Implementation of Reliability Centered Maintenance (RCM) and Design out for Reliability (DOFR) Approaches to Milk Powder Drying Unit of Dairy Plant – A Case Study

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Abstract— This paper presents a structured approach to RCM and DOFR, and discusses the various steps in the approach for critical components in a dairy plant as a continuous. The homogenizer, Air heating system, drying chamber and vibrofludiser are most critical equipments in drying unit of milk powder plant in dairy industry. The proper combination of RCM and DOFR method provides a framework for utilizing operating experience in a more systematic way. The requirements for reliability parameters and data are therefore highlighted. The effort is made to fill gap between existing maintenance and new plan, together with some future challenges. After the application of RCM and DOFR process to critical components of the milk powder drying unit, there is a considerable improvement of 12-15% in uptime. Moreover, there is also considerable savings on setup loss, equipment failure time etc. Finally at the end the paper suggestions for maintenance of homogenizer, air heater, drying chamber and vibrofludiser are indicated to ensure trouble free operation and maximum service life, which may ultimately improve uptime and productivity.

KeyWords - DOFR Approach, Maintenance, RCM Approach, Reliability

I. INTRODUCTION

There are many industrial needs to be implemented in maintenance to achieve benefits on the basis of reliability, availability and cost. There are numerous maintenance programmes available but most important tools includes RCM and DOFR that are widely and successfully employed to improve performance of plant and its components.

Out of various process industries, we selected the milk industry for case study as India is the largest producer of milk in the world and is on the verge of assuming an important position in the global dairy industry.

After considering the scenario of the performance and working of dairy industries as continues process industry, following facts related to maintenance were pointed out.

(1). The average capacity utilization of dairy industries in India is 80-90 % approximately, whereas 20-30 % of possible production time goes towards maintenance of equipments.
(2). The approximate down time for the plant is about 15-20 % of the total production time and hence, provides unique challenge to increase up time of the equipment and plant by at least 10 % approximately.
(3). The total cost of production is high due to heavy expenses towards the maintenance work, which accounts for approximately 25-30 % of total cost.
(4). The shutdown cost is approximately Rs. 20000 to 25000 per hour.

In the present study, we have made an attempt to provide better solution for the said problems faced by the selected process industry i.e. the milk industry, Thermal power plant, and Waste thermal treatment plant, Nuclear power plant, through proper combination of RCM and DOFR methodology.

II. OVERVIEW OF RCM AND DOFR APPROACH

A. *RCM Approach*

RCM is a procedure to identify Preventive Maintenance requirement of complex and critical systems. Reliability Centered Maintenance (RCM) is relatively a new tool for continuous process industries and helps to identify the flaws in system design, compare several possible system configurations, minimize downtime, maximize operational readiness, reduce operating cost and develop maintenance priority. It addresses reliability issues during operation and maintenance.RCM analysis is capable to develop an improved maintenance optimization programme.

The basic steps in developing a formal RCM analysis are:

(1). Define the major systems and components. The user defines the systems. Cases where systems are extremely complex and this complexity makes analysis difficult, the user may opt to define subsystems as a means of organizing the problem into manageable pieces.
(2). For each system, define all "functions" of that system.
(3). For each of those functions, define the possible "functional failures" that could occur (i.e., what could go wrong that would prevent the system function from occurring).
(4). For each functional failure, define all possible "failure modes" (i.e., each equipment failure could be the cause of the functional failure).
(5). For each failure mode, state whether it would be due to improper operation, improper maintenance, or both.
(6). DOFR Approach
(7). Design Out for Reliability (DOFR) approach goes straight to the core of reliability issue to address design shortcomings by introducing improvements. This is better method when compared to the existing methods since one only needs to make the improvement once to gain ongoing benefits. With

DOFR one can apply the concept of redesign to all types of potential failures that cause problems in performance.

III. CASE STUDY

In the milk drying plant; homogenizer, air heating system, drying chamber and vibro-fluidizer are the critical units, without which it is impossible for drying unit to run effectively. As almost all above units are important and if any of the above will not function properly, whole plant will stop leading to loss of production. In the milk powder plant unit, Homogenizer is the first in series and if it does not work properly definitely the production will not start. Also, homogenizer is very costly equipment and it is a high speed rotating machineries, so it faces high wear and tear, and also vibration problems related to bearing, gears, spindles etc. Air heating system supplies hot air to the drying chamber to convert spraying milk droplets to the dry powder form. Any breakdown in hot air supply system or drying chamber can stop the production of the dried product. The dried products conform to powder or agglomerates, all depending on the chemical and physical properties of the feed and drying chamber design and its operation. The quality of dried products is depending on the defined operation of the drying chamber and air –heating system. Improper hot air supply can results in the burning of dried powder or scorching of dried powder in the drying chamber. To maintain uniform quality of the dried powder it is paramount important to maintain constant moisture content of the powder. The moisture content is depending on the feeding system, drying condition, hot air temperature and other operating conditions. i.e. Inlet temperature ,Flow rate of liquid feed (pump speed; pump pressure),Air flow rate (fan speed; position of baffles),Particle size (adjustment of atomizer).Among other operating conditions, outlet temperature and relative humidity of the outlet air are particularly important and need careful attention. However these can only be indirectly controlled by adjusting the primary conditions. For outlet temperature, the condition is dependent upon liquid feed intake. If the feed intake is increased, the outlet temperature will drop. If the intake is reduced, the outlet temperature will increase and approach the inlet temperature. The outlet temperature will also be affected by the air flow rate. For a constant inlet temperature and constant feed intake, an increase in the air flow will raise the outlet temperature. Thus, in milk powder plant unit the dried powder quality is interdependent on the operating condition of all the associate equipments. So, if any of the above will not function properly, whole plant will stop leading to loss of production till it repair.

A. Identification of Problem

For implementing effectively the RCM strategy, some basic problems related to performance of the above described equipments are recorded, which are as follows:

(1). Homogenizer electrical and Mechanical fault (tripped due to power failure ,Milk seal valve wear ,bearing wear and shaft misalignment)
(2). Cyclone blocked
(3). Loss of hot air supply
(4). Variation in Inlet temperature of hot air
(5). Miscellaneous Drier mechanical fault
(6). Power supply Failure
(7). Vibrofludiser belt slippage and vibro blocked.

B. Study of Maintenance Records and Calculation of Reliability Parameters

During visit to powder manufacturing drying unit uptime, down time and frequency of failure were recorded for the critical equipments for june 2013 to February 2014 and from these data different Reliability parameters such as MTBF, MDT, MTTR, MTBM, Hazard rate, Operational and Inherent availability were calculated.

The purpose of this task was to understand the performance behavior of critical equipments. Table 1 and Table 2 gives clear picture regarding these data and specimen calculation is given here as an illustration.

C. Sample Calculation

1) Calculation of MTBF:

MTBF = Uptime (U_t)/ No. of frequency of failure (N) = 710/20 = 30.6 Hrs

2) Calculation of Hazard Rate (H_r) :

Hazard rate (H_r) = No. of frequency of failure (N)/Uptime (U_t) = 1/MTBF = 1/30.6 = 0.032

3) Calculation of Mean Down Time (MDT) :

MDT = Downtime (D_t)/ No. of frequency of failure (N) = 98/20 =4.9

4) Calculation of Mean Time To Failure (MTTR):

MTTR = 0.3 X MDT = 0.3x 4.9=1.47

5) Calculation of operational availability (A_{op}):

A_{op}=MTBF/(MTBM+MDT)=30.6/(30.6+4.9)=0.86

6) Calculation of inherent availability (A_{in}):

A_{in} = MTBF/(MTBF + MTTR) = 30.6/(30.6+1.47)=0.96

TABLE 1 RELIABILITY PARAMETERS

Month	No of failures (drying plant)	Total run time(hrs)	Up time (hrs)	Down time(hrs)	MTBF(hrs)	Hz	MDT	MTTR	Operational Availibility	inherent Avililibility
Jun-13	20	710	612	98	30.6	0.032	4.9	1.47	0.86	0.96
Jul-13	22	710	600	110	32.2	0.031	5	1.5	0.86	0.95
Aug-13	18	710	608	102	33.7	0.029	5.67	2.15	0.85	0.94
Sep-13	10	480	440	40	44	0.02	4	1.2	0.91	0.97
Oct-13	15	710	615	95	41	0.02	6.34	1.9	0.86	0.88
Nov-13	18	710	618	92	34.3	0.02	5.12	1.53	0.87	0.95
Dec-13	20	710	612	98	30.6	0.032	4.9	1.47	0.861	0.95
Jan-14	21	710	608	102	28.9	0.033	4.85	1.45	0.85	0.93
Feb-14	20	710	600	110	30	0.033	5.5	1.65	0.84	0.94

Fig. 1: mins /day for schedule maintenance

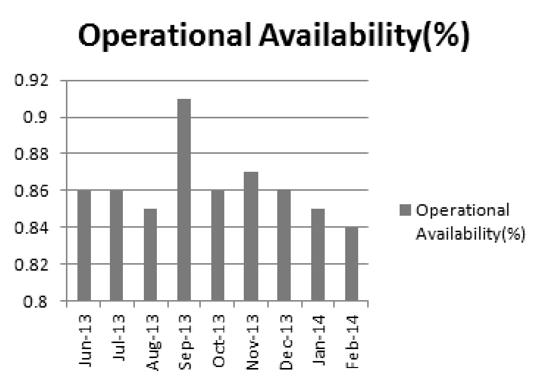

Fig. 2: Operational Availability graph

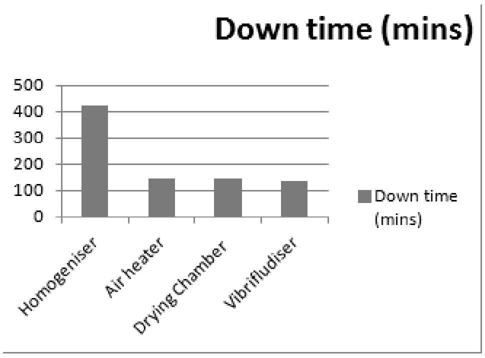

Fig. 3: Down Time Data Graph

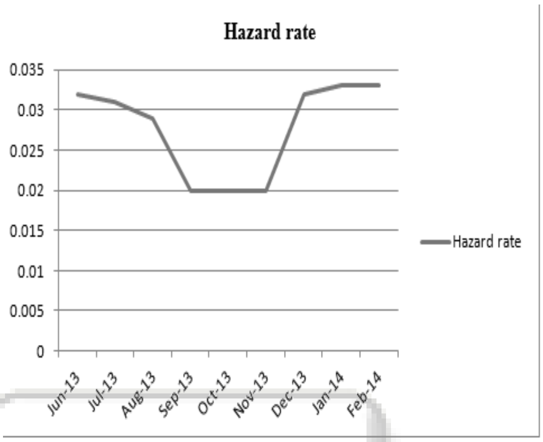

Fig. 5: Relibility bath curve (Milk powder plant)

fig 1" shows overall availibility of Drying plant .From the said graph we can observe that the drying plant operational avialibility for the month of june 2013 –feb 2014 is approximately 85% per month.In the month of september the operational availibility reaches to 91% due to yearly preventive maintenance in the said month.Otherwise the operational availibility of the drying plant is between 84%-87% only.which results in loss of production and enhancement of production and maintenance cost.

"fig 2 " shows critical equipments versus their respective downtime. The "fig 3 " shows the month versus hazards rate .The graph 3 represents Reliability Bath tub Curve for the study. The Bath tub curve is a plot of the failure rate of a product versus its operating life (time). Three types of failures exist according to the failure occurred during a product's operating life and accordingly the bath tub curve is divided into three phases.

In Phase 1, the failure rate is decreasing and the items become less likely to fail as their survival time increases.

In Phase 2 , the failure rate becomes nearly constant, (In this period, the failure rate is lowest and nearly constant). The useful life period is the most common time frame for making reliability predictions.

In **Phase 3,** the failure rate increases due to wearing out of critical parts with the wearing out of the critical parts, it takes less stress to cause system failure. The overall system failure rate increases.

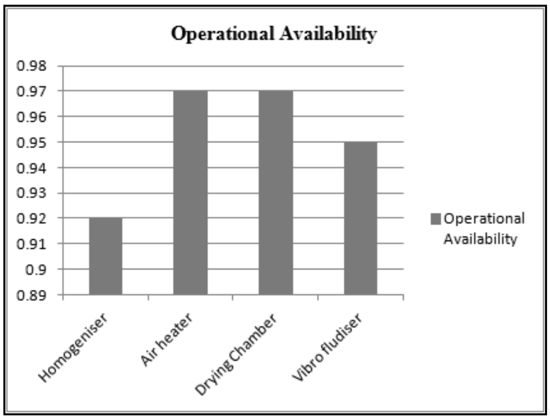

Fig. 6:

Graph 4shows the independent operational availability of critical equipments of milk drying plant. From the maintenance breakdown data, the individual operational availability has calculated for the critical equipments; It shows that the milk powder plant operational availability is interdependent to critical equipments performance and breakdown.

From the data analysis and discussion we can say that the overall availability of the plant can be enhanced by enhancing the availability of all the major system /subsystem simultaneously. To enhance the overall availability of drying milk powder plant, emphasis has been made on the causes of the failures and remedies to prevent the said failure causes and their solutions. The remedial suggestions are provided to enhance the up time of the milk powder plant. The solutions are suggested on the basis of historical maintenance and repair data and personal experience of the supervisor, labours and other staffs at the production department.

IV. Implementation of RCM Approach

After understanding and recording the problems and performance behavior of critical components (i.e. Homogeniser, Air heating system, Drying chamber and Vibrofludiser), important maintenance processes are suggested over tradition approach so as to maximizing the uptime.

Reliability centered maintenance approach for homogenizer, Air heating system, Drying chamber and Vibrofludiser are developed by using steps discussed previously. The main function of homogenizer is to convert condensate raw milk coming out of condensing unit to fine spray of atomization so as to maximize heating surface area which produces powdered form by contact with hot air coming out from air heater.

In the drying chamber, the milk concentrate from the atomizer is dispersed as a fine fog-like mist into a rapidly moving hot air stream, which causes the individual mist droplets to instantly evaporate wherein the hot air is supplied from the air heating system. Milk powder falls to the bottom of the chamber, from where it is taken to the vibro fluidizer, where final drying takes place to required product moisture. The fines are separated and taken to the cyclone.

The Cause and effect for each functional failures or problems recorded previously was analyzed and then a part of solution for each failure remedial action was suggested.if an operation is analyzed critically, if the right questions are asked and if clear methods are applied to find solutions, operations can be improved.

V. RESULT AND DISCUSSION

For studying and analyzing exiting data, the last seven months data were taken, then considering the limitations and results required, the problem solution is carried out in the best possible manner by applying RCM process.

Table 3 shows the comparison of primary results before and after the application of RCM and DOFR. Moreover, the improvement in percentage is also calculated and shown in this table.

TABLE. 1: SUGGESTED CORRECTIVE ACTION

PROBLEMS/ CAUSES	**CORRECTIVE ACTION**		
	Effect	**RCM PROCESS ACTION** **Remedial Suggestion**	**ACTION PLAN**
Pressure pump/ Feeding system problem ,wear in bearing, shaft misalignment at homogenizer	Enhancement of moisture content /burning of powder particles in the drying chamber	Dual feed system /stand by unit	Optimization of pressure pump breakdown causes
	Cyclone chocked	Hot air supply optimization	Feeding system operating condition optimization
	Plant shutdown		Original company made bearing installation
Drying chamber breakdown	Scorching /burning of milk powder particles in the chamber due to variable inlet air temperature	Limiting air inlet temperature and air outlet temperature	Optimization of temperature parameter
	divert valve for agglo/non agglo line chocked	Inclusion in Preventive maintenance	Optimization of operating condition and relative humidity of outlet air.
Hot air supply system tripped	Air supply fan tripped, Air leakage, Scorching /burning of milk powder particles in the chamber.	Multi pass heat exchanger installation between air inlet to the drying chamber and check leakages frequently. To check the leakage with the help of Thermo leak detector frequently.	Multi pass heat exchanger installation. To procure Thermal Leak detector
Vibrofludiser chocked	Vibro chocked, Belt slippage, breakdown	Cooling system and Fluid bed operating condition optimization	Operating condition optimization

TABLE. 1: SUGGESTED CORRECTIVE ACTION

TABLE. 2: RESULT COMPARISION (Approximate per Month)

MAJOR LOSSES	**BEFORE (HRS.)**	**AFTER (HRS.)**	**IMPROVE. (%)**
Homogenizer (Pressure	40-50	35-45	12.5

pump/Feeding system)			
Drying chamber	20-25	14-19	30
Hot air supply system	15-20	10-15	**33**
Vibrofludiser	25-30	20-25	20

TABLE. 2: RESULT COMPARISION (Approximate per Month)

VI. CONCLUSION

A proper implementation of RCM and DOFR for critical components is followed and within time frame systematic maintenance task is concluded as follows:

A. Homogenizer under **RCM** process
B. Drying chamber under **RCM** process
C. Relative humidifier under **DOFR** process
D. Multi pass heat exchanger under **DOFR** process

After the application of RCM and DOFR process to critical components of the milk powder drying unit, there is a considerable improvement of 12-15% in uptime. More over, there is also considerable savings on setup loss, equipment failure time etc

ACKNOWLEDGEMENTS

We are very much thankful to the people associated with powder manufacturing unit for giving us such a wonderful opportunity to pursue this study.

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