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Critical Analysis of Reliabilty Centered Maintenance on High Productivity Machines with Managerial Approach

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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,time and operation 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,time and operation 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 engineer 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.

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

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

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

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.,

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. 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.

Ao: - 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.

1.1 table: maintenance analysis of machine no: 12 for one shift-day (480mins)

components	quantity (ni)	failure rate b.t/11*30 λ/ (shift)	ni*λ in mins	maintenance time mins tmi/(shift)	ni*λ*tmi time mins per shift
t/o arm	2	1.62	3.24	32.4	104.97
tong head	1	0.92	0.92	9.2	8.46
vf mech	2	1.227	2.45	24.5	60.02
baffle arm	2	1.303	2.6	26	67.6
blow head	1	3.045	3.045	30.45	92.72
pusher unit	1	1.06	1.06	10.6	11.23
mold holder	1	1.954	1.954	19.54	38.18
n/r arm	2	3.333	6.666	66.66	444.35
Loading	1	1.667	1.667	16.67	27.78
moc&bh. spoolvalve	4	1.06	4.24	42.5	179.77
plg.ad loose	1	1.272	1.272	12.72	16.17
		f(t)= 18.46mins.		**m(t) =291.14mins.**	

a) evaluated parameters [10]:

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.

b) 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.

6.2.4 Final Calculations.

- Reliability **R0** = **1 – F(t)**
  = 1- 21.5/100 = 0.785*100 = 78.5%.
- Maintainability **Mo = M(t)/Total operating Time**
  = 324.0/432 = 0.75*100 = 75%.
- Operational Availability **AO = MTBM/(MTBM+MDT)**
  = 6250.2/(6250.2+178.2)
  = 0.9722*100=97.22%

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	7705.5	6629.7	6250.2	97.22	78.5	75
2	27	15840	11880	6233.7	98.18	88	35.03
3	14	11404.8	9187.2	6230.4	97.57	84.5	50.81
4	13	5940	5280	6230.4	95.93	73	97.7
5	15	11404.8	9197.1	6804.6	97.72	84.5	53.47

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. an fmea is often the first step of a system reliability study. it involves reviewing as many components, assemblies, and subsystems as

machine name: ais				suppliers and plants affected: emhart glass					prepared by: myself				
design/manufacturing responsibility: manufacturing				model date: don't know					fmea date: 12/08/2010				
other areas involved				engineering change level									
									action results				
process operation function or purpose	potential failure mode	potential effects of failure	sev	potential causes of failure	occ	det	rpn	area/inadividual responsible and completion date	actions taken	sev	occ	det	rpn
t/o	tong head bolts broken	damage to tong head and product	9	due to fluctuating loads	7	8	504	09-07-2010	replacement of tong head	7	5	7	245
tong head	links play more	link pins broken	6	due to wear and tear	7	7	294	09-07-2010	replacement of pins	5	5	5	125
v.f mech	damper plate broken	damage to product and for mold holder	8	due to thermal stress	8	9	576	09-07-2010	replacement of damper plate	6	6	7	252
b/a	lock ring loose	damage to product and for	8	due to rod broken	8	8	512	09-07-2010	replacement with weld	7	6	6	252

		blow head arm											
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
moc & bh spool rate	np	np	np	np	np	np	np	np	np	np	np	np	np
plan loose	plunger adaptor loose	damage to product	8	due to vibrations	7	6	336	09-07-2010	plunger adaptor is tightened	5	5	5	125

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. An 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]

IV. COST ANALYSIS AND FAILURE TIME ANALYSIS INTERMS OF RUPEES AND MINS PER SHIFT[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 analysis for components [13-14]

Repair cost analysis for components of machine-12

Components	Quantity	Time taken for repair per month	No.of repair per month of quantity	Cost consume for repair per month
T/O ARM	2	535/11=48.63	3*2=6	300*6=1800
TONG HEAD	1	300/11=27.27	2*1=2	350*2=700
VF MECH	2	405/11=36.81	1*2=2	400*2=800
BAFFLE ARM	2	430/11=39.04	1*2=2	350*2=700
BLOW HEAD	1	1005/11=91.36	4*1=4	550*4=2200
PUSHER UNIT	1	350/11=31.81	2*1=2	650*2=1300
MOLD HOLDER	1	645/11=58.63	3*1=3	650*3=1950
N/R ARM	2	`1100/11=100	4*2=8	450*8=3600
LOADING	1	550/11=50	3*1=3	350*2=1050
MOC&BH SPOOLVALVE	4	350/11=31.81	2*4=8	550*8=4400
PLG.OD LOOSE	1	420/11=38.18	2*1=2	300*2=600
			42	**19100**

V. REPLACEMENT COST ANALYSISOF 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]

REPLACEMENT COST ANALYSIS FOR COMPONENTS OF M/C NO-12

COMPONENTS	QUANTITY	NO OF FAILURE/MONTH	COST OF COMPONENTS	REPLACEMENT COST OF QUANTITY
T/O ARM	2	6	450	2700
TONG HEAD	1	2	500	1000
VF MECH	2	2	550	1100
BATTLE ARM	2	2	475	1050
BLOW HEAD	1	4	700	3600
PUSHER UNIT	1	2	725	1450
MOLD HOLDER	1	3	750	2250
N/R ARM	2	8	525	4200
LOADING	1	3	425	1275
MOC&BH SPOOL VALVE	4	8	610	4880
PLG.OD LOOSE	1	2	375	750
				24,255

Summary of replacement and repair(12,13,14,15,27)

Sl. no	Machines	Time taken for repairs	Time taken for replace	Time saved by replacement	Productivity increased by replacement
1	12	553.54	210	353.54	176.7
2	13	777.23	175	604.05	302.005
3	14	269.09	95	173.59	87.13
4	15	371.328	150	257.692	128.846
5	27	366.77	160	281.42	123.51
TOTAL		**2337.958**	**790**	**1670.29**	**818.193**

Summary of replacement and repair cost (12,13,14,15,27)

Sl.no	Machines	Replacement cost	Repair Cost
1	12	23655	19600
2	13	20200	15550
3	14	17380	15750
4	15	15865	13100
5	27	10300	9200
TOTAL		**87400**	**73200**

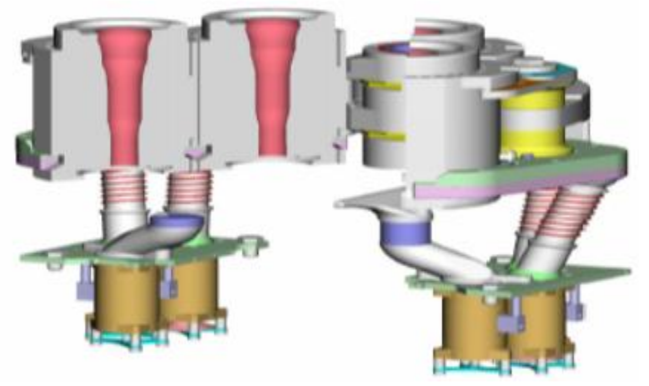
VI. RESULTS:

Total Replacement Cost of machines (12,13,14,15,27)=87400
Total Repair cost of machines (12,13,14,15,27)=73200
Cost saved by replacement:
Total repair cost of machines-total replacement cost of machines=14200
Time saved by replacement:
total time taken for repairs-total time taken for replacement=1547.95 min
Increase in productivity by replacement=818.193

OPERATION ANALYSIS

- **Vert flow component, rpn -252**
- **Baffel arm component , rpn -252**
- **Molder arm component, rpn-210**
- **Take out arm, rpn -245**

VERTIFLOW MECHANISM



Vertiflow Mechanism

Design Specification	Operations Performed	Benefits of Operations Performed	Recommended action to improve the operation efficiency	Despatch the operations sheet departments for improvement
AIS 6^1/4 DG=82.5mm	Higher cooloing efficiency	Speed increase potential	Increase radial blank cooling	Design simulation and ppc department
AIS 4^1/4 TG=78mm	Fumes and heat carried away	Improves operater environment	Min blank glass line should increase	Design process planning department (department (Ansys)
	Optimized cooling condition	Individual cooling of mould cavities	Modify vertical and horizontal temp distribution	Design department (Ansys)
	Easier mould change	Reduce the down time	Blank assembly should be done (insert+plenum+spacers) has to be prepared in the workshop	Assembly workshop department

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. RECOMMENDED MAINTENANCE PLAN TO OPTIMIZE PRODUCTIVITY

Maintenance Task for M/C:12

- Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm,N/r Arm,Catridges,BH.Arm) Should be Every Month.
- Increase Maintainability.
- Rpn of vert flow 252, rpn of baffle arm 252, rpn of take out arm 245 should be reduce.
- Vert flow, baffle arm, take out arm should be remodelled for increase its operational efficiency.

Maintenance Task for Machine 27

- Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm,N/r Arm,Catridges,BH.Arm) Should be Every Month.
- Increase Maintainability.
- Rpn of Blow Head Arm 210 rpn of take out arm 245 should be reduce.
- Blow Head Arm, take out arm should be remodelled for increase its operational efficiency.

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.
- RPN of take out arm 245 , rpn of Mold Holder 216,should be reduse.
- Increase Maintainability.

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 Months.
- Optimize the maintainability.
- RPN of take out arm 210 should be reduce.

Maintenance Task for Machine 15

- Periodical changing of variables (T/O Arm, Tong Head, Baffle Arm,N/r Arm,Catridges,BH.Arm) Should be Every Month.
- Increase Maintainability.
- RPN of take out arm 210 should be reduce.
- Take out arm should be remodelled for increase its operational efficiency

VIII. 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 operational analysis which project concludes. And if we incorporate the modelling and testing analysis on components in this work it provides more effectiveness to maintenance department in industry which is the future scope.

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