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MAINTAINABILITY, RELIABILITY AND SERVICEABILITY – INDUSTRIAL EXAMPLES AUTOMOTIVE INDUSTRY

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Abstract: Maintainability, reliability and serviceability are engineering and management functions spanning the product or service life cycle. It is a characteristic of equipment design, installation and operation, which is expressed in terms of ease and economy of maintenance, reliability of the equipment and safety and accuracy in the performance of maintenance actions. This paper shows industrial examples of a US automotive manufacturer. An overview is given of the plant maintenance and development, with which a sharp increase in the reliability and overall equipment effectiveness (OEE) could be achieved through the implementation of numerous activities and initiatives e.g. Total Productive Maintenance, long-term planning, design for maintainability, standardization and partnering, root cause focus, condition monitoring and constant adaption to new equipment.
Keywords: maintainability, reliability, standardization, design for maintainability, condition monitoring, total productive maintenance, OEE, industrial examples

INTRODUCTION

In this study, the automotive plant can be characterised as follows [1]: there has been no downtime since years and the equipment does not pose a stumbling block. Targets for overall equipment effectiveness exceed 90 percent (world class is considered 85 percent) [2,3,4,5]. This has proved achievable and, in some cases, has already been surpassed. Uptime nears 100 percent in some mission-critical areas. Maintenance attention is equally focused on the past, present and future (up to seven years down the line) and reactive work comprises less than five percent of the overall task load in a number of areas. Top management is a big advocate of effective plant maintenance, which is the reason for current state of reliability at the US plant.

Figure 1 – US automotive plant [1]

The plant located in North America (Figure 1) was constructed in 1993 and opened for full manufacturing in 1994. More than 1,400 of the company's high-end, technologically advanced, customization-heavy vehicles are built here on a daily basis. Inside the plant, the focus is on performance and taking a more stringent approach to reliability. Regardless of what is being operated and what is being tracked, the aim is to achieve
100 percent in terms of performance and reliability. Customers are paying for engineering and quality and do not expect breakdowns on the plant floor. To achieve maintenance and reliability excellence, the drivers are:

- Macro level: Seeking ways that can ensure the equipment is going to be able to do what it should do.
- Micro level: All maintenance is planned and scheduled.

Plant reliability has a strategic significance and there is a strong emphasis on planning, which is definitely one of the keys to ensuring reliability.

The former president of the US plant was a maintenance planner and later the director of maintenance planning at a German plant. He was passionate about maintenance when he was at the US plant and believes in its importance. This shows that there is support at top-level management for reliability matters. There have always been people at board level, who were very in tune with the floor and everyone in the higher management levels understands that the profit centre of a company doesn't reside in an office, but is at the line and dependent on how it is performing. Managers and technicians (known around the site as Equipment Service Associates, or ESAs) are empowered to structurally and functionally shape maintenance to fit the plant's needs.

PLANT SETUP AND PRODUCTION UNITS

Since the start of production in 1994, the plant has produced more than 3.7 million vehicles – a total of around 1,400 automobiles per workday. It provides jobs for 8,800 employees and is supplied by 270 North American suppliers. The setup of the plant (the site comprises 4.7 km^2, of which over 5-million-square-feet is under roof) is very unique. It is divided into four units: the Body Shop (Figure 2), Assembly (Figure 3), the Paint Shop and Facilities/Energy [6,7]. Each unit takes a slightly different approach to maintenance [1].

For instance, the Body Shop takes an integrated approach and has no "maintenance department", per se. While there are associates, whose focus is strictly on maintenance, they work together as a team with production and quality associates and report to the shop supervisor.

Figure 2 – Body shop - Best fit process [1]

Figure 3 – Assembly process [1]

The over 100 Body Shop ESAs work 10-hour base shifts with an additional two hours of mandatory overtime. If the line is running in top form after Hour 10, they punch out early. ESAs are not specialists, but are multi-craft technicians, who perform a range of preventive, predictive and corrective tasks. Since the vast majority of the line consists of automation equipment with around 1400 robots, a large proportion of the base shift is taken up with predictive maintenance, which mainly involves the use of infrared thermography and motor current monitoring, as well as scheduled corrective work and project planning. Preventive maintenance (PM) on the robots takes place after the shift or at any other scheduled point in time when the equipment isn't running, which is why planning is so important here.

Assembly operates in a more traditional manner. Its approximately 70 multi-craft ESAs report to the assembly/ installations engineering manager, who serves as the manager of maintenance. Shifts are similar to the Body Shop, but PM activities comprise the main share of the in-shift work. There are very few robots (nine) here, which is why 75 percent of the PM work can be done while the line is running. Corrective work is mostly scheduled for flexible time and off shifts.

Outsourcing plays a key staffing role in the maintenance of all four plant units. It provides flexibility and allows the groups to focus on their core competencies. A certain percentage of the maintenance tasks are contracted out. A core group of maintenance personnel is always kept on site to cover any possible volume fluctuation that may arise. Outsourcing provides the plant with the flexibility to expand and contract as necessary. This means that if a reduction of the workload becomes necessary, this can be achieved by cancelling outsourced contracts rather than eliminating the plant's own associates. The Facilities/Energy Unit [6, 7], with its staff of just over 20 employees, is reliant on contractors, who perform 30 percent of the unit's workload.

The automotive plant is operated on a very lean basis. It concentrates on its core competencies and on what needs to be done. The direction is to move towards equipment management, i.e. making the equipment run as efficiently as possible. There are commodity skills that can be easily purchased from external partners, e.g. changing air filters, a technical skill on which the staff's time should not be spent.

While the individual units are independent of one another, there are also collective issues involving all units. For example, there is no overall plant maintenance manager position, instead, managerial representatives from each unit form the Plant Maintenance Steering Committee, which is responsible for guiding the site's Maintenance &Repairs efforts.

MAINTENANCE AS DRIVER FOR RELIABILITY

The above non-traditional approach has played a major role in the plant's ascent into a world-class-and-beyond performance [1]. Maintenance and reliability doesn't reside in one department or with one individual. Everybody plays their part in achieving maintenance, reliability, uptime and overall equipment effectiveness. It's a team game and it is evident that this team mentality is the decisive factor in winning this game [1].

Overall equipment effectiveness OEE [2,3,4,5], uptime and the other factors are represented on the team-boards. OEE and uptime are the most substantial metrics at both the plant and departmental level, i.e. these Key Process Indicators are considered at all levels. OEE and uptime are directly related to the number of cars that can be produced for the customers. The OEE is calculated as:

$$OEE = \text{Equipment Availability} \times \text{Equipment Efficiency} \times \text{Quality Rate } (EA \times EE \times QR)$$

EA refers to technical uptime. It is planned runtime minus equipment downtime divided by planned runtime. EE refers to process performance in units. It is 'units produced' multiplied by 'cycle time' divided by 'planned runtime'. QR is the quality rate in terms of equipment. If a piece of equipment causes a vehicle to require reworking, then this counts against OEE. It is 'total units' minus 'defect units' divided by 'total units'. Although it is standard procedure to use the maximum speed as a basis for this calculation, it is not applied in this particular case. Instead the speed is based on a unit goal and the plant is then staffed for this particular workload. The equipment is installed with a speed range and adjusted to market conditions. Two layers of OEE exist: Department-level OEE measures the whole line against a target, while Equipment-level OEE measures each piece against a target.

Assembly has a departmental OEE goal of around 93 percent, which includes the EA and EE sub-goals of 98.5 and 98 %, respectively. For the productivity and quality components of OEE, the target represents 100 percent. Facilities/Energy [6, 7] had an OEE target of 90 percent, but averaged a higher percentage. Charting uptime, the shops surpass 90 percent, both as a department as a whole and for critical pieces of equipment. Assembly's overall mark regularly exceeds 95 % and has been as high as 99.4 percent. In the warehouses, uptime scores of 99.99 and 99.8 percent have been achieved on critical equipment such as cranes, transfer cars and systems.

Only a small percentage of maintenance (less than five percent) is reactive, unplanned work, with 88 percent of the work performed according to the planned schedule. All maintenance work is planned, scheduled and tracked with regard to how well the plan is actually adhered to. The target for maintenance is set at 90 percent. It should be noted that, generally, there are only few equipment problems and the equipment cannot be considered a stumbling block for the plant.

ACHIEVEMENT OF RELIABILITY BY MAINTENANCE ACTIVITIES AND TOOLS

To achieve optimal reliability, there are many maintenance activities and tools that can be employed, which are briefly described in the following paragraphs [1].

Total Productive Maintenance TPM

Total Productive Maintenance (TPM) has helped raise uptime and OEE [2,3,4,5] by creating a team approach to maintenance work and improving reliability and serviceability. TPM activities vary by unit and production area. In the Body Shop, equipment is shut down in some areas for 15 minutes in each shift, so production workers can perform cleaning and adjustment activities. In other Body Shop areas, the shutdown can occur more often (15 minutes every two hours) or less frequently (a one-hour block once a week), while in Assembly, some production workers are assigned full-time TPM duties. The glazing cell and fluid fill cell each has two people per shift devoted to these tasks.

Production workers do have TPM limits. For instance, lubrication is strictly a maintenance task. It must be ensured that the associates responsible for maintaining the equipment cannot have a negative impact on it. This differs from Facilities/Energy, where basic and advanced TPM activities are outsourced to the plants contractors. TPM has worked to raise reliability through increased communication, ownership and responsiveness.

Long-term planning

The plant has drawn up documents that examine the maintenance needs of critical systems over a timeframe spanning several years. Major and minor activities are identified, which need to be performed to ensure the long-term sustainability of the assets. This has played an instrumental role in highlighting maintenance issues for which resources are needed. For example, the plant must regularly overhaul its gas turbines, because of the workhorse manner, in which they are used. It helps to look at the useful life of equipment and when it needs to be brought back to like-new condition.

Design for maintainability

The plant has been substantially extended and has changed its assembly layout from a two-line system to a one-line system. All vehicles are assembled on the same line. After the extension and conversion, the plant was able to take a fresh start approach to many things, including maintenance. New equipment was set up and installed in a manner that increased accessibility and maintainability.

Standardization and partnering for maintainability

The plant is a big supporter of equipment standardisation. For example, the site embarked on a project to convert its programmable logic controllers to Siemens products. The plant and the company are now on one

PLC platform. For a spread-out organisation such as this, standardisation makes corporate and cross-plant partnering possible.

Most of the equipment is the same at all company sites. This makes is possible to receive solutions to problems from plants around the worldwide corporate production network. This increases OEE and uptime. Equipment and maintenance standards (and maintenance best practices) are collected on a global basis at the company's Centre of Competencies in Munich, Germany.

All information gathered and lessons learned goes to the centre, where it can be accessed and used by other sites. Sharing these insights from the experiences of the different plants on a company-wide platform help others to get things right the first time and build reliability into equipment and processes. Considerable partnering/idea-sharing also takes place between the plant and its many capital and MRO (maintenance, repair and operations) suppliers.

Condition monitoring

The extension and conversion of the plant also provided an opportunity to install sensors on many highly critical equipment components. The initial system used monitored the entire factory and broke it down into zones, but now it is possible to precisely locate the problem down to the individual equipment. When a degradation or a potential issue is discovered, action is taken immediately and the issue addressed before any incident can occur (Figure 4).

The sensors and the PLCs interface with the plant's computerised maintenance software and SAP system to submit current status information. On the basis of this data and the subsequent comparisons to standard deviations, SAP can determine the need for a countermeasure. Depending on various factors, it may produce a work order or notification in the Computerised Maintenance Management System (CMMS) or send out a page, phone call and/or e-mail. Condition monitoring equipment is implemented on a cost-efficiency basis.

Root cause focus

The plant and its maintenance organisations are dedicated to identifying the source of problems and preventing their reoccurrence [8]. In the Body Shop, if a line breakdown takes 15 or more minutes to resolve (in Assembly, the standard is 10 minutes), maintenance leaders and ESAs perform a complete “five-whys” root cause analysis (RCA) to determine and correct the true root of the problem.

All possibilities are used for problem-solving and the associates stay tuned until the problem is solved. RCA is not a quick action. It requires manpower to implement it, whether it be people on the floor or the planning group. An appropriate course of action must be drawn up for simple tasks, i.e. 'in cases for which it is unreasonable to carry out the "five-whys" RCA with the effort and expenditure it entails.' In such cases, a full RCA is not necessary. Furthermore, if the equipment is very new and a malfunction occurs, it will take maintainers longer to solve the problem and rectify it, because they are still learning about its special features.

The recognition of problems and their solutions are transferrable to all similar pieces of equipment in the plant and the groups concerned ensure that the information they have gained is shared with senior departmental managers. This way, the managers are continually kept up to date with what maintenance is doing as well as why it is important and what is being undertaken to ensure that the production processes remain up and running. In other words, it is ensured that a constant spotlight is kept on equipment performance and maintenance.

Figure 4 –High-tech maintenance: Passion for perfect production processes

The plant, as a whole, also investigates and eliminates the root cause of problems through Lean Six Sigma projects. Currently, master black belts, black belts and green belts play key roles on five- to seven-person attack teams. Lean Six Sigma is data driven. That's the difference between it and the other problem-solving measures. Looking at the data and analysing it will lead to the correct solution to a particular problem.

Constant change

The plant functions on intervals. New car lines are introduced. With each new car line comes new equipment to produce the vehicle. This provides some OEE benefits. The equipment is often cutting-edge technology. This means the maintenance staff is constantly on the learning and training curve for that particular piece of equipment.

The changes and staff turnover means that maintenance must consistently re-evaluate its PM processes and activities. For example, if a machine undergoes PM events eight times per year and exhibits no problems, the annual PM frequency could possibly be cut in half. The aim is to find the right balance, i.e. not to perform too much, not to perform too little and to perform the right thing. PM frequencies are quickly changing from time-based to condition- or cycle-based. Preventive maintenance is based on how hard the equipment is running.

The trend to digitalisation [9] and demographical change [10] will lead to new challenges and adaption to new technology for maintenance.

CONCLUSIONS

The plant holds premier-level status because of its performance, style and reliability and because of its progress in these three areas. Years ago, there was not nearly the same level of utilization of the CMMS system. With SAP, preventive maintenance can be tracked and its effectiveness monitored. The mean time between repair and the response to calls and the level of predictive maintenance has been significantly improved.

However, the journey towards maintainability, reliability and serviceability is not yet finished and if plants aren't undergoing changes, they are either doing something wrong or they are falling way behind. Everything, including an inability to change, has a negative impact on customer satisfaction and customer demand.

The trend to digitalisation [9] and demographical change [10] sets the bar higher and maintenance must now adapt to new challenges and perform at a higher level.

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