Mechanical Reliability Management for Recycle Gas Compressor Using Reliability Centered Maintenance (RCM)

Wee Chabthanom

1Rayong Engineering and Plant Service Co.Ltd, SCG Chemicals, Rayong, Thailand 21150
* Corresponding Author: Tel: (6638) 383393 ext 2208
E-mail: weec@scg.co.th

Abstract

Plant reliability has become much more challenging due to aging assets, high turnover rate, environmental and safety regulations, especially for high value business such as petrochemical plants. One of the acclaimed methodologies to optimize reliability is Reliability Centered Maintenance (RCM). This paper proposes the implementation of RCM at Linear Low Density Polyethylene (LLDPE) Plant Recycle Gas Compressor of SCG Chemicals Group. The results are compared with the traditional maintenance strategy. It is markedly found that the ratio of condition based maintenance is significantly increased (from 4% to 8%) while time-based maintenance is lessened (from 16% to 12%). After the implementation of RCM, the reliability of the machine is immensely boosted. The Mean Time Between Failure (MTBF) of the machine is increased from 360 days to 1091 days. In conclusion, RCM is the methodology proved to maximize plant reliability while minimize the maintenance work which leads to a magnification of the production opportunity.

Keywords: Reliability Centered Maintenance, Maintenance Engineering Technology, Reliability Optimization

1. Introduction

The definition of “Maintenance” can be defined as any operation or process done on machine to enhance the efficiency of the machine before or after the breakdown. Good maintenance can be a contribute part in more reliability, smooth production and also cuts the life cycle cost of the machine down. Traditionally, maintenance work can be separated into four types [1] referred to “Fig.1”.

![Fig.1 Maintenance strategy](image-url)
First, reactive maintenance, this maintenance work occurs as the breakdown is present. Normally, for high competitive business with high loss such as, petrochemical business, machine breakdown means an opportunity loss. Then, this kind of maintenance is not acceptable.

Second, preventive maintenance or time-based maintenance, this one is undertaken before the interruption of the production or major breakdown.

Third, condition-based maintenance, this one uses the real condition of the operating machine to generate maintenance plan. This type of maintenance depends significantly on the accuracy of predictive maintenance techniques such as vibration monitoring or oil analysis. The last one is design out. This type of maintenance is to find the weakness in design of the machine and enhance it. However, the main problems in modern industries are the optimization of maintenance strategy which has to correspond with failure pattern. In the past, it is believed that most machine failures are age-related referred to “Fig.2”.

![Age-related failure pattern](image)

**Fig.2 Age-related failure pattern**

From this notion, numbers of machine manufacturer encourage their customers to do time-based maintenance. However, from the research in aviation business, it is found that the portion of age-related failure is just 2% comparing with 14% of random failure or 68% of enfant mortality pattern as shown in “Fig.3”.

![Portion of failure pattern in aviation business](image)

**Fig.3 Portion of failure pattern in aviation business**

That means, if we use time-based maintenance strategy, most of them would be futile or the failure rate of the machine would be increased. This leads to the development of a methodology to develop suitable maintenance strategies for each machine, Reliability Centered Maintenance (RCM). At first, the concept of RCM was developed in early 1960s by the Commercial Airline Industry Maintenance Steering Group, the Air Transport Association, the Aerospace Manufacturers Association, and the US Federal Aviation Administration. This methodology was designate MSG-1 and was continuously updated to MSG-3 in 1978. Even it is originally structured to meet the requirement of airline industry [2]; RCM approach soon has found application in various other fields, specially those needing safety and reliability, for example, military, nuclear power plants, coal mine, petrochemicals [3,4], etc.

The objective of this article is to illustrate an approach for application of RCM to the process plant, petrochemical industry. This article
will be highlighting the process of implementation and the benefit of RCM at recycle gas compressor, LLDPE plant of SCG Chemicals.

2. RCM Methodology

2.1 What is RCM?

There are many definitions of RCM, but in conclusion, RCM is the process used to determine the maintenance requirement of any physical asset in order to ensure that it can be operate as define in its operating context [5]. The selecting maintenance strategy is based on safety, environment, operational and economic criteria. After RCM process, reliability of the machine and resources will be at the optimum point.

2.2 RCM Implementation Steps

The implementation steps of RCM are based on seven questions as followed

2.2.1 What are the functions and associated performance standards of the asset in its present operating context?

This is the first step in implementing RCM. Functions are what each asset is expected to do according to operating context with performance standard.

2.2.2 In what way does it fail to fulfill its function?

The objective of this step is to define the functional failure. Because for us to apply a suitable failure management tools, we need to identify what failure can occur.

2.2.3 What causes each functional failure?

The causes of functional failure in RCM are called failure mode. Failure modes that we considered in RCM analysis are based on the event occurred on similar equipment, failure which is currently prevented by existing maintenance plan and failure that never been happened but possible according to engineering knowledge.

2.2.4 What happens when each failure occurs?

The fourth step in RCM is defining the failure effects. This failure effects describe what happens after each failure mode occurs which will be a useful information to evaluate the consequence of the failure.

2.2.5 In what way does each failure matter?

This step is called failure consequence evaluation. In RCM consequence of each failure mode will be separated into four categories, Hidden failure consequence: no direct impact normally associated with protective function, Safety and environment consequence, Operational consequence, and Non-operational consequence.

2.2.6 What can be done to predict or prevent each failure?

Next step of RCM is to define maintenance measure to prevent each failure mode. Maintenance tasks are logically selected using decision diagram shown in “Fig.4”. It can be seen that condition based maintenance is taken in to consideration first.

![Fig.4 RCM Decision diagram for failure consequence and task selection](image)
2.2.7 What should be done if a suitable proactive task cannot be found?

If the proactive task such as condition based maintenance or time-based maintenance cannot be applied or not feasible. RCM has an option to deal with this kind of failure mode, such as, redesign, no schedule maintenance or combination of task.

2.3 RCM Benefit

After implementing RCM, safety and reliability of the systems will be enhanced by the development of high quality maintenance plan focused on their functions. The consequence of the failure will be mitigated. Moreover, the review of failure consequences focuses on maintenance tasks that are more effective, and divert the resources away from those which have little effect. This help to ensure reliability and resource optimization.

3. Case Study: RCM Implementation at recycle gas compressor, LLDPE Plant, SCG Chemicals

LLDPE plant is one of the plastic pellet production plants under SCG Chemicals. One of the main equipment in LLDPE plant is recirculation compressor. This equipment is used for circulate the gas within polymerization reactor. If the recirculation compressor breakdown, it will affect the reaction in the reactor and the plant will be shutdown.

When we considered breakdown history in “Fig.5”, it can be seen clearly that from year 1999 to 2003, breakdown occurred every year. Moreover, from root cause analysis, we found new root causes of machine breakdown regularly. That means our maintenance plan may not be suitable, and we need to be more proactive. Then, we implement RCM on this machine.

Fig.5 Recycle gas compressor failure history

After we decide to implement RCM, we set up the team for RCM analysis. Normally, RCM team is consisting of RCM Facilitator, Process Engineer, Mechanical Maintenance Engineer, Instrumentation Maintenance Engineer, and Electrical Maintenance Engineer. The schedule for this project is around two months.

Then, we follow RCM implementation step. First, define function of this recycle gas compressor as in “Fig.6”, totally 45 functions.

Next step is to define functional failure for each function. From 45 functions, we get 106 functional failures as shown in “Fig.7”.

Fig.6 Function of recycle gas compressor

Fig.7 Function failure of recycle gas compressor
After that, the most important step in RCM, we have to define the causes of each failure. For this equipment we have 339 failure modes defined as shown in “Fig.8”.

![Fig.8 Failure modes of recycle gas compressor](image)

After we get the failure modes, we consider the effect of each failure mode as shown in Fig.9

![Fig.9 Failure effect of recycle gas compressor](image)

After that, we use the decision diagram to find what to do to prevent the failure modes. For example, for failure mode compressor bearing lubrication failure, we find that it affects operational, so we decide to use time-based maintenance to replace oil every year. This task can be done by operator themselves.

![Decision diagram for compressor bearing lubrication failure mode](image)

4. RCM Implementation Result

After implement RCM, we get the 17 condition-maintenance tasks, 44 time-based maintenance tasks, 23 redesigns, 22 work instruction and 62 functional tests as shown in Table 1. It is also found that the ratio of condition based maintenance is significantly increased (from 4% to 8%) while time-based maintenance is lessened (from 16% to 12%). After the implementation of RCM, the reliability of the machine is immensely boosted. No breakdown can be found, and the MTBF of the machine is increased from 360 days to 1091 days. The resource used for this project is around 400 man-hours.

![Recycle gas compressor breakdown result after RCM implementation](image)

Table 1 No. of task for recycle gas compressor

<table>
<thead>
<tr>
<th>Function</th>
<th>Failure Mode</th>
<th>CBM</th>
<th>TBM</th>
<th>Redesign</th>
<th>WI</th>
<th>Functional Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>45</td>
<td>106</td>
<td>339</td>
<td>17</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>22</td>
<td>62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Conclusions

This paper addresses the applying of RCM in petrochemical plant. RCM is the methodology applied for optimize plants reliability and resources by considered maintenance strategy based on functions of the system. RCM
methodology is applied on recycle gas compressor which the breakdown occurred every year. After implementing RCM, the maintenance tasks applied to the equipment change. Condition-based maintenance is increased while time-based maintenance decreased. We also get the redesign recommendation from RCM analysis. After we implement all tasks and redesign, it is found that breakdown for this equipment reduces to zero since then.

In conclusions, RCM methodology is proved suitable for enhancing and increasing effectiveness of planned maintenance in petrochemical plants.

6. References