Total Productive Maintenance (TPM) Application for Cable Manufacturing Organisation

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Abstract—This study assesses the current maintenance practices at a cable manufacturing company, and then recommend possible strategic solutions which enable the implementation and sustaining of continuous improvement as well as involvement in strategic changes such as Total Productive Maintenance (TPM) for all employees. The paper affirms the use of people centred and holistic TPM approach

Keywords—production, maintenance, plant availability, cable manufacturing, TPM

I. INTRODUCTION

The principles of Total Productive Maintenance (TPM) have been around for some time. It entails harnessing human and material resources in the most effective way to achieve an organisation’s objectives [1]. This management philosophy recognises that customer satisfaction, plant and people’s health, safety, environmental considerations and business objectives are mutually dependent. Application of TPM primarily involves investment in time, people and systems: time to implement new concepts, time for people to recognise the benefits, and time for people to move forward into new and different company cultures. The participating organisation has to take this vision on board if TPM is to succeed [1].

The objectives and goals of TPM include customer satisfaction, business objectives such as profit growth and market growth.

In industrial set ups, the main focus is usually on maintenance; which is the management, control, execution and quality of those activities which will ensure that optimum levels of availability and overall performance of plant are achieved, in order to meet business objectives [2]. In 1999, the Department of Trade and Industry, UK, commissioned a report “Managing Maintenance into the New Millenium”.

One conclusion of this report was that a 5% improvement in machine availability could result in a 30% improvement in net profit [3].

A direct inference to this statement is that this is possible by eliminating the six losses which reduce the effective production time. The six losses have been divided into three groups shown in the table 1 below:

<table>
<thead>
<tr>
<th>Table 1: The Six Losses [5]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DOWNTIME</strong></td>
</tr>
<tr>
<td>• Failure from breakdown</td>
</tr>
<tr>
<td>• Set-up and adjusting</td>
</tr>
<tr>
<td><strong>SPEED LOSSES</strong></td>
</tr>
<tr>
<td>• Idling and minor stops</td>
</tr>
<tr>
<td>• Reduced speed</td>
</tr>
<tr>
<td><strong>DEFECT/QUALITY</strong></td>
</tr>
<tr>
<td>• Process defect</td>
</tr>
<tr>
<td>• Reduced yield</td>
</tr>
</tbody>
</table>

II. BRIEF MAINTENANCE REVIEW

Maintenance is considered to be “the combination of all technical and associated administration actions intended to retain an item in or restore it to a state in which it can perform its required function”. Maintenance is “all activities that are performed to maintain and restore an equipment in such a condition that the planned production can be accomplished free of troubles” [6]. It ensures that optimum levels of availability and overall performance of plant are achieved to meet business objectives [8]. From a technological point of view, the term “zero-technology” is used to encompass maintenance and defined as “the branch of technology and engineering concerned with the installation, maintenance and replacement of industrial plant and equipment with related subjects and practices” (from the Oxford English Dictionary). In accounting terms maintenance is dubbed the “Asset Preservation”. Maintenance includes the entire project, research and development, manufacturing, utilisation, and scrapping [4].

III. MAINTENANCE STRATEGY

Techniques to help make the most appropriate maintenance strategy decision have been developed. Some of these are explained below.

A. Decision trees

The consultants Wolfson Maintenance have developed one of these [8]. The decision is primarily based on the failure pattern, but also the mean time between failures. Both of these are determined by historical data of the machine.
B. Failure mode effect analysis (FMEA)

To carry out an FMEA, a table is constructed which lists every probable failure mode and the resulting effect on the machinery, production system, people, and safety. Typical data would include: part identifier, probable failure cause, failure effect, and how the failure can be reduced or eliminated, as shown in the next example [10].

**TABLE II**

<table>
<thead>
<tr>
<th>Part identifier</th>
<th>Failure</th>
<th>Cause of failure</th>
<th>Effect of failure</th>
<th>How to Eliminate Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear</td>
<td>Broken Tooth</td>
<td>Wear</td>
<td>Will not Transit Power</td>
<td>Heat Treat</td>
</tr>
</tbody>
</table>

Heat-treating becomes the solution to the problem.

C. Modes of failure

A plant machine or equipment will experience different modes of failure throughout its life. These are [7]:
- Run-in - these are failures in new equipment, possibly from manufacturing errors.
- Useful life – failures are generally random in nature.
- Wear-out- the equipment is nearing the end of its useful life. Failures increase as a result of components wearing out.

Not all components follow this pattern. There are some which follow a more random failure pattern (e.g. light bulbs).

D. Cost savings

Data supplied by monitoring devices can help users avoid unplanned stoppages. The devices provide instant reports on a regular basis, and following the trends, scheduled maintenance windows can be utilised. This saves both time and money, and facilitates timely procurement of spares and optimum stock levels. The effectiveness of maintenance can affect profitability in three ways [3]:
- Lost production through plant unavailability
- Cost of maintenance resources
- Life of the plant

This implies that the maintenance function (itself regarded a cost) can have a direct measurable effect on the company’s balance sheet (remember “asset preservation”).

E. Improvement on maintenance efficiency

One renders maintenance more effective by obtaining and implementing a preventive maintenance plan for recurrent preventive maintenance work such as cleaning, lubrication, repairs, exchanges, condition monitoring and inspection.

IV. RESULTS OF INEFFECTIVE MAINTENANCE

This inevitably results in [5]:
- Excessive machine breakdowns.
- Frequent emergency maintenance work and shortened life span of facility
- Disproportionate investment in spare parts and maintenance materials
- Poor utilisation of maintenance staff
- Loss in production output and lower quality products
- Panic operation changes and excessive overtime costs (both maintenance and production)

V. MACHINE INEFFECTIVENESS VS COMPANY PERFORMANCE

Below is a step by step causal analysis on shoddy maintenance and its effect overall on company performance.

1. Causes
   - Minimal maintenance effort
   - Incomplete maintenance history
   - No inspection
   - Limited inspection

2. Primary
   - Equipment poorly maintained
   - Increased need for spares
   - Frequent equipment breakdowns
   - Low equipment utilisation and interruption to product
   - Poor quality parts produced, increased scrapped and reworked parts.

3. Operational effects
   - Decreased morale
   - Overtime and low productivity
   - Increased order to delivery lead-time, and poor due date performance

4. Business effects
   - Customer dissatisfaction
   - Low sales leading to poor profit
   - Increased cost [1]

VI. CASE STUDY

The Cable Manufacturing Company manufactures a wide range of low voltage power cables, general wiring cables and telecommunication cables. The company is both SAZ ISO 9002 and ISO 14001 certified.

With minimum disturbance, the factory produces an average of 100 tonnes per week of products, an equivalent of 400 tonnes for a four –week month, and 500 tonnes for a five week month. This tonnage increases or decreases depending on the nature of the product.

If smaller cables are to be run, most of the machines will be working. Thus breakdowns are likely to be higher, resulting in higher downtime, and the need to have a well planned maintenance system. Dirt in form of dust from chalk, scrap in terms of PVC and faulty cables is inevitable, but through continuous improvement the company aims at keeping this at the minimum levels possible.

VII. MACHINES

The following is a list of machines currently in use. In the table, functions of the machines are also highlighted. Of importance to note also are the machines that can easily cause bottlenecks due to multiple use when compared with other machines.
TABLE III
MACHINE LIST

<table>
<thead>
<tr>
<th>Machine No.</th>
<th>Machine Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drum Lay Twister</td>
<td>Laying up wires</td>
</tr>
<tr>
<td>2</td>
<td>Drum Armourer</td>
<td>Armouring cables with steel wire or stranding</td>
</tr>
<tr>
<td>3</td>
<td>Outokumpu (OTK)</td>
<td>Copper melting and rod casting</td>
</tr>
<tr>
<td>4</td>
<td>GG Rewinder</td>
<td>Stranding and laying up</td>
</tr>
<tr>
<td>5</td>
<td>NM100</td>
<td>Insulating and sheathing</td>
</tr>
<tr>
<td>6</td>
<td>42 Armour No. 1</td>
<td>Armouring cables</td>
</tr>
<tr>
<td>7</td>
<td>42 Armour No. 2</td>
<td>Armouring cables</td>
</tr>
<tr>
<td>8</td>
<td>Heinrich Rod breaker</td>
<td>Wire drawing</td>
</tr>
<tr>
<td>9</td>
<td>Heinrich intermediate</td>
<td>Wire Drawing</td>
</tr>
<tr>
<td>10</td>
<td>Heinrich 8-wire</td>
<td>Wire drawing</td>
</tr>
<tr>
<td>11</td>
<td>Heinrich Buncher</td>
<td>Bunching</td>
</tr>
<tr>
<td>12</td>
<td>DS130</td>
<td>Insulating and sheathing</td>
</tr>
<tr>
<td>13</td>
<td>BM80-1</td>
<td>Insulating</td>
</tr>
<tr>
<td>14</td>
<td>BM80-2</td>
<td>Insulating</td>
</tr>
<tr>
<td>15</td>
<td>37 Strander</td>
<td>Stranding (up to 37 strands)</td>
</tr>
<tr>
<td>16</td>
<td>24 Strander</td>
<td>Stranding (up to 24 strands), mainly aluminium cables.</td>
</tr>
<tr>
<td>17</td>
<td>18 Strander</td>
<td>Stranding (up to 18 strands)</td>
</tr>
<tr>
<td>18</td>
<td>Unity Strander</td>
<td>Stranding</td>
</tr>
<tr>
<td>19</td>
<td>Northampton</td>
<td>Laying up</td>
</tr>
<tr>
<td>20</td>
<td>Francishaw</td>
<td>Insulating</td>
</tr>
<tr>
<td>21</td>
<td>PG 1000</td>
<td>Laying up</td>
</tr>
<tr>
<td>22</td>
<td>Godderidge</td>
<td>Laying up</td>
</tr>
<tr>
<td>23</td>
<td>Sheathing line</td>
<td>Sheathing</td>
</tr>
<tr>
<td>24</td>
<td>Twinners 1&amp;2</td>
<td>Twinning</td>
</tr>
<tr>
<td>25</td>
<td>Braiders</td>
<td>Braiding (for optical fibres and communication cables)</td>
</tr>
<tr>
<td>26</td>
<td>PS coiler</td>
<td>Coiling of wire or armouring machines</td>
</tr>
<tr>
<td>27</td>
<td>Compressor</td>
<td>Compressing air</td>
</tr>
</tbody>
</table>

VIII. PRODUCT RANGE

A. Metallic telecommunication cables

Cables are manufactured to British Telecom and Zimbabwe’s Posts and Telecommunications (PTC) specifications. However, the company can produce a wide range of telecommunication cables for worldwide applications to national and international standards or customised to meet operator’s specific requirements. These cables are in two broad categories – internal and external telecommunication cables.

B. Power cables

The range of power cables is rated at 600/1000V and 1900/3300V and supplies both armoured and unarmoured cables which conform to British Standards (BS), South African Bureau of Standards (SABS), Standards Association of Zimbabwe (SAZ) and to international requirements as defined in IEC standard 502.

C. General wiring cables

The company also manufactures a wide range of wiring cables. Included in this range are single core house wires, circular armoured and unarmoured cables, instrument and panel wires, and a wide range of other cables including flexibles for general and specialised applications.

IX. KEY MAINTENANCE SCOPE

In the present facility, the main function of the engineering department is purely that of maintenance on the following key areas:

A. Work on the OTK furnaces

The major constraint on these is lack of available time by way of the availability of a maintenance window; the research suggests the following in carrying out an overhaul on the reticulation system for the OTK Furnaces.

Poor pump delivery – It will be a good idea to overhaul all the pumps, one at a time - there are only three pumps, of which two are supposed to be working at any one time. The suction ball valves can also be replaced, since the current ones are old, and look suspect.

Unconventional cooling design – The idea is to have the return water straight to the sprays at the top of the cooling towers, implying a possible redesign of the whole system.

Poor filtration --the bypass valve that is suspected to be malfunctioning should be replaced, so that the cooling water passes through the filters. The filters also need to be redesigned so as to design out maintenance.

High levels of scaling, rusting, and blockages --it is suggested that an RCM MSG or FMECA be carried out on the de-ionising plant.

B. Armourer and 37 stranding machines

Whereas the target availability of these machines (97%) has been achieved, there is some time that is lost in setting up the machines. This needs to be dealt with so as to improve production on these machines. The starting point will be the designing or availing of a better loading system, manual or electronic
C. Spares for scrapped machines
These should be liquidated as soon as possible if found that they could not be used on any other machine. Keeping them means keeping the money tied up without earning any interest. If liquidated, the company will be in a position to release this money for other uses or investments.

D. Overstocked items
This is a sign of inefficiency on the stores and purchase departments. For those items that are not imported, and have a short lead-time, there is really no reason why the items should be overstocked, and that by over a hundred percent. Some of the overstocked items have been in stock for over 3-4 years; in some cases this is a sign that the items are slow moving, and hence the maximum stock level could be reduced, and some of the items liquidated.

E. Under stocking
This should be prevented at any costs. Stock items should be kept at their recommended levels, above the minimum required. This will in turn help the maintenance department by preventing unnecessary direct purchases, which might end up affecting the department’s budget.

X. IMPLEMENTING TPM
A typical TPM process should start with three key areas: policy and strategy, management and improvement of the organisation.

A. Policy and strategy
Management needs to establish a mission statement, strategic corporate objectives, and a business plan for achieving the TPM objectives. There also needs to be a visible and sustained commitment from every member of the business through personal leadership and example.

B. Management
The next step requires planning to establish an effective organisational structure, establish, audit and keep under review an effective management system. The organisation will also need an effective, planned information system and a good communication system both internally and externally with suppliers and customers.

C. Improving the organisation
This means looking at the working environment, the measurement of performance, improvement objectives and plans, and monitoring and reviewing processes. The physical environment and relationship between the individual and the organisation and other employees should be structured so that each individual and team is aware of its contribution to the mission statement and the planned methods by which it can make improvements.
Equally important is to have an effective reporting and feedback mechanism and structure.

An effective way of implementing TPM is through the use of small group activities. These are actually achieved by using three main Task Groups.
1. A management task group 1.
2. An engineering task group 2.
3. A production on task group 3.
The management group will be responsible for:
-Formulating the TPM policy and objectives
-Staff training.
-Introductory Seminars to remove resistance to change are necessary.
The other Task Groups, 2 and 3 are responsible for:
-Defining current problems in their areas.
-Analysing the problem areas and bottleneck operations.
-Evaluation of the equipment, materials and malfunctions.
-Autonomous maintenance can be achieved by using the five S’s or 7 Nakajima stages (Table5) of step 8 in the 12 step TPM implementation plan (Table5).
Preventive maintenance, reduction of breakdowns through continuous improvements, spare part consumption reduction, maintenance for quality and reliability. It is important to note that these groups are not mutually exclusive but have to interact. This is important especially on the implementation and reviewing of TPM performance as indicated in Fig. 1. The benefits achieved will form the basis of a Kaizen path (continuous improvement cycle). Twelve Steps are considered for TPM development Programme:

**Step-1:** Announce top management decision to introduce TPM.

**Step-2:** Launch education and campaign to introduce TPM.

**Step-3:** Create organizational set up.

**Step-4:** Establish basic TPM policies and goals.

**Step-5:** Formulate master plan for development.

**Step-6:** Hold TPM kick-off.

**Step-7:** Improve effectiveness of each piece of equipment.

**Step-8:** Develop an autonomous maintenance programme for operators.

The seven stages of Nakajima involving the following to build diagnosis skill and establish certification procedure.

i. Initial cleaning
ii. Counter measures for the cause and effect of dirt and dust
iii. Cleaning and lubricating standards
iv. General inspection
v. Autonomous Inspection
vi. Organisation and Tidiness
vii. Full implementation of autonomous maintenance

**Step-9:** Set up a scheduled maintenance programme for the maintenance department.

**Step-10:** Conduct training to improve operation and maintenance skills.

**Step-11:** Develop early equipment management programme.

**Step-12:** Implement TPM fully and aim for higher goals.

**XI. CONCLUSION**

By looking at the maintenance significant items or machines out of the 27 listed it has been possible to detail some of the pertinent and attendant problems and then to proffer unique solutions to each of these problems for the critical machines. A broad based holistic approach was then suggested for the whole plant premised on implementing Total Productive Maintenance that is management led and steered by three groups that seek to have total involvement of all players, major and minor, shop floor and white collar. Technically competent techniques such as the 5 Ss and Nakajima’s 7 stages of imbuing autonomy to workers are then used. It is the expectation of this paper that the readership will find parallels with their operations and use the material herein to stimulate adoption of a holistic and broad based maintenance approach to maintenance problem resolution and maintenance improvement itself.

**REFERENCES**


