Reliability Centered Maintenance on High Productivity Machines with Managerial Approach

K Naresh raj, T. Malyadri, Gore Sanket Dilip, Pabba Sharath Kumar

***Abstract*— Reliability Centered maintenance on Machines had widely Applicable in all sorts of industries. Till now this RCM tool generated efficient results for its applications on machineries. It is efficient enough in the direction of generation of maintenance plan by performing Maintenance, FMEA Analysis with consideration of limited parameters and less amount of prime focus on machine components i.e., lack of management approach. Now in this Area of work we are concerned with the high expensive and high productive Machineries of "High productivity", which Manufactures glass bottles (beverages).The work Performed is Maintenance Analysis, FMEA Analysis, additive to this i.e., Cost and Time Consumed Analysis which is an management approach for generation of High Effective and least expensive Maintenance Plan. This work is very useful for small and medium scale industries/organizations.**

***Index Terms*— Maintenance Analysis, FMEA Analysis, Cost and Time consumed Analysis.**

I. INTRODUCTION

RCM is a maintenance tool that applicable for all types of engineering systems. Especially for mechanical machines. Methodology of this tool is to generate maintenance plan by performing Analysis like Maintenance, FMEA on the Machines/systems. Today the question 'Is RCM is effective enough to serve the maintenance engineers who belongs to small and medium scale firms?' is increasingly being asked. Continual modernization and the pressing need for higher and higher productivity have resulted in the increased development and use of sophisticated & complex Machines and equipments. This has resulted in increased capital employed in Production equipment (Waeyenbergh & Pintelon, 2002). Systems are also becoming more costly relative to their operation & support. In case of capital equipment used in process and various other plants, which are one-off and cannot be prototype tested, incipient failures occur. This affects production and resulted in= loss of revenue. Till now RCM tool worked as technique which generates effective maintenance plan.

Addition of managerial approach to this RCM tool in order to restrict the loss of revenue and to generate effective maintenance plan in economical manner. This is achieved by performing cost and time analysis for machines/systems. And prime focus of analysis is on the elements of machines which give more effective result.

Collected data for analysis from glass bottles (beverages) manufacturing industry

Machine photos

Machines break down report for one year in mins (2013)

II. MAINTENANCE ANALYSIS PROCESS FOR MACHINES [10]:

Data Extrusion: Extracting required data from collected data for one shift-year in minutes. Data is as machine wise.

Maintenance Analysis: Analysis of the machines sub-element wise (components wise) for evaluation of failure rate and maintenance rate and total time rate for both the functions.

Evaluated parameters: Evaluating the parameters and listing out of them for determining of the reliability terms they are MTBM,MTTF,MTD,etc.,

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K Naresh Raj: Assistant Professor In Cmrit, Dept Of Mechanical Engineering.

T Malyadri: Assistant Professor In Cmrit, Dept Of Mechanical Engineering.

Gore Sanket Dilip: 4^{th} Yr Aeronautical Engineering Student In Institute Of Aeronautical Engineering.

Pabba Sharath Kumar: 4^{th} Yr Mechanical Engineering Student At Institute Of Aeronautical Engineering.

Final Calculations: Determining the reliability terms of machines and Availability, Reliability, Maintainability for one shift-year.

Summary of performances of machines: In this summarizing the machines Reliability, Availability, Maintainability of machines that to sequential decremented order.

A. Table: Maintenance Analysis of Machine No: 12 for One Shift- Day (480mins) [1-9]

M/C	T/O ARM	TONG HEAD	V.F MECH	BAFFLE ARM	BLOW HEAD ARM	PUSHER UNIT	MOLD HOLDER	N/R ARM	LOADING	MOC& BH SPOOL VALVE	PL.AD LOOSE
25	765	160	740	150	560	820	385	315	170	400	360
26	575	95	375	120	350	100	105	560	550	165	20
27	225	110	165	175	185	945	120	390	0	0	640
28	2020	325	1675	440	775	1675	490	490	390	300	85
29	595	260	180	765	260	4420	590	590	430	100	385
11	585	20	365	900	735	230	800	810	670	305	700
12	535	300	405	430	1005	350	645	1100	550	350	420
13	510	135	3360	400	140	380	45	800	190	0	1930
14	485	165	235	615	480	260	250	640	310	50	545
15	750	80	335	405	235	475	280	850	420	20	235
16	1225	40	150	660	355	295	320	380	245	245	0
17	1505	205	1030	1390	530	505	145	1080	900	135	225
TOTAL	9775	1835	9015	6450	5610	6455	4175	8070	4825	2070	5545

B. Evaluations [10]:-

Operational Availability: It is defined to be the probability that a system or Machinery shall operate

satisfactorily when used under stated conditions and in an actual supply environment at any given time. It expressed as

A_o: - MTBM / (MTBM+ MDT).

Reliability: - It is the Probability of a device performing its purpose adequately for the period intended under the given operating conditions. It may express in mathematically as.,

R (t):- 1 – F (t).

Maintainability:- It is the probability that a unit or system will be restored to Specified conditions within a given period when maintenance. Action is taken in accordance with prescribed procedures and Resources. It is a characteristic of the design and installation of the unit or system. It expressed as.

Mo: - Number of Repairs for given period time/ Total number of repairs For total time period.

1.2 .1 Evaluated Parameters:

Number of failures per shift is F (t) : 18.46 ~ 18.5 mins.

Number of Maintenances per shift is M (t) : 291.14mins.

Number of expected probability : 3.0 mins.

Of hazard failures shift

Total number of failure per shift is : 18.5 + 3 = 21.5 mins.

Total number of Maintenances per shift M (t) : 291.14+33=324.0 mins.

Total operating time per shift : 8x60 = 480.0 mins.

Number of runs per shift is : 98.7 / 480 *100 =20.56 mins.

Total number of runs per shift is : 20.56 + 3.0= 23.56 mins.

Average breakdown time i.e., for month is : 194.0 mins.

Average breakdown time for shift is : 194/30 = 6.466 mins.

Down time per shift : 6.466 / 480*100 = 1.347 mins.

Uptime per shift : (1 – 0.013)*100 = 98.7 mins.

Percentage of break down time per month = 44.9 mins.

1.2.2 Calculations for M/c 12(mins/ shift-day):-

MTD (mean down time) : (1.347+23.56)/44.9= 0.55mins.

MTBF (mean time between failures) : 480 / 18.5= 25.94 mins.

MTTF (mean time to failure) : 480 / 21.5= 22.32 mins.

MTBM (mean time between maintenance) : 480 / 23.56= 20.37 mins.

1.2.3 Calculations for M/c 12 (mins/shift-year)

MTD = 0.55*11*30 = 181.5 mins

MTBF = 25.94 * 11*30 = 8560.2 mins

MTTF = 22.32*11*30 = 7365.6 mins.

MTBM = 20.37*11*30 = 6722.1mins.

1.2.4 Final Calculations.

Reliability R0 = 1 – F (t) = 1- 21.5/480 = 0.955*100 = 95.52%.

Maintainability Mo = M (t)/Total operating Time = 324.0/480 = 0.675*100 = 67.5%.

Operational Availability

AO = MTBM/ (MTBM+MDT)
= 6722.1/(6722.1+181.5)
= 0.9737*100=97.37%.

Summary of Performance of Various Machines Studied (Mins/shift-year) [1-9]

Sl no	Machines	MTBF	MTTF	MTBM	Ao	Ro	Mo
		In mins	In mins	In mins	%	%	%
1	12	8560.2	7365.6	6722.1	97.37	95.52	67.5
2	27	17598.9	13200	6711.8	98.32	97.5	31.53
3	14	12672	10216.8	7791.4	98.04	96.7	45.73
4	13	6600	5864.1	6708.9	96.25	94.37	87.97
5	15	12672	10216.8	6705.6	97.64	96.77	48.13

III. Failure Mode and Effects Analysis (FMEA) [11-12]

was one of the first systematic techniques for *failure analysis*. It was developed by *reliability engineers* in the 1950s to study problems that might arise from malfunctions of military systems. A FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet. There are numerous variations of such worksheets. A FMEA is mainly a qualitative analysis.[1]

A few different types of FMEA analysis exist, like

Functional, Design, and Process FMEA.

Sometimes the FMEA is called FMECA to indicate that Criticality analysis is performed also.

An FMEA is an *Inductive reasoning* (forward logic) single point of failure analysis and is a core task in *reliability engineering, safety engineering and quality engineering*. Quality engineering is especially concerned with the "Process" (Manufacturing and Assembly) type of FMEA.

A successful FMEA activity helps to identify potential failure modes based on experience with similar products and processes - or based on common physics of failure logic. It is widely used in development and manufacturing industries in various phases of the product life cycle. *Effects analysis* refers to studying the consequences of those failures on different system levels.

Functional analyses are needed as an input to determine correct failure modes, at all system levels, both for functional FMEA or Piece-Part (hardware) FMEA. A FMEA is used to structure Mitigation for Risk reduction based on either failure (mode) effect severity reduction or based on lowering the probability of failure or both. The FMEA is in principle a full inductive (forward logic) analysis; however the failure probability can only be estimated or reduced by understanding the *failure mechanism*. Ideally this probability shall be lowered to "impossible to occur" by eliminating the *(root) causes*. It is therefore important to include in the FMEA an appropriate depth of information on the causes of failure (deductive analysis) [11-12]

2.1 table: FMEA worksheet for machine 12[11]

<table>
<tr><td colspan="4">Machine name: AIS</td><td colspan="5">Suppliers and plants Affected: Emhart Glass</td><td colspan="5">Prepared by: Myself</td></tr>
<tr><td colspan="4">Design/Manufacturing responsibility: Manufacturing</td><td colspan="5">Model date: don’t know</td><td colspan="5">FMEA Date: 12/08/2010</td></tr>
<tr><td colspan="4">Other areas involved</td><td colspan="5">Engineering change level</td><td colspan="5"></td></tr>
<tr><td rowspan="2">Process operation function or purpose</td><td rowspan="2">Potential failure mode</td><td rowspan="2">Potential effects of failure</td><td rowspan="2">SEV</td><td rowspan="2">Potential causes of failure</td><td rowspan="2">OCC</td><td rowspan="2">DET</td><td rowspan="2">RPN</td><td rowspan="2">Area/Inadividual responsible and completion date</td><td colspan="5">Action results</td></tr>
<tr><td>Actions taken</td><td>SEV</td><td>OCC</td><td>DET</td><td>RPN</td></tr>
<tr><td>T/O</td><td>Tong head bolts broken</td><td>Damage to Tong head and product</td><td>9</td><td>Due to fluctuating loads</td><td>7</td><td>8</td><td>504</td><td>09/07/2010</td><td>Replacement of tong head</td><td>7</td><td>5</td><td>7</td><td>245</td></tr>
<tr><td>Tong head</td><td>Links play more</td><td>Link pins broken</td><td>6</td><td>Due to wear and tear</td><td>7</td><td>7</td><td>294</td><td>09/07/2010</td><td>Replacement of pins</td><td>5</td><td>5</td><td>5</td><td>125</td></tr>
<tr><td>V.F mech</td><td>Damper plate broken</td><td>Damage to product and for Mold holder</td><td>8</td><td>Due to thermal stress</td><td>8</td><td>9</td><td>576</td><td>09/07/2010</td><td>Replacement of damper plate</td><td>6</td><td>6</td><td>7</td><td>252</td></tr>
<tr><td>B/A</td><td>Lock</td><td>Damage</td><td>8</td><td>Due to</td><td>8</td><td>8</td><td>512</td><td>09/07/2010</td><td>Replacement</td><td>7</td><td>6</td><td>6</td><td>252</td></tr>
</table>

	ring loose	to product and for Blow head arm		rod broken					with weld				
Blow Head Arm	Locking ring clogged	Damage to mold	7	Due to carbon	9	6	378	09/07/2010	Replacement of locking ring	5	8	4	160
Pusher Unit	Pusher finger back plate broken	Damage to product and pusher unit	6	Due to shear stress	7	7	294	09/07/2010	Repaired by welding operation	4	5	5	100
Mold Holder	Np	Np	Np	Np	Np	Np	Np	09/07/2010	Np	Np	Np	Np	Np
N/R Arm	Lock broken	Damage to product and N/R	7	Due to vibrational stress	8	7	392	09/07/2010	Replacement of new neck ring arm	5	6	5	150
Loading	Tong head setting	Damage to product	5	Due to takeout arm	8	7	280	09/07/2010	Setting up of tong head	3	5	5	75

IV. Cost Analysis of Machine Components for Repairs[13-14]

Cost analysis procedure:

In this analysis we considered the number of repairs, quantities, and cost incurred by them. Based upon them determination of expenditure is resolved for durations three months and one month, of components with their quantities in machine.

Determination is came out by division of, product of components repairs cost with quantities for three months and one month. And in this additional cost is incurred for repair shop maintenance. This is for to know investment status for maintenance of repair strategy.

A. Repairs Cost Data of Components

Number of time componenets failed for one month is (nr). : 113 times.

Number of times under gone for repairs per one month In rupees (ntrm). : ni * nr.

Number of times under gone for repairs per three months In rupees (ntr3m). : (ntrm)*3.

Cost consume for repairs per one Month in mins(crm). : (ntrm)*100 rupees

Cost consume for repairs per three Month in mins(cr3m) : (ntr3m)*300 rupees.

V. Repairs Cost Analysis for Components [13-14]

Components	qty ni	no of repairs per month	repair stimes per 1month in rupees (ni*repairs)	repairs time per 3month in rupees (ni*repairs)*3	cost consume for repairs per 1 month in rupees (ni*repairs)*100	cost consume for repairs per 3 month in rupees (ni*repairs)*300
T/o arm	2	17	34	102	3400	10200
Tong head	1	15	15	45	1500	4500
Vf mech	2	12	24	72	2400	7200
Baffle arm	2	14	28	84	2800	8400
Blow head	1	12	24	72	2400	7200
Pusher unit	1	10	10	30	1000	3000
Mold holder	1	8	8	24	800	2400
N/r arm	2	10	20	60	2000	6000
Loading	1	6	6	18	600	1800
Moc & bh. Spool valve	4	4	16	48	1600	4800
Plg.ad loose	1	5	5	15	500	1500
		113times	190times	570times	Rupees 19000/-	Rupees 57000/-

VI. Failure Time Analysis of Components in Mins[15-16]

Cost Analysis procedure:

In this analysis we considered the number of repairs, quantities, and time incurred by them. Based upon them determination of time consumed is resolved for durations three months and one month, of components with their quantities in machine. Determination is come out by division of, product of components repairs time with quantities for three months. And time consumed for one month without consideration of repairs i.e., replacement. This analysis states the time consumption for repairs and replacement strategies [15-16]

5.1 Repairs Time of Components Data:

Number of time componenets failed for one month is (nf). : 113 times.

Number of times fails per one month : ni * nf. In mins (ntfm).

Number of times fails per three months : (ntfm)*3. In mins (ntf3m).

Time consume for failure per one Month in mins(tfm). : (ntfm)*5mins.

Time consume for failure per three Month in mins(tf3m). : (ntf3m)*15mins.

5.1 table: failure time analysis of components [15-16]

Components	Qty Ni	No of Fails per Month	Num Of Times Fails Per 1Month In mins (ni*fails)	Num Of Times Fails Per 3Month In mins (ni*fails)*3	Time Consume For Failures Per 1 month In mins (ni*fails)*5mins	Time Consume For Failures Per 3 month In mins (ni*fails)*15mins
T/o arm	2	17	34	102	170	510
Tong head	1	15	15	45	75	225
Vf mech	2	12	24	72	120	360
Baffle arm	2	14	28	84	140	420
Blow head	1	12	24	72	120	360
Pusher unit	1	10	10	30	50	150
Mold holder	1	8	8	24	40	120
N/r arm	2	10	20	60	100	300
Loading	1	6	6	18	30	90
Moc&bh. Spoolvalve	4	4	16	48	80	240
Plg.ad loose	1	5	5	15	25	75
		113times	190mins	570mins	950mins	2850mins

VII. SUMMARY OF ANALYSIS [1-9]

A. *Summary of Chronic Problems of Machines*

Chronic Problems in Machine12
Maintainability is low of 67.5%
VertFlow Component has High RPN of 252
Baffle Arm Component has High RPN of 252
Take out Arm Component has High RPN of 245
Chronic Problems in Machine 27
Maintainability is very low of 31.53%
Take Out Arm Component has High RPN of 245
Chronic Problems in Machine 14
Maintainability is low of 45.73%
Take out Arm Component has High RPN of 245
Mold Holder Component has High RPN of 216
Chronic Problems in Machine 13
Compare to other the available machines Reliability and Operational Availability is low of 94.37&96.25.
Take out Arm Component has High RPN of 210
Blow Head Arm Component has High RPN of 210
Chronic Problems in Machine 15
Maintainability is low of 48.13%
Take out Arm Component has High RPN of 210

B. *SUMMARY OF COST ANALYSIS [13-14]*

Description	Replacement Of Components (rupees)	Repair Of Components (rupees)	Marginal difference In Amount
One month cost	21,829.93/-	19000.00/-	2829.93/-
Three months cost	65,490.00/-	57000.00/-	8490.00/-
Difference in cost	53230.02/-	38000.00/-	15230.02/-
Amount to spend	17743.34/-	12666.66/-	5076.67/-

VIII. RESULTS

A. Replacement Cost Analysis For Components Results:

Cost for components of one month is : Rupees 65,490.00/-
Cost for components of three months is : Rupees 21,829.93/-
Difference in cost is (65,490 – 12,259.98): Rupees 53230.02/-
Costs spend for every month if this : Rupees 17743.34/-
Strategy applied is (53230.02/3)
Repair shop maintenance for month : Rupees 00000.00/-
Total costs spend for every month is : Rupees 17743.34/

7.2 Repairs Cost Analysis for Components Results:
Cost consume by components : Rupees 19000.00/-
Due to repairs for one month is
Cost consume by components : Rupees 57000.00/-
Due to repairs for three months is
Difference in cost (57000-19000) : Rupees 38000.00/-
.
Cost saved for each month is (38000/3) : Rupees 12666.66/-
Repair shop maintenance for month : Rupees 10000.00/-
Total costs spend for month is (12666.66 + 10000) : Rupees 22666.66/-

7.3 Failure Time Analysis for Components Results:
Time consume by components : 950 mins.
Due to failure is for one month
Time consume by components : 2850 mins.
Due to failure is for three months
Difference in time (2850-950) : 1900 mins.Time saved for each month is (1900/3) : 633 mins.

IX. DISCUSSIONS:

Identification of Chronic Problems are been achieved by Maintenance and FMEA Analysis. It is done by evaluating the Availability, Reliability, Maintainability, and Risk Priority Number of Machines.

Optimal Cost for Machine Components had been achieved by Cost Analysis with consideration of Repairs and Replacements. It is came out by taking difference in amount spend i.e., 22666.66 – 17743.34 = Rupees 4923.32/-/month, if we replace the components instead of repairing.

Productivity time increment has possibility with replacement instead of repairs. it is came out of failure time analysis .increment amount of time is 1900/3 = 633 mins/month.

Optimal cost saved for year if adopt Replacement strategy is: 4923.32 * 11 = Rupee 54156.52/- /year.

Productivity time increment for year if adopt Replacement strategy is: 633* 11 = 6963 mins.

Additional production generated by Replacement: 6963 / 2 = 2321/bottles.

Additional Revenue generated by increasing production by Replacement = 2321*30 = Rupees 69630/-/year.

X. RECOMMENDED MAINTENANCE PLAN

Maintenance Task for M/C: 12
Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm, N/r Arm, Catridges, and BH.Arm) should be Every Month. And Increase of Maintainability is required.
Maintenance Task for Machine: 27
Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm, N/r Arm, Catridges, and BH.Arm) should be Every Month. And Increase of Maintainability is required.
Maintenance Task for Machine: 14
Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm, N/r Arm, Catridges, BH. Arm) should be Every Month. Periodical changing of Mold Holder Should be Every 4 Months.
Increase Maintainability is required.
Maintenance Task for Machine: 13
Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm,N/r Arm,Catridges,BH.Arm) Should be Every Month. Periodical changing of Blow Head Arm Should be Every 4 Months. And optimization of maintainability is required.

Maintenance Task for Machine: 15
Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm, N/r Arm, Catridges, and BH.Arm) should be Every Month. And Increase Maintainability required.

XI. CONCLUSIONS

Present work is focused to provide guidance to maintenance engineer to generate “Effective Maintenance Plan” and that should be economical. That has been achieved by maintenance analysis, FMEA analysis, cost analysis and failure time analysis which project concludes. And if we incorporate the design analysis on components in this work it provides more effectiveness to maintenance department in industry which is the future scope.

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K NARESH RAJ: Assistant Professor In CMRIT, Dept Of Mechanical Engineering.

T MALYADRI: Assistant Professor In CMRIT, Dept Of Mechanical Engineering. Pursued B.E. In Industrial Production Engineering From Chaitanya Bharati Institute Of Technology. Further Studied M.Tech In Mechanical Engineering From Jawaharlal Nehru Technological University. Also Worked As Design Engineer For 2 Years In Infotech Enterpizes Ltd.

Gore Sanket Dilip: Currently 4th Yr Aeronautical Engineering Student In Institute Of Aeronautical Engineering. One Month Of Internship Experience In TATA ADVANCED SYSTEMS In Manufacturing Engineering Dept Of S-92 Helicopter Cabin. Presented A Paper On Smokeless (Minimum Signature) Solid Rocket Propellant In International Conference On Renewable Energy Resources. Also Received A Best Session Paper Award For The Same Paper. Currently Working On New Concept Of Lightweight Yet Strong Bio-Composites.

PABBA SHARATH KUMAR: Currently 4th Yr Mechanical Engineering Student At Institute Of Aeronautical Engineering. Internship Experience In Sugarcane Technology. Also Internship Experience On Steam Turbines At BHEL(Bharat Heavy Electricals LIMITED)