RISK MITIGATION THROUGH STRATEGIC MAINTENANCE AND RELIABILITY

Manufacturing plants today contain numerous equipment items that require some form of maintenance to help deliver company output and profit. This paper presents a practical case study detailing various methods that can be applied to achieve a structured approach to maintenance and reliability.
INTRODUCTION

Manufacturing plants today contain numerous equipment items that require some form of maintenance to help deliver company output and profit. This paper presents a practical case study from the initial Reliability Centered Maintenance concept using a computerised simulation approach, followed by the detailed Root Cause Analysis on some high consequence failure modes.

The company had recognised through their internal data management processes that a particular critical equipment item was causing unexpected outages resulting in a loss of business profit. It was therefore decided by the business to embark on a continuous improvement path that would enable them to fully understand the equipment and how to prevent the unexpected losses from re-occurring. The approach taken for the critical equipment item was to initially perform a Reliability Centered Maintenance (RCM) study, in which all the likely and the dominant failure modes are identified. A Failure Mode Effect and Criticality Analysis (FMECA) model was then populated with the consequences of failure using the corporate risk matrix and financial cost of failure. The outputs of the study now gave the company the ability to optimise the choice of maintenance tasks from both a cost and safety perspective.

Once the optimum maintenance plan was developed, lifetime simulations using a Monte Carlo simulator were performed to provide a forward maintenance budget prediction and also to assess the effectiveness of the plan in reducing the impact of any critical failures. Where maintenance was not able to reduce the failure effects to acceptable levels, they were subjected to detailed root cause analysis in order for effective solutions to be identified.

In conclusion, this paper illustrates how a manufacturing plant developed a fully documented maintenance plan with associated work instructions for implementation through the site maintenance management system. The RCM study addressed a critical item of equipment within the manufacturing facility to develop a plan to ensure safe, reliable and economical use of the plant item throughout its life.

1.1 RELIABILITY CENTERED MAINTENANCE

Reliability Centered Maintenance (RCM) is a systematic approach that focuses on preserving function rather than preserving the asset. It addresses only failures that matter using a logical process for making maintenance decisions.

During this process, the equipment is broken down to the lowest maintainable item. The failure causes for each maintainable item are then identified and analysed. If reliable failure/maintenance history is available, then this can be used to establish the failure rate or expected life of each failure cause. However, more often than not this information is not readily available or its accuracy is not very reliable.

In such cases this information can be estimated based on technical, operational and maintenance experience on similar machines, as well as general engineering knowledge. The maintenance strategy for each failure cause identified must also be derived. These strategies may be predictive maintenance, preventive maintenance or a run-to-fail strategy.

As part of the RCM process, the failure effect or failure consequence is assigned to each failure cause. It is important to identify the failure causes that have a potential impact on the availability of the equipment so that the equipment can be correctly modeled when the data is transferred into a Reliability Block Diagram.
1.2 RELIABILITY BLOCK DIAGRAM

Reliability Block Diagrams (RBD’s) are a tool used to carry out a system availability analysis and produce performance predictions. They are made up of series and parallel relationships that represent equipment redundancy levels. The RBD can predict downtime, number of interruptions and the Mean Time Between Failures (MTBF). The information collated during the RCM process can be utilised to create the Reliability Block Diagram (RBD) model.

1.3 ROOT CAUSE ANALYSIS

Root Cause Analysis is a problem solving methodology that is aimed at identifying the root causes of problems or events. If the root causes are identified and effective solutions implemented then it would be fair to say that we should not see the problem reoccur again in the future.

2. CASE STUDY
ZINC STRIPPING MACHINE

The equipment identified for further improvement by the business was a zinc stripping machine. The stripping machine is not something available “off the shelf”; it was designed specifically for the business and is unique in its operation. The stripping machine main function is to strip two 20 kilogram sheets of zinc every 4 seconds with a daily target of 450 tonnes a day.

2.1 THE ANALYSIS

The RCM study began by collating as much information as was available, including equipment lists and current maintenance plans. Work order history, and performance data were analysed using Weibull Analysis to determine what failure patterns were occurring across the stripping machine. This information was then used to develop a “Desktop” Reliability Centered Maintenance (RCM) model using the simulation software package Availability Workbench™ (AWB). The asset hierarchy was built using AWB based on the current structure within the business SAP Computerised Maintenance Management System (CMMS). This alignment with SAP was required for future use of the AWB SAP portal and the uploading and downloading of maintenance plans.

With the asset hierarchy developed the next stage of the process was to define equipment functions, functional failures and failure modes. This was predominately completed using available information and equipment experts located within the business. The first model developed was the current maintenance strategy which used the plans that were being currently performed on the stripping machine. Once the current maintenance plans were implemented the next step was to assign the consequences of failure using the corporate risk matrix. The severity levels within the table were calibrated to the company’s risk matrix. See Table 1.

With the current practice AWB model complete the business was now in a position to simulate using the Monte Carlo Simulator built within AWB to determine the impact of the maintenance tasks on the lifecycle costs and risk levels. The simulation results provided rapid analysis, and allowed for further optimisation of maintenance plans to take place. Where maintenance was not effective in either preventing or predicting a failure mode then Root Cause Analysis was performed to determine what effective solutions could be implemented to prevent reoccurrence.

[Ref 1 - Availability Workbench™ (AWB) is a Trade Mark owned by Isograph Limited UK]
2.2 THE RESULTS

With the AWB desktop model now complete, we needed to perform a reality check and challenge the model results. This is carried out by first examining the Cost Criticality Pareto chart. The Cost Criticality Pareto ranks the failure modes based on total cost which includes any business costs associated with failure, labour cost, spares cost and equipment cost. See Figure 1.
Using the Cost Criticality Pareto Chart, the high cost failure modes were examined in detail by carrying out a validation of the failure mode information. Once validation was complete, the Cost Criticality Pareto identified areas for improvement. The type of recommendations made for improvement included root cause analysis (RCA), equipment redesign and maintenance strategy optimisation. The second method used to challenge the model results was to examine the historical maintenance costs and compare to the budget prediction using AWB.

The goal of this was not primarily to ensure the budget prediction matched the historical spend but rather to clearly understand the reasons for any discrepancies in the results. In this case study, the predicted results were within 4% of actual maintenance spending. See Figure 2.

Now failure modes had been addressed from a cost perspective, the next step was to determine if the safety risk associated to the stripping machine was less than the acceptable business exposure threshold. This threshold was calibrated with the business risk matrix to align with a target of 1.

If any failure modes exceeded this target then a safety risk exposure existed. With the stripping machine, four failure modes exceeded the target and showed safety risk exposure. These failure modes were associated to emergency stop switches and the testing regime for those switches.

The comparison between current maintenance and optimised maintenance can be seen with a reduction in safety risk to below the target of 1 following maintenance optimisation. See Figure 3 and Figure 4.
With the model details validated, it was then important to recognise the comparison between the alternative strategies on offer to the business. In this case, run to failure, current practice, optimised and optimised with redesign strategies were compared. See Figure 5.

Once optimisation was finalised a maintenance budget prediction was developed to determine spares and resource requirements. Using AWB, the budget prediction could be interrogated at many levels including system, sub-system, individual asset and individual failure mode level. See Figure 6.

We were now in a position to determine what impact the optimised maintenance strategy was having on the stripping machine overall availability. This would indicate single points of failure and bottlenecks within the machine and identify further opportunity for improvement. See Figure 7.
2.3 THE IMPROVEMENT WORKSHOPS

With a new maintenance strategy developed for the stripping machine, it was important to recognise that two failure modes that were occurring on the machine could not be prevented or predicted with any form of regular maintenance. See Figure 1 Cost Criticality Pareto. It was therefore decided to conduct a detailed RCA [Root Cause Analysis] workshop on these two failures.

Table 2 Failure Modes for RCA

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>DESCRIPTION</th>
<th>COST PER YEAR</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monorail</td>
<td>Light curtains trip</td>
<td>$1,107,070</td>
<td>Once/shift for 5 min</td>
</tr>
<tr>
<td>Side Shifter</td>
<td>Flag damage</td>
<td>$493,765</td>
<td>Once/week for 30 min</td>
</tr>
</tbody>
</table>

The approach was taken to create a common reality and build a cause and effect chart that would address the conditions and the actions surrounding both problems using the Apollo Root Cause Analysis™ Method. The goal of the Apollo Root Cause Analysis™ Method is to identify not only the cause and effects but identify the effective solutions that will prevent reoccurrence of the problem. The methodology is based on the four elements of cause and effect principle:

- Cause and effect are the same thing
- Causes and effects are part of an infinite continuum
- Every effect has at least two causes in the form of actions and conditions
- An effect exists only if its causes exist at the same point in time and space.

The ‘light curtain trip’ identified 63 cause and effects and 12 solutions.

The ‘flag damage’ identified 22 cause and effects and 3 solutions.

With potential solutions identified a cost benefit analysis was carried out to ensure payback on the cost of solutions.

Table 3 Solution Cost Benefit

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>COST/YEAR</th>
<th>COST OF SOLUTION</th>
<th>PAYBACK DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Curtain Trip</td>
<td>$1,107,070</td>
<td>$34,800</td>
<td>11.47</td>
</tr>
<tr>
<td>Flag Damage</td>
<td>$493,765</td>
<td>$2,880</td>
<td>2.17</td>
</tr>
</tbody>
</table>

2.4 FMECA SUMMARY

The Stripping machine FMECA analysed a total of 1798 failure modes (see Table 4). The new optimised maintenance plan produced 51 Maintenance Schedules with a total of 1466 maintenance tasks. The maintenance strategy was categorised into 10% Preventive Work and 90% Inspection Work.

Table 4 FMECA Summary

<table>
<thead>
<tr>
<th>OPTIMIZED FMECA SUMMARY</th>
<th>Action</th>
<th>Number of Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use As Is</td>
<td>929</td>
<td></td>
</tr>
<tr>
<td>Deleted</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Extend Interval</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>New Tasks</td>
<td>471</td>
<td></td>
</tr>
<tr>
<td>Reduce Interval</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Run to Failure</td>
<td>344</td>
<td></td>
</tr>
</tbody>
</table>

2.5 CONTINUOUS IMPROVEMENT

With the new maintenance strategies uploaded into the CMMS via the AWB SAP portal, it was recognised that a periodic review would be performed to validate the strategy and update according to new information and data becoming available. This will form part of the business continuous improvement process.
3. CONCLUSION

The paper has presented a Reliability Centered Maintenance approach to evaluating current maintenance regimes. Once complete, the models can be used to predict budgets, maintenance labour and resource requirements and spares usage. The approach also incorporated Root Cause Analysis on high cost failure modes that could not be prevented through the maintenance regime.

The paper shows through the breadth of results available, the benefit in applying an RCM and RCA approach to plant strategy optimisation. The outcomes can help ensure that the throughput goals are achieved at least cost and minimum risk exposure to the business.

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Apollo Root Cause Analysis™

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