bound to occur in terms of failure.

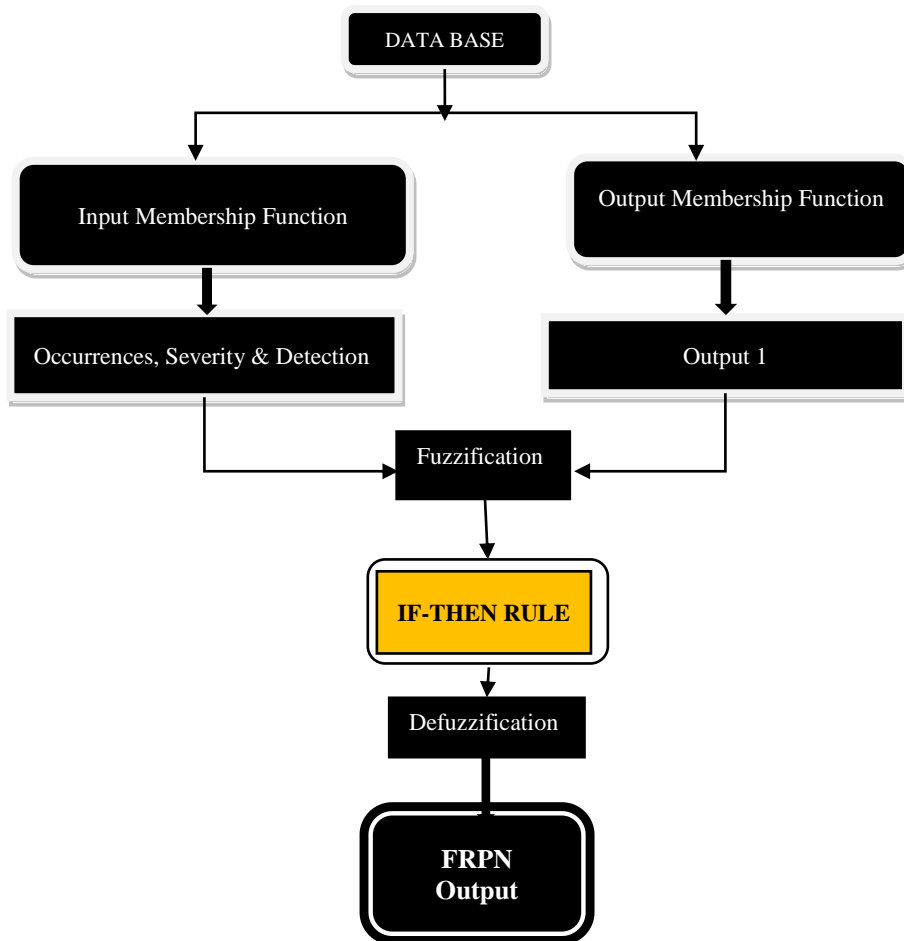


Fig.2 Fuzzy FMEA Flow Chart

A schematic representation of the structure is presented in Fig 2 which defines the flow of methodology. The flow chart is prepared by careful investigation of the sequencing of the work and to have a better understanding in dealing with the objective so that the result can be deduced with much ease and clarity. Therefore, it is a good practice to provide a framework that denotes the work order flow.

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Table 3. FMEA Sheet

Components	Function	Potential failure mode	Potential effect of failure	Potential cause of failure	or	S	Od	RPN
<i>Lathe M/c</i>								
Lathe 001	To perform turning	Feed is not working	Irregular surface	Thrust bearing is broken[L1]	8	8	6	384
Lathe 002	To perform knurling	Knocking	Breakage	Chuck screw broken[L2]	6	7	7	294
Lathe 003	To perform facing	Vibration	Less tolerance	Excessive feed & speed[L3]	5	6	5	150
		Feed is not working	Irregular dimensions	Shaft pin loose [L4]	7	5	8	280
<i>Boring M/c</i>								
Bearing	To sustain the loading	Wearing	Operational loss	Free blade pulley damaged[B1]	4	7	9	252
Gear box	Transmission	Tearing	Loss in machining	Blade sport bearing damaged[B2]	6	8	5	240
		Vibration	High cost losses	Bearing and oil seal damaged[B3]	5	9	6	270
<i>Tapping M/c</i>								
Hydraulic system	To exert pressure	Vibration	Unbalancing	Shocker damage[T1]	4	7	4	112
		Fail to operate	Pressure loss	Hydraulic pipe burst[T2]	3	8	6	144
<i>Drilling M/c</i>								
Multiple point tool	To drill the hole	Tearing	Eccentric in holes	Unsteady operations[D1]	5	8	7	280
		Notching	Tool life decreases	High work load [D2]	7	9	8	504
<i>Vertical Lathe M/c</i>								
Machine Oil pump	To perform work	Fail to operate	Misalignment	Motor burnt of rapid[V1]	3	5	9	135
Gear box	To circulate the oil	Leakage	Pressure loss	Oil seal damaged[V2]	4	6	8	192
Pump motor	Transmission	Vibration,	Locking	Inadequate greasing[V3]	5	8	7	280
	Power to Pump to circulate	Knocking,	Barrier in the continuous working	Improper selection of motor[V4]	3	5	6	90
		Jamming						
Slotter M/c	To make slots on the job	Feed is not working	Fail to impart desired slots on the job	Big helical gear teeth broken[S1]	5	6	4	120

FMEA Sheet is presented in Table 3 which determine RPN according to the scaling done by experts for the potential failures. These are compared with the Fuzzy ranking at a later stage.

Fuzzification is the first step in the fuzzy inference process where the standard (ordinary inputs) are transformed into fuzzy inputs, so that each ordinary (crisp) input has its own group of membership functions or sets to which they are transformed as shown in Fig.3

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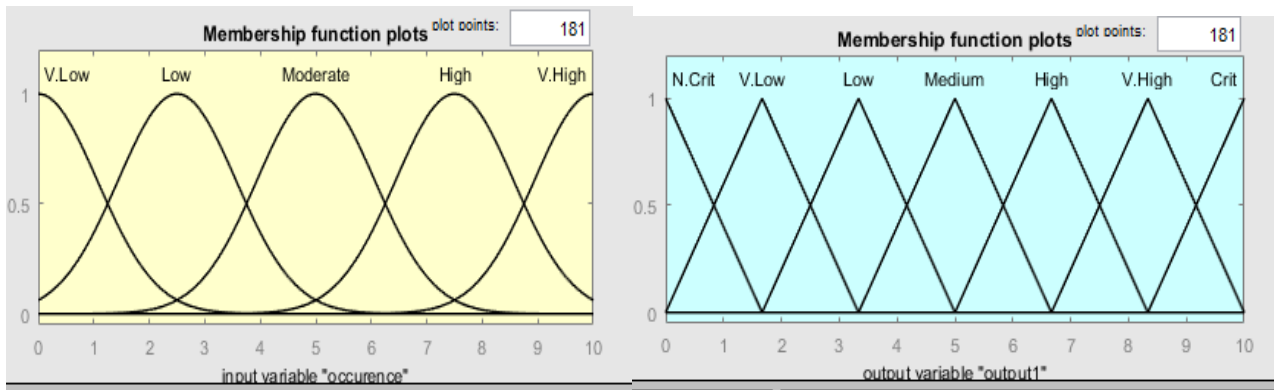


Fig 3. Input and Output Membership Function

The input membership function is divided into five criteria namely very low, low, moderate, high and very high in the Gaussian format whereas the output membership function in the triangular format are segregated into seven categories namely not critical, very low, low, moderate, high, very high, and critical.

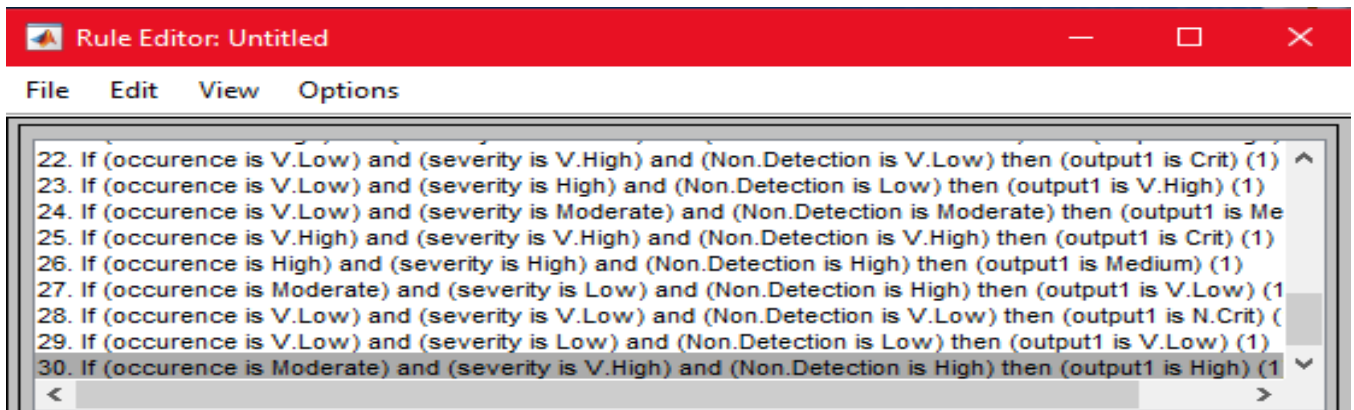


Fig.4 Conditions of IF-THEN Rule

Once the fuzzification is done, the next step is to define a set of rules in which the fuzzified inputs and the outputs are subjected to IF-THEN rules in MATLAB as shown in fig.4. Fuzzy rule and fuzzy reasoning are the most important modelling tool based on fuzzy set theory where are considered the backbone of fuzzy inference systems. These rules can be in any number and it depends upon the needs and requirement to demined the failure. A system that is almost in a dead state needs to have more set of set to determined its functionality. In this, a combination of occurrence, severity and Non-detection are varied with the output for different conditions in order to cover all the possible scenarios for a machine that can be in a vulnerable state.

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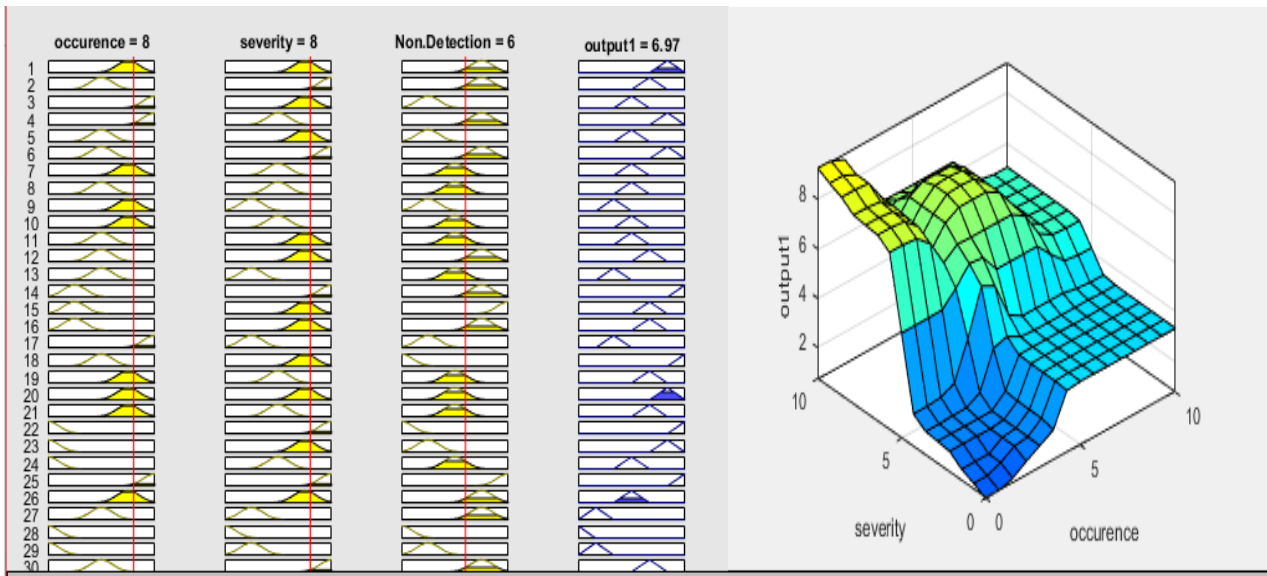


Fig.5 FRPN Output & Surface plot for potential cause L1

The Fuzzy Ranking Priority Number (FRPN) is obtained for all the machines along with the surface plot. Fig 5 Show the FRPN output for Lathe machine (L1) and also its surface plot. The red marking denotes the position of that of each parameter indicating the scaling value.

V.ANALYSIS OF RESULT

Component codes	FRPN Outputs	Fuzzy Ranking	RPN Output	RPN Ranking
L1	6.97	1	384	1
L2	6.67	2	294	2
L3	5.38	3	150	4
L4	5.02	4	280	3
B1	6.72	1	252	2
B2	6.36	3	240	3
B3	6.68	2	240	1
T1	5.03	2	112	2
T2	6.73	1	144	1
D1	6.68	1	280	2
D2	6.67	2	504	1
V1	4.17	4	135	3
V2	6.54	2	192	2
V3	6.68	1	280	1
V4	4.52	3	90	4
S1	5.38	1	120	1

Table 4. Comparison between FMEA and FRPN Ranking

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FRPN Output obtained from simulation is ranked which detects the critical system in its own category and similarly RPN output is also evaluated from the FMEA sheet. A comparison is drawn between these two methodologies which shows the dynamic behaviour of the failure pattern as shown in Table.4. The machine L1 stands for a higher rank and thus more focus should be set on this machine for its better function. Similarly, in each section the rank decides the critical system.

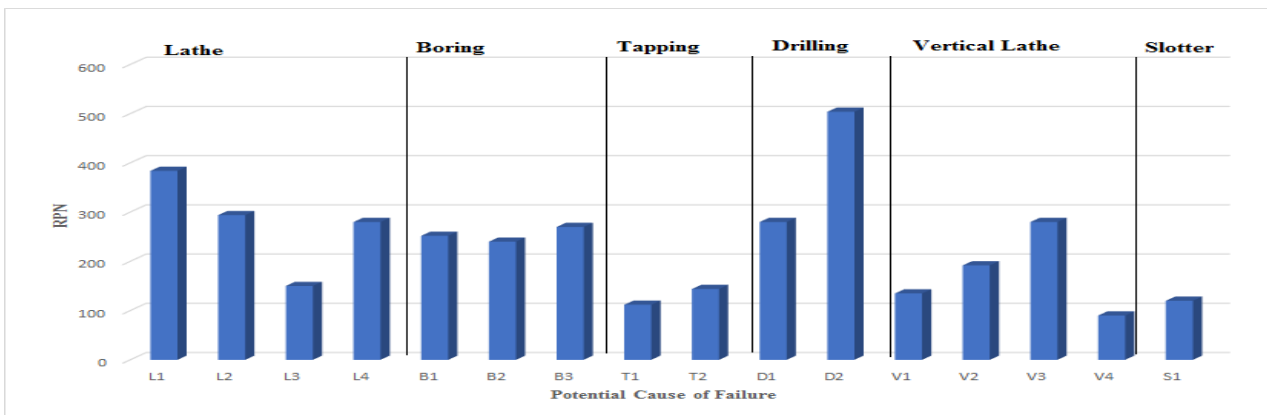


Fig 6. Graphical representation of RPN

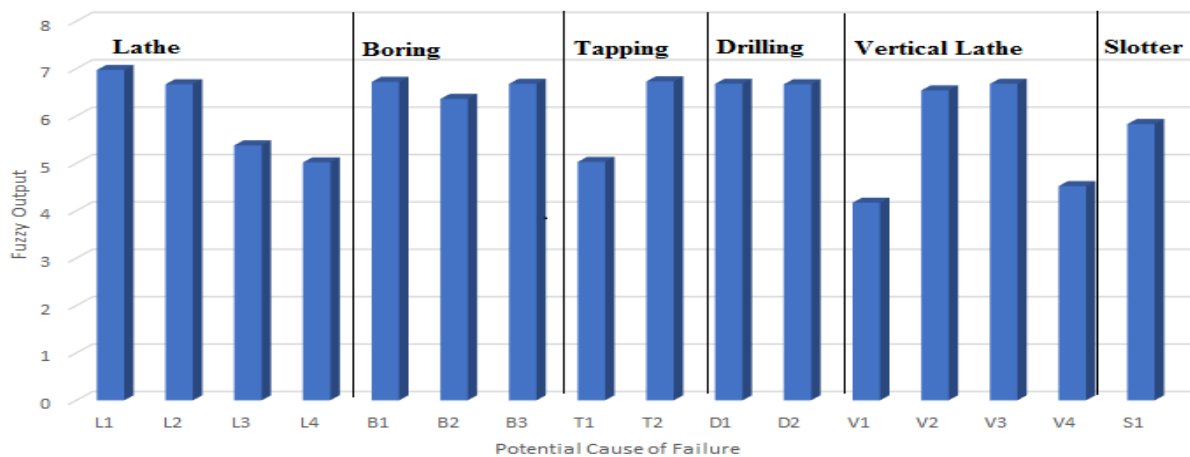


Fig 7. Graphical representation of Fuzzy ranking

The graphical representation in fig 6 and 7 denotes the height of RPN and Fuzzy output corresponding to each component. The demarcation line separates each category in order to clearly differentiate the most critical machine that has to be focussed upon immediately. The comparison denotes slight variation in both ranking and thus the maintenance engineer has to study them and act according to the needs of the production plant.

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VI. CONCLUSION

The term risk is a fact that cannot be completely eliminated from the system but can be measured and minimized. The present work is a risk analysis of centrifugal pump industry with in depth analysis for determining the failures occurring in the system. The comparison between FMEA and FRPN showcases the components with higher ranking that are to be dealt with utmost care and therefore careful investigation has to be followed for these components in all the areas. These results will be helpful to the system analyst to analyse the behaviour of the system and to plan an appropriate maintenance policy for improving the system performance. This effort will lead to an increase in efficiency and proper maintainability of the sub-systems which will be beneficial to the entire production line.

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