Design Out For Reliability & Long Term Profitability

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Abstract

How do companies prosper? Most of us know the answers. Reduce costs. Improve quality. Utilize existing technology to the maximum. Unfortunately, most of the present methods do not fulfill the objectives comprehensively. For example, Total Productive Maintenance (TPM) accepts a machine as it is and tries to ensure basic maintenance and operating conditions to prevent accelerated degradation and failures. On the other hand, Reliability Centred Maintenance (RCM), now an integral part of TPM development, tries to prevent or take safeguards against the consequences of failures and operate the machines within their design limits. However, the RCM process may be best described as a method of living with the imperfect which leads to reducing operating costs from their present levels but rarely tackles the root design imperfections [1].

The new approach presented in this paper called Design Out for Reliability (DOFR) goes straight to the core of reliability issue to address design shortcomings by introducing improvements. This is a better method when compared to the existing methods since one only needs to make the improvement once to gain ongoing benefits. In contrast the use of Condition Based Maintenance (CBM) or Time Based Maintenance (TBM) is an ongoing activity with recurring costs which aims at reducing the effects of unreliability, not improving the reliability itself [1]. The key feature of the new approach DOFR is to tackle unreliability not its effects or consequences? That is we tackle the root cause that causes problems in business operations not its symptoms.

However, there are two prerequisites for implementation of DOFR. First, a management team that believes in innovation and is market driven. Second, the approach would need investigators who are very competent and knowledgeable and are provided the time and funds to do the analysis/synthesis to make the improvements [1]. Clearly it may be applied to companies that see the entire operation of an organisation as a dynamic system and believe that the investment will pay for itself.

With DOFR, we apply the concept of redesign to all types of potential failures that causes problems in business performance. However, in this paper, we would only discuss the issue of equipment reliability with examples since in modern manufacturing 'managing equipment effectively' is a fundamental factor of production. In the now traditional approach only those failures that were not age related and were also not susceptible to condition monitoring were treated to reliability improvement through design out. DOFR extends this to all modes of failure related to equipment that affect business performance.

1. Introduction

Improving reliability means freedom from failures. This is done by improving the life of a component, machine or event. There are various types of failures in an organisation. Equipment fails. Quality fails. Process fails. Product fails and so does safety. Needless to stress that improvement in one aspect leads to the improvement of other aspects as well. However, there still remains a need to develop reliability of each of these aspects individually. Whatever aspect, the organisation chooses to improve, the improvement in reliability has far reaching effects like the following:

1. Reduction of cost and improvement in profits
2. Improvement in Quality, markets and products
3. Improvement in Productivity and Cost effectiveness of internal processes of an organisation.
4. Improvement in Technology, Safety and Environment
5. Improvement in Human Talent, Innovative capability and Knowledge base of an organisation.
6. Improvement in Information management

Clearly, the answers to 'How a company becomes a winner in the market place' lies within the organisation itself and improvement of reliability in all aspects of the organisation holds the key to such answers since there would always be a physical limit on 'economies of scale' and 'scaling up of technology'. We would examine the effects of DOFR on organisational performance and leadership position thru examples.

2. TBM, CBM, RCM, TPM ….

RCM is a method of studying ways in which a system's functions can fail, and the consequences of those failures. It helps determine the most appropriate, cost-effective proactive maintenance strategies to counter the effects or consequences of such failures. The main objectives of RCM are to reduce operating costs from existing levels and reduce the consequence of equipment failures; not directly the failures.

In short, RCM may be described as a method of living with the imperfect which leads to reducing operating costs from their present levels but rarely tackles the root design imperfections [1]. DOFR approach goes straight to the core of reliability issue to address design shortcomings by introducing improvements. This is a better approach because one only needs to make the improvement once to gain ongoing benefits and reduce maintenance activities. The use of CBM or TBM in contrast, is an ongoing activity and with recurring costs which aims at reducing the effects of unreliability, not improving the reliability itself. This is because CBM focuses on detection of various faults that develop during operation. It tackles a part of the problem but not the whole. It is more concerned with detection rather than aim for a permanent solution to the problem. Moreover, the practitioners of CBM are not very inclined to establish relationships between the various problems or disturbing factors, a necessary effort for a permanent solution. On the other hand, TPM aims to restore equipment to its original condition and maintain good operating condition and maintenance skills to prevent failures from taking place. It treats problems in an isolated way as they surface thru small improvements – called 'Kaizens'. It therefore, fails to discover/anticipate potential problems thru system study (studying equipment as a whole) and solve potential modes of failures simultaneously (in one go). Similarly, TBM is concerned with discarding/replacing a machinery element at predetermined interval with the assumption that the useful life of the element is over. It does not attempt to improve or extend the useful life to the maximum possible limit. Hence, the present maintenance management strategy and planning is flawed and gives a very limited impact on organisational performance. Moreover, both CBM and TBM are not very concerned with 'good operations'. In addition, present maintenance planning is also not very concerned about improving the other important issues of organisational performance like quality, technology improvement and the like.

Thus DOFR as an approach overcomes such difficulties, shortcomings and limitations. The key feature of DOFR approach is to tackle unreliability not its effects or consequences. The process focuses on the root cause not its symptoms. Moreover, it relates various faults and connects other issues of organisational growth and performance. Therefore, DOFR redesigns equipment management system customized for an organisation.

3. Reasons for Equipment failures [2]

The reasons for equipment failures may be summed up in the following manner:

1. Natural Degradation
2. Human Factors
3. Tolerance Stacking
4. Variation in Operating Parameters
5. Material Incompatibility of spares.
6. Local factors
7. Root Design Imperfections like unclear parameter definition, material incompatibility, energy transfer, design morphology, inappropriate signals etc. This is more so, since industrial equipment design cannot be standardized as functional requirements and local requirement vary from case to case. Hence at times, design of an industrial machine is a matter of trade offs, compromises and optimization and at times invalid assumptions leading to imperfections.

However, the underlying cause of the first six causes as listed above is Root Design Imperfections. Such causes are the basis of failures, delays and wastages in an organisation where technology is one of main factors of production. Tackling delays, wastages and failures is the answer to enhanced organisational performance since there is always an effective upper limit to 'economy of scale' and 'equipment scaling' once a factory is set up. Moreover, considerable investments are needed to improve economy of scale. The objective of DOFR is to remove or tackle all such imperfection in a step by step manner by following a systematic but flexible methodology. The methodology is flexible in the sense that it varies in relation to an organisation's degree of reliance on technology to produce its products and slowly over time evolves a customized system relevant to an organisation to meet its business challenges.

4. Cases and Examples

The concept of DOFR may be illustrated thru real life cases and examples. Though there are many cases, all cannot be discussed due to space limitations. Hence, the problems are divided into three types: simple, intermediate difficulty, higher difficulty and two problems from each category are selected as illustrations. Then the overall effect of DOFR in an industry is shown and discussed.

Simple Examples:

a) Problem: A shaft fractures within 3 to 6 months of operation from the bearing shoulder area.

Table 1

Method	Actions	Cost	Effects
Traditional	Replace shaft as it breaks	High	Loss of productivity. Recurring cost
RCM	Monitor the shaft for fractures and replace during opportunity	Cost lower than Traditional method by not eliminated	If opportunities are not available then there is a loss of productivity otherwise only a cost of replacement is incurred. Recurring Cost.
DOFR	Redesign the shaft with shoulders < 5% change in diameter & change material.	One time cost. Cost equal to original shaft	Life enhanced to 10 years. No loss of productivity due to shaft breakage. No recurring cost. Life cycle costs much lower, low inventory. Maintenance free.

b) Problem: A grease lubricated bearing of a high speed fan seizes frequently. Life approximately one year.

Table 2

Method	Actions	Cost	Effects
Traditional	Replace bearing as and when it breaks.	High	Loss of productivity. Recurring cost
RCM	Monitor bearing life with vibration monitoring and replace during opportunity	Cost lower than Traditional method (since opportunity utilized) but not eliminated. Recurring cost remains.	If opportunities are not available then there is a loss of productivity otherwise only a cost of replacement is incurred. Recurring Cost.
DOFR	Redesign with oil lubricating system since D x N > 3500.	One time cost.	Life enhanced to three years. No loss of productivity No recurring cost. Life cycle cost much lower; low inventory. Maintenance free.

Problems of intermediate difficulty:

c) Problem: A motor driving a crusher main shaft thru pulley and belt mechanism, burns out randomly (approximately once a year) and the belts become slack at regular interval (more-or-less after every three months or so).

Table 3

Method	Actions	Cost	Effects
Traditional	Replace motor as and when it burns out and adjust/replace belts regularly.	High	Loss of productivity. Recurring cost.
RCM	Monitor motor to determine the optimum replacement time. Replace belts every three months. the shaft for fractures and replace during opportunity	Cost same as Traditional method	If opportunities are not available then there is a loss of productivity otherwise cost of replacement is incurred. Recurring Cost.
DOFR	Redesign the pulley size taking into account the principles of Moment of Inertia and radius of gyration.	Low one time cost.	No loss of productivity. No recurring cost. Maintenance free.

d) Problem: Dry hot abrasive material falling on a rubber conveyor belt from a chute. Creates a lot of dust and causes secondary damages to other elements of the conveyor system. Makes inspection difficult due to unhygienic condition and dusty atmosphere in an enclosed space.

Table 4

Method	Actions	Cost	Effects
Traditional	No definite answer. Clean regularly by casual workers. Inspect whatever best was possible and replace when defects were found or after a breakdown.	High	Loss of productivity. Recurring cost. Secondary damages high. High inventory. High maintenance effort.
RCM	No answer. Only better maintenance planning and strategies.	High	Loss of productivity. Recurring cost. Secondary damages high. High inventory. High maintenance effort.
DOFR	Redesign the system by matching the velocity of falling material to that of the belt.	Practically no cost.	No loss of productivity. No recurring cost. No secondary damages. Maintenance effort nil. Low inventory.

Problems of Higher Difficulty:

e) Problem: In a steel mill, journal bearings seized rather randomly. There were 28 reported cases in a period of one year.

Table 5

Method	Actions	Cost	Effects
Traditional	Pay attention to lubrication. Pay attention to fitting and tolerances. Replace when damaged	Very high as the bearings were imported	High loss of productivity. High recurring costs. High inventory. High maintenance efforts.
RCM	No definite answer. Probably monitor cleanliness levels and monitor wear of bearings, which was not possible due to inaccessibility and costs. Pay attention to tolerances and eccentricity during fitting.	High	Productivity loss continues. No solution. High and costly inventory. No reduction in maintenance efforts.
DOFR	Use heater in the lubrication sump to lower viscosity of the oil entering the bearings within 93 to 95 cSt.	No cost,	Life enhanced to more than 4 years. No loss of productivity. No recurring cost. Very low inventory. No maintenance effort.

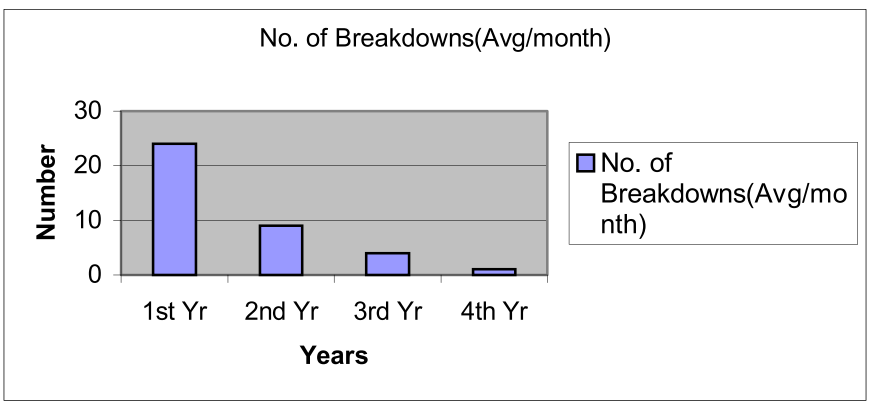
f) Problem: In a particular conveyor of a steel mill, the motors usually tripped at least once a month. The average current consumption was 12 amps which at times shot to 18 amps. There were cases of many bush bearing failures and failure of other components.

Table 6

Method	Actions	Cost	Effects
Traditional	Lubricate, inspect, replace	High, since failures did not reduce.	Loss of productivity. High recurring costs. High maintenance efforts. Higher inventory
RCM	Monitor, replace. Monitoring did not help.	High, since the solution did not work	Loss of productivity continues. High recurring costs. High maintenance efforts. Higher inventory.
DOFR	Redesign thru small viable modifications taking the entire equipment as a system.	Very low	No tripping observed for five months after modifications. Average current consumption dropped to 8 amps. No failures of other components. No maintenance effort. Less inventory.

Overall effect of DOFR:

When DOFR was applied to a chemical company the results were impressive. This company was having on the average of 24 failures a month with their critical machines. After an integrated effort of the application of DOFR the number of failures came down to one failure per month for the critical machines (46 in number). The graph (1) below illustrates the result achieved over a period of four years.



Graph 1

The graph also shows the consistency achieved. But the system is still far from perfect. More work is to be done to achieve better results. The accompanying table (Table 7) presents a comparative analysis of the some important parameters of improvement.

Table 7

Sr. No	Parameters of Audit	Before 1998	After (May 01)
1	Reliability (Moving Reliability Index) –only considered for critical flow path.	75% (24 failures/month)	95% (One/Zero failures/month)
2	MTTR (Mean Time To Repair)	4 hours	2 hours
3	Steady State Availability (Markov Analysis)	96.10%	99.5 %
4	Median Corrective Maintenance Time (i.e. 50% of the jobs would be completed within this time)	2.49 hours	1.64 hours
5	Maximum Corrective Maintenance Time (i.e. 95% of the jobs would be completed within this time)	10.86 hours	7.16 hours
6	Maintenance Manpower	126	107
7	Spares cost	Rs195.83 Lakhs	Rs 177.85 Lakhs
8	Annual Mean Maintenance Labour Hours in a year	4675.66 hours	3108.87 hours
9	Maintenance Budget	Rs 3.4 Crores	Rs 1.41 Crores
10	Production rate	1.66 T/hr	1.87 T/hr
11	Quality	3.5 σ	6σ
12	Leadership Position	4Th	1st (sells at premium)

It is interesting to note that over a period of five years, market forces have pushed down the company's selling price almost to the extent of 20%. But even with lower selling price the company is making more cash gains than they did when selling prices were higher. Also note the reduction in cost as reflected in the maintenance budget (a reduction of about 58%) and the improvement in quality. Note that management with a sharp focus on reliability improvement of equipment achieved market leadership position from a lower position in about two years time. This has been possible through continuous improvement in reliability of equipment and productive system and subsequent rise in sustained productivity, quality and cost reduction (the key factors to face competition).

5. Advantages

1. Companies need to do the improvements only once. Thereafter the company gains ongoing benefits.
2. Recurring cost of maintenance is reduced to nil or minimum. And maintenance effort is also reduced to the minimum. It follows that maintenance planning is reduced to the minimum.
3. With design imperfections removed and functionality improved, quality is improved and the process is also made more stable.
4. Investment made in DOFR will pay for itself.

6. Prerequisites

1. It needs a management team that believes in innovation and is market driven. Without market demands innovation is not possible since innovation is a response to customer demands.
2. DOFR would need investigators who are competent and knowledgeable and are provided the time and funds to do the analysis/synthesis to make the desired improvements. It means that investigators need to know in depth the physical and chemical laws, principles and effects to solve engineering problems. Research shows that the average engineer knows 50 to 100 physical and chemical laws, principles and effects which can be used for solving engineering problems, but there are over 6000 such effects described in scientific literature [3].

7. Conclusions

1. DOFR's concept of redesign may be applied to all types of potential failures so that the intrinsic life (reliability) is enhanced. In the now traditional approach only those failures that were not age related and also not susceptible to condition monitoring were treated to reliability improvement thru design out. DOFR extends this to all modes of failures affecting business performance thru the understanding of the complex interrelationships between different modes of failures, observing the system as a whole and design thinking.
2. Operational cost is minimized, so are the delays and wastages. Quality losses due to malfunctioning of equipment are minimized. Therefore, the companies would be not only be able to reduce their operating costs to the minimum but also achieve and sustain a very high level of quality (6σ).
3. Thru the application of DOFR, maintenance effort is greatly reduced and maintenance planning is simplified and optimized to the barest possible. Potentially this feature may useful to downsized companies.
4. On continuing application organisations would become highly competent to engineer new technology as and when the need comes to gain competitive advantage.
5. Engineering knowledge base (a new factor of production) of the organisation is greatly improved. It would help an organisation to respond to competitive forces effectively within a short time.
6. DOFR is a better method when compared to the existing methods since one only needs to make the improvement once to gain ongoing benefits.
7. However, the approach would gain a bad name if applied by less competent/untrained people. This of course has been the problem that has plagued CBM and indeed maintenance improvement generally [1].

8. References

1. Discussion notes and comments of Prof. Tim Henry, Chairman, WM Engineering Ltd., Manchester, U.K., Oct, 2003, internal note of RMC
2. Dibyendu De, Minimizing Equipment 'Failures' To Gain Competitive Advantage, International Journal of COMADEM, (2003), 6(3) July 2003. PP. 19-24
3. George E. Dieter, Engineering Design, 3rd Edition, McGraw Hill International Editions, 2000, PP. 168

9. Notes:

DOFR is a part of the overall organisational reliability improvement plan which is named as ROMS ™ (Reliability of Manufacturing Systems ™ or Result Oriented Management Systems ™) developed by RMC.