A frame work for Reliability Analysis of Mechanical Systems in a Manufacturing Industry

M.Srinivasa Rao

Abstract: ***The Paper will be produced in any paper industry with the help of various machinery & equipments. Several components of these undergo repairs and failures during production process with time. Therefore it is required to analyze the reliability of these components w.r.t time. In this work, Reliability analysis of all the systems of the industry have been performed. The existing maintenance policies of this industry are also studied. Reliability analysis has been performed in this work by using statistical methods and identified that feasible results can be obtained through Weibull analysis. In addition to this, a user friendly software has been developed for making ease to reliability analysis. This work is a helping agent for working professionals in process industries.***

Key words: FMEA, Mechanical systems, Statistical method, Reliability analysis.

I. INTRODUCTION

In recent past, the organizations identified that the quality consciousness alone would not guarantee sustained business growth and started exploring the lean concepts [1]. Lean practices are not identical among the enterprises which are performing these principles [2]. Pettersen [3] described that lean production implementation in organizations has not explored fully in the literature. Thanki and Thakkar observed that due to the improper tackling of human related issues, the status of lean implementation and awareness in Indian industries was not so encouraging [4]. Technologies used in operations and implemented lean practices are not coinciding each other in practical [5]. Saurin et al [6] shown the use of lean production practices in poductio processes. Empirical research is very much useful in analyzing the data in implementing lean practices [7]. Lean research and its implementation in supply chains are the main focus of Indian automotive industry [8]. Performing High quality and reliability processes in a production industry can give reliable products as outputs [9]. Quality and reliability assurance activities must be implemented in production process. This challenge has been faced by manufacturing enterprises [10]. The results of quality deviations observed while production and used parametric and non parametric reliability analysis process [11.

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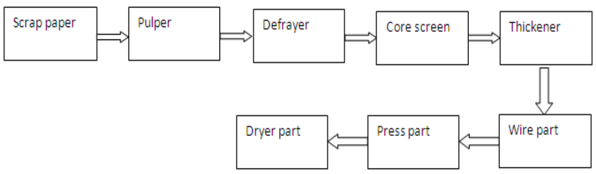
Reliability assessment and assurance activities are vital elements in manufacturing enterprises [12].Arab and Feng examined that reliability assurance activities must be performed at system level [13]. In design process or in production stage of any product, the effect of uncertain factors must not be neglected [14]. Due to the increased complexity in modern systems, the fault diagnosis of these systems has become challenging task [15]. Reliability is an important phase in durable system designs, specifically in the early phase of the product development [16]. From the literature, it is found that reliability based quantitative analysis has not performed for practical use in production processes. Therefore this paper aims to introducing such a model and its applications in a paper industry. The plan of the work is as follows. Section II presents the technical details of the paper industry. Section III proposes Failure mode and effects analysis for a paper manufacturing enterprise. Section IV describes Reliability Modelling and Analysis of a Paper Industry. Section V concludes the paper.

II. INTRODUCTION TO PAPER INDUSTRY

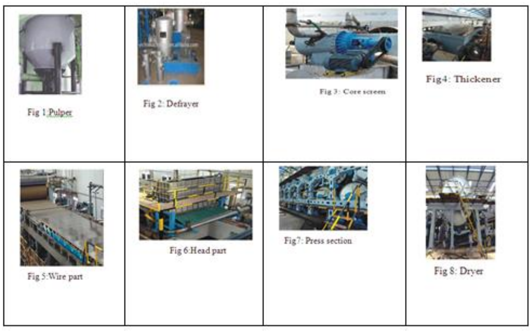
In this work a paper industry has been taken as a case study for its Reliability analysis. The organization process chart has incorporated as follows.

Organization Process Chart:



A. Machinery in the Industry:

This paper industry consists of the following machines:



Pulper

It chops the paper into small pieces and after heated it converts into a mushy mixture called pulp.

Defrayer:

Defrayer is used for final crushing of pulp into small particles which is coming pulper. Heating the mixture breaks the paper down more quickly into small pieces, and it turned into pulp. The main components of Defrayer are rotor blades, bearings gears etc.

Core screen:

The core screens removes small contaminants such as bits of plastics, glass of glue and tiny iron pieces and other light particles through Center Nozzle and Fiber passes through drilled screen.

Thickener:

Thickener is used to Thickening the pulp, our range provides consistent operations with maximum operating speed. The main function of thickener is to remove the water from pulper by dehydration process. The main components of thickener are gears, belts, bearings and rollers etc.

Wire part:

The function of the wire part is to mix the water and chemicals to pulp to make the paper. After mixed , it goes to the head box fallowed by a screen where the water will be dried and gives the watery sheet of paper.

Dryer part:

Paper Machine Dryers which are available in the boiler quality plates and provided with heavy duty graded cast iron and mild steel frame which offers maximum coverage of paper under dryer. The main components are shafts, chain drives, pulleys rollers etc.

Press section:

In this section, the paper will getting dry by the pressure of rollers when it passes through them.

At the end, the finished paper is wound into a giant roll and removed from the paper machine and made products such as envelopes, paper bags, or boxes. The main components are roller and ball bearings, gears, shaft etc.

III. III. INTRODUCTION TO FAILURE MODE EFFECTS AND ANALYSIS

Failure mode and effect analysis (FMEA) is a bottom up, qualitative dependability analysis method, which is particularly suited to the study of material, component and equipment failures and their effects on the next higher functional system level. This method is used to the analysis of systems of different technologies like electrical, mechanical, hydraulic, software, etc. with simple functional structures.

A. *Failure Effect Ranking*

In this process, the failure effects are grouped in to levels and then be ranked based on effects of various parameters as fallows.

Level C: probability of occurrence is rare.

Level B: probability of occurrence is medium.

Level A: probability of occurrence is more.

Risk priority number (RPN): It is a numerical assessment assigned to a process or step in a process as a part of FMEA. This is computed using the probabilities of the occurrence, severity, Non detection of the failure mode.

RPN = O*S*D

A. FMEA for Pulper: Pulper is used to maceration of waste paper.main part of pulper are bearings,gears,conveyor belts etc. FMEA results are shown inTable 1.

Table 1: FMEA for Pulper

S.No	Failure mode	Level of probability occurrence	Failure cause	Failure effect	Remedies
1	Bearing failure	C	Excessive functioning	Production stops	Proper maintenance of lubrication
2	Conveyor belt failure	B	More load	Machine stops	Replacement
3	Gear and pinion trouble	C	Continuous working	Alignment problems	Replacement
4	Failure of crushing blades	A	Over load	Paper maceration problems	Less maintenance of load

After conducting the FMEA for pulper, it is found that the main causes to failure of pulper are failure of crushing blades. Similar FMEA analysis for all the remaining machines of the industry has been performed and the results obtained as follows.

B. Results from FMEA:

After conducting FMEA analysis, the following failure modes have been found as critical and needs immediate action:

- In crushing department, major critical problem has been found to be pulper breakdown which occurs as a result of material overload which effects in machine breakdown and the remedy for this problem is restricting the flow of material.
- In screening department primary and secondary core screen are the major problems, which occur due to breakage of bearings as results production stops remedy retains proper maintenance of load and lubrication.
- In Thickener machine, major critical problem has been found to be Roll Former problems which effects in uneven material flow in the machine and also improper functioning of the machine. The cause for this problem is gear box problem and remedy retains in proper lubricating the machine and proper maintenance.

IV. RELIABILITY MODELLING AND ANALYSIS OF A PAPER INDUSTRY

A. Reliability analysis using empirical method:

Model Calculations:

As per the empirical method, the following empirical equations have been used to calculate various parameters for reliability analysis of the Paper Industry.

Sample calculations for the Spreader machine have been conducted using the following formulae:

Reliability $R(ti) = n_i/n$

Failure density $f(t) = (n_i - n_i +1)/(t_i+1-t_i).n$

Hazard Rate $\lambda(t) = f(t)/R(t) = (n_i - n_i +1)/(t_i +1- t_i).\ n_i$

Where n_i =no.of. secured units, n = no.of units considered

Reliability = n_i /n = 17/20 = 0.85

Failure density = $(n_i - n_i +1)/(t_i+1-t_i).n$ = (17-12)/(18-12).20 = 0.0417

Hazard rate = f(t)/R(t) = 0.042 /0.85 = 0.049

Pulper: Reliability analysis

Table 2. Reliability analysis for pulper machine

Time (Months)	Number of failures	Number of survivals	Reliability	Failure density	Hazard rate
6	0	20	1	0.025	0.025
12	13	17	0.85	0.042	0.049
18	15	12	0.6	0.067	0.111
24	18	4	0.2	-----	-----

After calculation of Reliability, Failure density f(t) and hazard rate for pulper, the obtained results are plotted as follows.

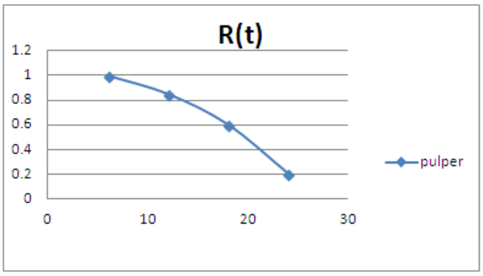


Fig.1: Reliability graph for pulper

From Fig.1, it can be found that Reliability for pulper is decreases as the time increases.

Failure rate (Hazard rate) **analysis:**

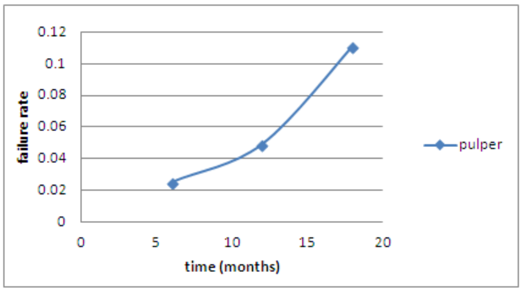


Fig.2: Hazard rate graph for Pulper

From the Fig.2 it is found that the failure rates are increases as the time increases.

Failure density analysis:

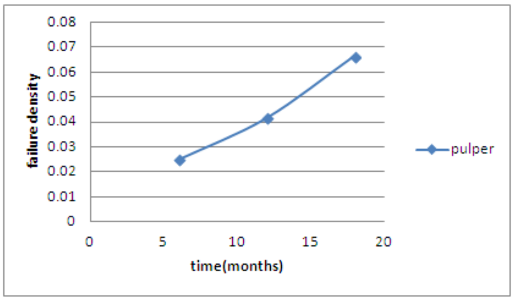


Fig.3: Failure density graph for pulper

Fig.3 shows the variation of failure density with respect to time.

The similar Empirical calculations have been performed for all other machines of the paper industry. After that as per their relation with other machines according to the reliability block diagram of the industry, the system reliability has been calculated as explained below.

B. Parametric Reliability analysis:

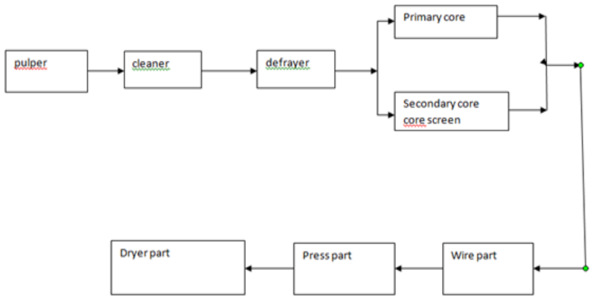


Fig.4 Reliability Block Diagram for paper processing industry

As per the Fig 1, it can be said that all machines are in series in this paper industry.

The total Reliability is calculated as follows:

R(s)=R1R2R3R4R5R6R7=0.817*0.88*.908*0.783*0.8611*0.844=0.314

C. Reliability analysis using parametric method:

Pulper:

An available statistical software has been used for two years data and found that Weibull distribution has been fitted (Fig.5).

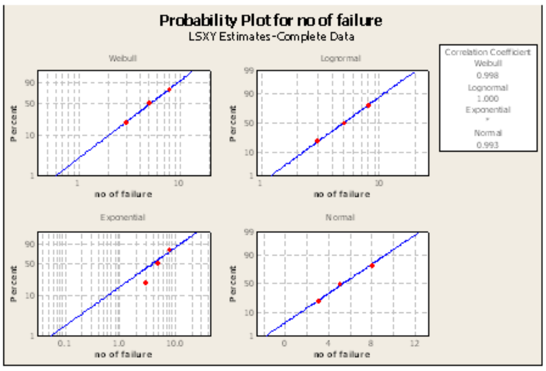


Fig.5: Probability Distribution fitting curve for pulper

Table 3: Reliability of pulper using parametric method

Time	Number of failures	Reliability	Failure rate	f(t)
6	0	1	0	0
12	3	0.788938	0.156	0.123
18	5	0.522424	0.256	0.133
24	8	0.193852	0.404	0.078

By using the obtained results the graphs have been plotted for reliability, failure rate and probability distribution with respect to time.

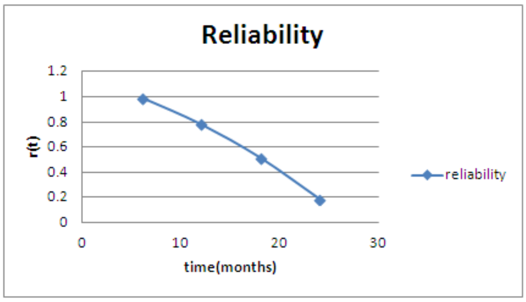


Fig.6: Reliability Graph for pulper using Parametric method

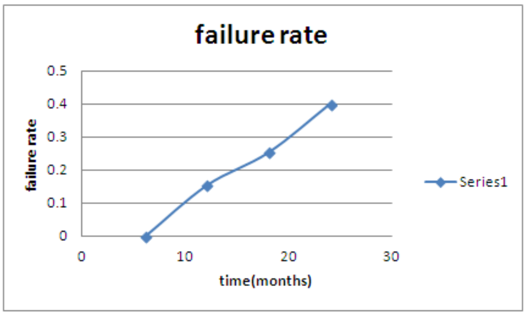


Fig.7: Failure rate Graph for pulper using parametric method

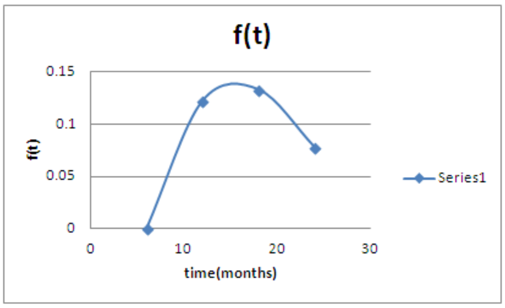


Fig.8: F(t) Graph for pulper using Parametric method

The System Reliability is calculated as follows:
For pulper :R(1)= 0.770454
For core screen:R(2)=1-(1- 0.914275)^2= 0.992651
For defrayer:R(3)= 0.754284
For thickener:R(4)= 0.883569
For wire part:R(5)= 0.893389
For press part:R(6)= 0.751785
For dryer part :R(7)= 0.897708
Total system reliability R(s)= R(1)R(2)R(3)R(4)R(5)R(6)R(7)= 0.342336

D. Comparative analysis between empirical and parametric methods:

In this work a comparative analysis have been performed between empirical method and parametric method to identify which method is best suitable and all the machines reliabilities which are calculated as earlier are shown below.

Table 4: Reliability comparative analysis

S.No	Name of the Machine	Reliability by Empirical Method	Reliability by Parametric Method
1	Pulper	0.663	0.770
2	Core screen	0.543	0.754
3	Defrayer	0.785	0.914
4	Thickener	0.625	0.883
5	Wire part	0.725	0.893
6	Press part	0.708	0.751
7	Dryer part	0.733	0.897

Table 5: Failure rate comparative analysis

S.No	Name of the Machine	Failure rate by Empirical Method	Failure rate by Parametric method
1	Pulper	0.061	0.204
2	Core screen	0.027	0.205
3	Defrayer	0.094	0.192
4	Thickener	0.068	0.287
5	Wire part	0.049	0.339
6	Press part	0.054	0.229
7	Dryer part	0.042	0.424

Table 6: Pdf comparative analysis

S.No	Name of the Machine	f(t) by Empirical Method	f(t) by Parametric Method
1	Pulper	0.061	0.083
2	Core screen	0.027	0.078
3	Defrayer	0.094	0.083
4	Thickener	0.068	0.104
5	Wire part	0.049	0.105
6	Press part	0.054	0.107
7	Dryer part	0.042	0.215

Table 7: System Reliability

Reliability Analysis	System Reliability
Using Empirical method	0.314
Using parametric method	0.343

After observing the above graphs for reliability analysis, the weibull method is best suitable.
Model HTML code used for this analysis has been given as follows.

E. HTML code for machines of the paper industry:

```
<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8" />
<title>machines</title>
<link rel="stylesheet" type="text/css" href="style.css" media="all" />
</head>
<body>
  <div id="header">   <div id="logo">
        <a href="index.html"><img src="images/logo.jpg" alt="" /></a>  </div><ul><li><a href="index.html"><span>home</span></a></li>
        <li><a href="about.html"><span>Overview</span></a></li>
        <li><a href="services.html"><span>process</span></a></li>
        <li class="selected"><a href="products.html"><span>machines</span></a></li>
        <li><a href="contact.html"><span>reliability</span></a></l  </ul>
  </div> <div id="body"><div class="products">
  <h1>machines</h1><div><h2>machinary in paper industry are as follows:</h2>
  <img src="images/m.jpg" alt="" />
<img src="images/over.jpg" alt="" />
<h2>click on machine </h2>
<ul>
<li><h3><a href="pulper.html">pulper</h3></li>
<li><h3><a href="screen.html">screen</h3></li>
<li><h3><a href="defrayer.html">defrayer</h3></li>
<li><h3><a href="thickener.html">thickener</h3></li>
<li><h3><a href="wire part.html">wire part</h3></li>
<li><h3><a href="press part.html">press part</h3></li>
<li><h3><a href="dryer part.html">dryer part</h3></li>
  </ul>
</div><div></div></div></div>   </body>
</html>
```

V. CONCLUDING REMARKS

In this work, Reliability analysis of all the systems of a paper industry have been performed using statistical methods. It is found that Weibull method can give better results. Most critical system in the industry has been identified though FMEA analysis. A software has been developed to make ease to reliability analysis. This work can be treated as a helping agent for working professionals in process industries.

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