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Reliability Centered Maintenance of a Ply Industry : A Case Study

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***Abstract*— Reliability centered maintenance (RCM) is a corporate level maintenance strategy that is implemented to optimize the maintenance program of a company. The final result of an RCM program is the maintenance strategies that should be implemented on each of the assets of the company. The maintenance strategies are optimized so that the functionality of the plant is the main trained using cost effective maintenance techniques. To get maximum reliability and availability achieved by minimizing the possibility of system or component failure is the focus of Reliability Centered Maintenance with this maintenance strategy the function of equipment is considered and possible failure modes and their causes are indentified. Maintenance techniques that are cost effective in minimizing the possibility of failure are then determined. RCM can be conducted and implemented in many ways one way can be based on rigorous FMEA and FMECA, complete with mathematically calculated probabilities of failure based on design or historical data, intuition or common-sense and/or experimental data and modeling, such approaches may be called classical or rigorous RCM. Other way may use more of CBM, Pm optimization and some FMEA and RCA but less of analysis and calculations and such approach are generally called streamlined RCM. This case studies has been done on Durga Ply Mills, which is situated at Purnea District in the state of Bihar. This is a field application of the development of a Reliability Centered Maintenance Strategy for ply manufacturing industry.**

Keywords*— *Reliability centered maintenanc, optimized, failure, FMEA, FMECA.

I. PROBLEM IDENTIFICATION

All the industries pay a huge amount of money and time for the plant maintenance purpose. This money is basically used for setup, equipment spare parts change, labour chrge. Also there is tiem required to restore back the system to its originsal condition. Huge time is consumed for this purpose and company has got some production losss to restrre back the system to its original position in that time. Therefore maintenance department has an important role to maintain plants and equipments at its maximum oprationg efficiency, reducting downtimes and ensuring operational safety, safeguard inventment by minimizing rate of deterioratin and achieveing this at optimum cost through budgeting and controls. With the help of Reliability centered maintenance methodilogy, reliability of each and every equipment and instrument can be found some serious questions like “what are the majour causes of failure or fault and how easily they can be rectified?” are to be answered using RCM methodology. The reliability prediction of ply manufactureing plant has become faithful to focus on the components having more failure frequencies and to be taken care of. RCM methodology will reduce the chances of failure of the equipment.

II. MAINTANABILITY & RELIABILITY CENTERED MAINTENANCE

Introduction

Reliability is the ability of a system or component to perform its required functions under stated conditions for a specified period of time reliabiity engineering is a sub discipline within system engineering reliability is often measured as probablity of failure frequency of failures or in terms of availability a probability derived from reliability and maintainbility.

Maintenance

The definittion often stated maintenance as an activity carried out for any equipment to ensure its reliability to perform its function. Mintenance to most people is any activity crarried out on an asset in order to ensure that the assset continues to perfrorm its intended functions or to repair any equipment that has failed or to keep the equipment running or to restrore to its favourable operating condition. Over the years, the new strategies have been implemented as maintenance strategies which are intended to overcome the problems which are related to equipment berakdown.

Inspection

Inspection are used in order to uncover the hidden failures. In general, no maintenance action is performed on the component during an inspection unless the component is found failed, in which case a corrective maintenance aciton is initialed. However there might be cases where a partial restoration of the inspected item would be performed during an inspection for example, when checking the motor oil in a car between scheduled oil changes, one might occasionalilly and some oil in order to deep in at a constant level.

Maintainability

Like reliability it has its own unique and diverstified elements. It is a characteristics of the design and installation of a complex system. The time taken to repair a system depends on how it has been designed. Further the design and installation characteristics will also dictate the

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maintenance policies. On the other hand it is possible to define some of the maintenance policies in advance and take design decision accordingly. The process of designing involves decision regarding module size, test procedures, built-in redundancies, and degree of automation, inspection intervals, special test equipments and safety requirements and so on. The maintenance policy will cover issues regarding general repairs, repair or discard policies, emergency recorder policies, inventory control, provisioning of spare etc. The technician requirements involve education, experience, training, capability analysis etc. Therefore the definition of maintnability is the probability that a unit or a system will be respored to specified conditons within a given period when maintainbility actionis taken in accordance with prescribed procedures and resoueces. It is characteristic of the design and installation of the unit or system since maintainbility also is a probabiity in the same way a reliability, its value lies between zero to one.

Availability

Abailability is a performance criterion for repairable systems that accounts for both the reliability and maintaninbility properties of a component or system it is defined as the propbability that the system is operating properly when it is requested for use. That is availablity is the probability that a system is not failed or undrgoing repair action when it needs to be used.

Down Time

When a system is often unavaibale due to breakdown and is put back into operation after each breakdown with proper repairs, the meantime between breakdown was defined as the meantime between failures (MTBF). If we consider only the active repair time i.e, the time spent for actual repair, the menatime to repair (MTTR) is the statistical mean time for active repair. It is the total active repair time furing a given period divided by the number of malfunctions during the same interval, frequently, a system may become unavailable on account of periodic inspections and not because of breakdowns. The main difference betweeen MTBF and MTBM is perventive maintenance down time.

Reliability Centered Maintenance

RCM's roots trace back to the 1960s when it was advanced to improve the safety and reliability of commercial aircraft. Since then it has begun to move into the industrial sector as a result of work conducted by severeal authors. RCM is a procedure for determining maintenance strategies based on reliability techniques and encompasses condition monitoring and well known analysis methods such as Failure Mode Effects and Criticality Analysis (FMECA). The primary objective of the RCM process is to identify ways to avoid or reduce the consequences fo failure which if allowed to occur will adversely impact personned safety environment health , mission accomplishement or enconomics. It is the ptimum mix of reactive preventtive predictive and proactive maintenance practices. It involves some design/redesign and redundancy also.

Table 1. RCM Application

Maintenance Strategy	Action Required	RCM Based Application
Run to Failure (Reactive)	Repair or replace upon Failure	Non-critical and small items; Cost to control or detect failure exceeds benefits (Not cost-effective)
Scheduled Change or restoration (preventive)	Repair or replace on fixed time or cycle basis.	Asset has a well documented MTBF and a small standard deviation; Subject to wear-out and failure pattern known.
CBM (Predictive)	Employ condition monitoring to detect early stage failures, Replacement or repair are scheduled on condition.	Asset fails randomly critical nature justifies early detection techniques. Not subject to wear. PM induced failures.
Minor Redisign and condition-control (Proactive)	Changes in hardware loading or procedures, condition monitoring detects the presence of root cause of failure.	Objective is to reduce the failure rate for a given time period; RCFA, FMEA, Age exploration
Redundancy	Deploy active shared-load or stand by edundant systems	Critical asets (or mission) for which no other approach is acceptable

III. PRESENT INVESTIGATION

The present investigation involves the survey of the plan view of the plant, machineries and the operation of the different machine tools under the guedance of the plant and service department of the company. The present study aims to focus on the reliability and maintainability aspects and availability aspects of the ply manufactureing plant.

Plywood

Plywood is made of three or more thin layers of wood bonded together with an adhesive. Each layer of wood or ply is usually oriented with its grain running at right angles to the adjacent layers in order to reduce the shrinkage and improve the strength of the finished piece.

Raw Materials

Plywood may be mede from hardwoods, sofwoods, or a combination of the two. Some common hardwoods include ash, mahogeny, oak and teak. The most common hardwood used to make plywood is Douglas, fir redwood. The outer layers of plywood are known respectively as the face and the back. The face is the surface that is to be used or seen, while the back remains unused or hidden. The central layers of plywood are known as the core. In plywood with five or more ples, the intermediate layers are known as the crossband.

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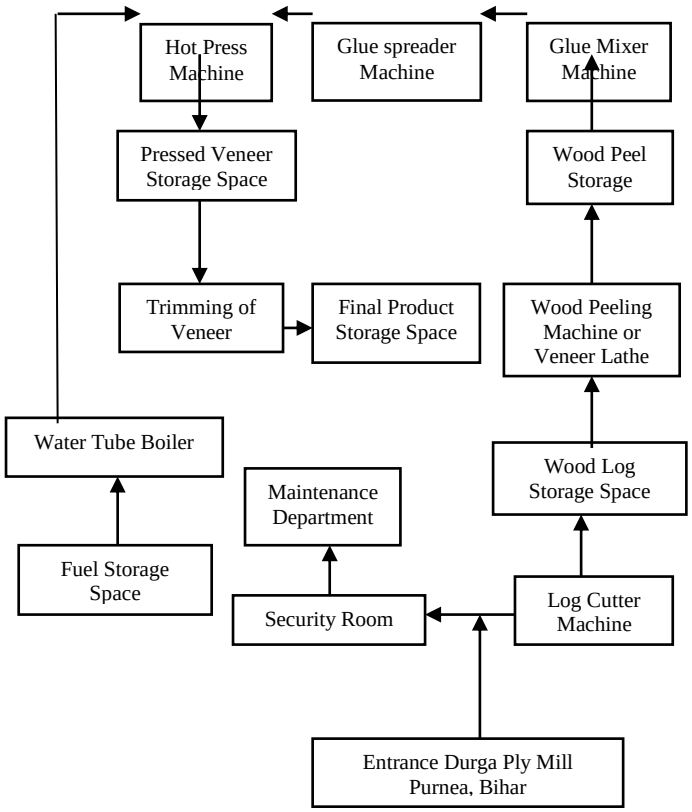

Figure 1. Plan View Of The Plant

IV. STEPS INVOLVED IN MAKING PLYWOOD

Veneer Manufacture

It is usually accepted that manufacture includes all the process from the time, the log enters the yard to the stage where a dried, graded veneer ready for further processing into plywood has been produced. The logs are then cut into suitable lengths for peeling. These lengths are called peeler blocks or sometimes pillerbillets.

Veneer Cutting

Veneer cutting done on the veneer lathe machine. The loading of veneer on the lathe can be done manually with a hoist and log tonges or automatically with machanical loading and centring devices.

Uses of Adhesives or Glue

The pricnicpal difference between adhesives used in plywood manufacture is the degree to which they are waterproof. To ascertain the degree of waterproofness of a glue line the standard association of Austtralia, under close direction from the plywood industries have defined a series of bond tests.

Glue Spreading Operation

In the glue spreading operation the crossbands are spread on both sides simultaneously. Close control over the amount of adhesive spread is obtained by adjusting the spreader doctor roll gap.

V. COLLECTION OF DATA

The most essential precondition for reliability analysis or maintenance planning is the availability of relevant data. For the present analysis, failure data related to different constituents of Ply Manufacturing Plant duing last 5 years (Aug 2009 to July 2014) are collected from the maintenance department of the company. This data includes the following:

No. of breakdowns related to different types of failure of Ply Manufacturing Plant and their components.

Monthly available hours and breakdown hours for individual components of Ply Manufacturing Plant.

The vaurious data on maintenance actions taken for Ply Manufacturing Plant has been colleted from daily breakdown record book supplid by maintenance section. From the daily maintenance record book, the failure hours, frequency of failures has been estimatted and plotted. To get an overview about the performance of the ply manufacturing plant during the period under study (Aug 2009 to July 2014).

Table 2. Failure of the Component of Ply Manufacturing Plant

Sl. No.	Name of the Different Machinery/Componet	Number of Failures (Aug 2009 to July 2014)
1.	Water Tube Boiler	19
2.	Wood Peeling Machinge	15
3.	9-Delight Pressing Machine	11
4.	Glue Spreader Machine	20
5.	Glue Mixer Maching	15

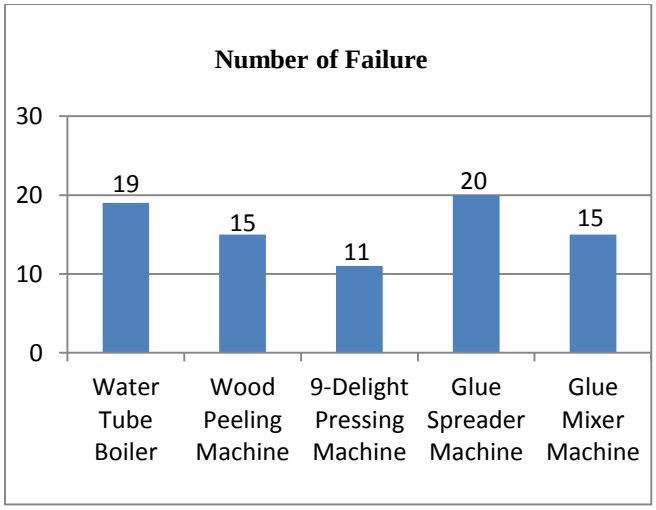

Figure 2. Number of Failure of Different Componetn (August 2009 to July 2014)

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VI. ANALYSIS OF THE STUDY

Failure Analysis

These mechanical components are failed due to mechanical failure. The major and minor causes of failures are there which are shown in the tabular form:

Table 3. Failure of the Different Component

Sl. No.	Name of Componet	Failure Due to
1.	Failur of Boiler	Spark plug problem, Back fire problem, knocking or detonation, water inlet filter, chock water outlet chock, stress rupture, water side corrosion, fatigue, damage during chemical cleaning, Mterial defects.
2.	Failure of wood peeling machine or veneer lathe	Head stock problem, bearing problem, belt drive problem, motor problem, chuck problem, tail stock problem, carriage problem, saddle problem, cross slide problem, tool post problem, peeling teeth problem
3.	Failur of Pump	Speed too low, broken impeller, air leak in suction line, excessive shaft misalignment, lubricant contamination,
4.	Failure of 9-Delight pressing machine	Steam pressure problem, gap between plate problem, motor problem, excessive heat problem

Failure Modes and effect Analysis (FMEA)

Failure modes and effect analysis has been carried out to examine potential failure modes in the ply manufacturing plant components. It has been used to evaluate risk priorities for mitigating known threat- vulnerabilities. FMEA has been carrid out to select remedial actions that reduce cumulative impacts of lifecycle consequences from system failure.

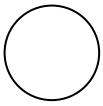
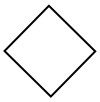
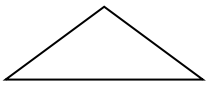
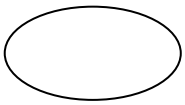
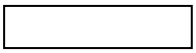
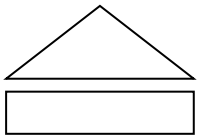
Table 4. The FMEA Process

Steps	Types
Step 1	Identify Function
Step 2	Identify failure modes
Step 3	Identify dffects of the failure modes
Step 4	Determine severity
Step 5	Apply procedure for potential consequences
Step 6	Identify potential causes
Step 7	Determine occurances
Step 8	Calculate criticality
Step 9	Identify design or process control
Steps 10	Determikne Detection
Steps 11	RPN and final risk asessment
Steps 12	Take accounts to reduce risks
Steps 13	Identify root cause
Steps 14	Identify special characteristics

Fault Tree Analysis

It is first developed in Bell Telephone Laboratories in 1962 for the U.S. Air forces for use with the minuteman system. Fault tree analysis is one of the symbolic "Analytical logic techniques" found in operation research and in system reliability. Fault tree diagrams are logic block diagrams that display the state of a system (Top event) in terms of the states of its components (basic events). It uses a graphic model of the pathways within a system that can lead to an undesirable loss event (or a failure).

Table 5 Traditional Fault Tree Analysis

Primary Event Block	Classic FTA Symbol	Description
Basic Event		A basic initiating fault or failure event.
Undeveloped Event		An event which is no further developed. It is a basic event that does not need further resolutions.
Transfer		Indicates a transfer contribution to a sub tree
Conditioning Event		A specific condition or restriction that can apply to any gate.
Combination Event		An event resulting from combinations of more basic events.
External Event		An event that is normally expected to occur.

Reliability Analysis

The machines and equipments are selected for reliability analysis of a ply manufacturing plant are water tube boiler, wood peeling machine, 9-delight pressing machine, glue mixer machine, glue spreader machine.

Hazard Model & Probability distribution

The initial stage of reliability analysis is to predict the hazard model of the failures and to choose a distribution among various probability distributions like normal distribution, exponential distribution, poisson, distribution, weibull distribution etc.

Graphical Evaluation for Reliability Prediction

There are generally two ways for graphical evaluation viz. Exponential plot and Weibull plot. When the failure rate is

constant, the distribution follows exponential probability law and when failure rate is not constant, i.e. non-linear hazard model follows Weibull distribution.

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Linear Regression Analysis: Selection of Distribution

The observed data regarding the failures of different components of the manufacturing plant shows that the failure rates of the components are not constant. So the Weibull distribution model can be adopted. Moreover the technique of linear regression analysis confirms the suitability to use Weibull distribution for the different components of the ply manufacturing plant. The analysis determines the best-fit line in the least square sense. The least square test has been performed to obtain the increasing/decreasing rate of failures linear regression analysis has been carried out by using the probability equation.

Weibull Distribution

About all the distribution available for reliability calculations, the weibull distribution is the only unique to the field. Professor Wallodi Weibull (1887-1979) pointed out that normal distributions are not applicable for characterizing initial metallurgical strengths during his study on metallurgical failures. He then introduced a function that could embrace a great variety of distributions and used seven different case studies to demonstrate how this function allowed the data to select the most appropriate distribution from a broad family of Weibull distributions. Probably the most widely used distribution in reliability engineering.

Computation of Maintenance Policy

Breakdown occurs at random. It forms any of the following types of frequency distribution, exponential, normal, logarithmic, gamma or weibull. In a situation like this, statistical methods are used in laying down maintenance policy such as standard preventive maintenance cycle time (Ts), average time between breakdown (Ta) and average preventive maintenance time (Tm).

Maintenance Policy for Wood Peeling Machine

For this purpose the year (2014), data is collected. Breakdown and Maintenance cost data is collected from the Maintenance Department of the ply manufacturing plant.

Table 6 Breakdown Details of Wood Peeling Machine

Sl. No.	Month	No. of Failure	Breakdown Probability
1	May 2014	3	0.272
2	June 2014	0	0
3	July 2014	0	0
4	August 2014	1	0.090
5	September 2014	1	0.090
6	October 2014	0	0
7	November 2014	2	0.181
8	December 2014	0	0
9	January 2015	1	0.090
10	February 2015	1	0.090
11	March 2015	1	0.090
12	April 2015	1	0.090

Table 7 Maintenance Cost Details of Wood Peeling Machine (year-2014)

Month	B/D Probability	Cumulative Probability	Expected B/D=n	Cost Of B/D (Rs)	Cost of P/M (Rs)	Total Cost (Rs)	Maintenance cost p.m (Rs)
Jan	0.272	0.272	2.992	9574	4000	13574	13574
Feb	0	0.272	3.805	12176	4000	16176	8088
Mar	0	0.272	4.026	12883	4000	16883	5627
Apr	0.090	0.362	5.077	16246	4000	20246	5061
May	0.090	0.452	6.621	21187	4000	25187	5037
June	0	0.452	7.383	23625	4000	27625	4604
July	0.181	0.633	9.675	30960	4000	34960	4994
Aug	0	0.633	10.953	35049	4000	39049	4881
Sept	0.090	0.723	12.671	40547	4000	44547	4949
Oct	0.090	0.813	14.645	46864	4000	50864	5086
Nov	0.090	0.903	16.979	54332	4000	58332	5302
Dec	0.090	0.993	19.567	62614	4000	66614	5551

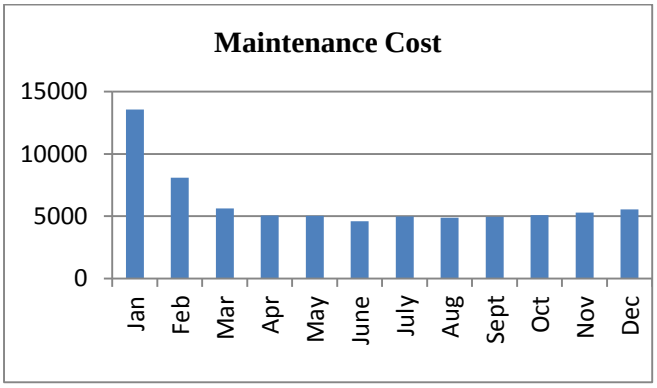

Figure 3 Maintenance Cost Pattern of Wood Peeling Machine

Maintenance Policy for Glue Mixer Machine

For this purpose the collection of the taken from year 2014. Breakdown and Maintenace cost data is collected from the Maintenance Department of the Ply-Manufacturing Plant.

Table 8 Breakdown Details of Glue Mixer Machine (Year 2014)

Sl. No.	Month	No. of Failure	Breakdown Probability
1	May 2014	1	0.2
2	June 2014	0	0
3	July 2014	0	0
4	August 2014	1	0.2
5	September 2014	1	0.2
6	October 2014	1	0.2
7	November 2014	0	0
8	December 2014	0	0
9	January 2015	0	0
10	February 2015	1	0.2
11	March 2015	0	0
12	April 2015	0	0

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Table 9 Maintenance cost details of Glue mixer machine (Year - 2014)

Month	B/D Probability	Cumulative Probability	Expected B/D=N	Cost Of B/D(Rs)	Cost Of P/M(Rs)	Total Cost (Rs)	Maintenance Cost P.M(Rs)
1	0.2	0.2	1	3200	4000	7200	7200
2	0	0.2	1.2	3840	4000	7840	3920
3	0	0.2	1.24	3968	4000	7968	2656
4	0.2	0.4	2.248	7193	4000	11193	2798
5	0.2	0.6	3.6496	11678	4000	15678	3133
6	0.2	0.8	5.1699	16543	4000	20543	3423
7	0	0.8	5.721	18307	4000	22307	3186
8	0	0.8	6.0816	19461	4000	23461	2932
9	0	0.8	6.6435	21259	4000	25259	2806
10	0.2	1	8.5412	27331	4000	31331	3133
11	0	1	9.8151	31408	4000	35408	3218
12	0	1	10.596	33907	4000	37907	3158

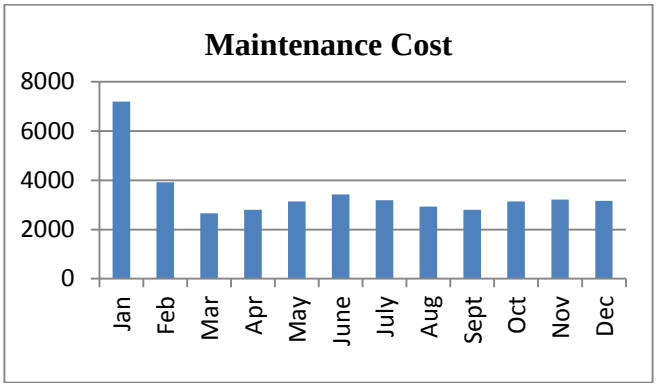

Figure 4 Maintenance Cost Pattern of Wood Peeling Machine

VII. RESULT AND DISCUSSION

Reliability Estimation

Reliability estimation of the different components of the ply manufacturing plant provides the values of reliability which focuses on the performance of the components of the ply manufacturing plant during the period of August 2009 to July 2014.

Table 10 Reliability of the Ply Manufacturing Plant Components

Sl. No.	Name of the Components	Mean operation Hour (In hrs.)	Reliability %
1	Water tube boiler	456.06	68.44
2	Wood peeling machine	378.91	66.68
3	9-Delight pressing machine	420.03	81.82
4	Glue spreading machine	600.5	55
5	Glue mixer machine	558.16	66.7

From the above table it is found that the estimated reliability of the different component of the ply manufacturing plant is in the range of 55% to 81.82%. The reliability of the 9-Delight pressing machine is the maximum (81.82%) waheras the minimum (55%) reliability is for the glue spreading machine. So the reliability prediction of ply manufacturing plant has become fruitful to focus on the components. Glue spreading cachine should be taken care of. All the other components have moderate reliability.

Availability of Different Component of the Ply-Manufacturing Plant

As per the definition of operational availability, the availability of different component of the ply manufacturing plant is caluculated for a particular month starting from Aug 2009 to July 2014. After that the operational availability of each plant is calculated. A detailed list of estimated average operational availability of different cdomponents of th eplay manufacturing plant is given in the table below:

Table 11 Estemated Maximum Availability of the Ply manufacturing plant component

Sl. No.	Name of the Components	Average operational Availability
1	Water tube boiler	0.9967
2	Wood peeling machine	0.9949
3	9-Delight pressing machine	0.9950
4	Glue spreading machine	0.9965
5	Glue mixer machine	0.9955

Computation of Maintenance Policy

From the table below The Maintenance cost for wood peeling machine in the 1st month is Rs.13574. The maintenance cost for wood peeling machine in the 2nd month is decreased to Rs.8088. The maintenance cost for wood peeling machine in the 3rd month is again decreased to Rs.5627. The maintenance cost for wood peeling machine decreases till 9th month but it again increased in 10th month. So in case of wood peeling machine, from the maintenance policy it does appear that Preventive maintenance policy is not suitable for wood peeling machine

Table 12 Maintenance cost detais of wood peeling Machine (May 2014 to April 2015)

Months	Maintenance cost per Month (Rs.)
May 2014	13574
June 2014	8088
July 2014	5627
August 2014	5061
September 2014	5037
October 2014	4604
November 2014	4994
December 2014	4881
January 2015	4949
February 2015	5086
March 2015	5302
April 2015	5551

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Maintence Cost Details Of Glue Mixer Machine

From table below it appears that total maintenance cost for the entire machine/month, there is no perfect relationship which suggest for ensuring non- stop uninterrupted production system combination of preventive and Breakdown maintenance policy is suitable for the machine available in the Ply- Manufacturing plant. The maintenance cost for Glue mixer machine for the 1st three month is Rs. 7200, Rs.3920; Rs.2656 from the 4th month maintenance cost is again increased. So in case of Glue mixer machine, from the maintenance policy it does appear that Preventive maintenance once in three month is suitable.

Table 13 Maintenance Cost Details Of Glue Mixer Machine
(May 2014 to April 2015)

Months	*Maintenance cost per Month (Rs.)*
May 2014	7200
June 2014	3920
July 2014	2656
August 2014	2798
September 2014	3133
October 2014	3423
November 2014	3186
December 2014	2932
January 2015	2806
February 2015	3133
March 2015	3218
April 2015	3158

VIII. CONCLUSION

From the present studies we found the following conclusion:

1. The Maintenance policy is necessary to decide the frequency of maintenance to determine how frequently maintenance should be done so that the equipment are highly reliable when needed.
2. It is necessary to deal again with breakdown frequencies of the ply manufacturing plant component.
3. Since the preventive maintenance program costs more than the breakdown maintenance program, We should look to preventive maintenance scheduling alternatives such as providing preventive maintenance only every second or third month.
4. Therefore detail and continuous study is required for analyzing the benefits obtained in terms of maintenance cost, operational effectiveness for ply manufacturing plant components on reliability aspects.

IX. FURTHER SCOPE OF THE STUDY

The present investigation can be extended meaningfully for further study in the following areas:-

1. The study can be carrying out to development of a detailed maintenance plan to improve availability of components.
2. The detailed study can be carry out for the effects of the proposed guidelines on the overall MTBF improvement of the ply manufacturing plant components.
3. The study can also be carry out on the preventive Maintenance policy is necessary to decide the frequency of maintenance of the other component of the ply manufacturing plant like- wood peeling machine, water tube boiler.
4. The study can be done the effects of the proposed guidelines on the reliability of the ply manufacturing plant.
5. Detailed study of the effects of the proposed guidelines on the availability of the ply manufacturing plant can also be carrying out.
6. Reliability and Availability of the other machines or components can be evaluated by further study.

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