A Review on Total Productive Maintenance

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ABSTRACT: Manufacturing tries to minimize waste and improve the overall effectiveness of its equipment (OEE). A manufacturer must use an appropriate decision method while managing machine tool maintenance in order to uncover hidden expenses connected with production losses, effectively minimize equipment downtime, and similarly assess the machines' performance. TPM (total productive maintenance) is a maintenance program that includes ideas for efficiently maintaining plant and equipment. OEE is a strong indicator of manufacturing performance that includes measurements of process, machine, and manufacturing line utilization, yield, and efficiency. It bolsters TPM efforts by keeping track of progress toward "perfect output." This article examines maintenance management methods and how they may be used to make decisions on positional error calibration. The goal of this study is to assess how maintenance techniques, particularly TPM, contribute to increasing manufacturing performance and how they may be used to minimize downtime caused by machine inaccuracy. This is to strike a compromise between predictive calibration, on-machine quality assurance, and lost output owing to inaccuracy. This paper redefines the role of maintenance management methods and provides a framework to assist the process of establishing a predictive calibration program as a primary way for supporting a shift in machine tool calibration decision-making philosophy.

KEYWORDS: Down Time, Decision Making, Maintenance Strategies, Predictive Calibration, TPM,

1. INTRODUCTION

Maintenance management is essential for the equipment to function properly. Managers may plan and carry out maintenance operations proactively or reactively, taking into account different program ideas. When a breakdown or issue arises, a reactive approach begins maintenance operations [1], [2]. This strategy is common in conventional manufacturing companies that place a high emphasis on throughput or have a minimal investment in reconfiguring production systems. Due to increased demand on manufacturing firms to enhance efficiency, maintenance managers at industrial companies take preventative steps before crises arise to ensure machine tool availability. In terms of general maintenance, this entails ensuring that manufacturing keeps running. In terms of machine positioning accuracy, higher tolerance needs from customers imply that maintaining the quality performance of specific machine tools is critical to prevent costly rework or scrap, which has a negative effect on product production rate. A proactive maintenance strategy[3], as the name suggests, employs well-defined preventative procedures to avoid breakdowns and shutdowns [4]–[6].

Predictive calibration is the focus of this article as a proactive method to preventing production failure owing to machine tool inaccuracy. The significance of distinguishing between response to accidents and the requirement for on-machine inspection and preventative and predictive calibration is addressed as part of the decision-making process issue.

The article discusses different methods to maintenance management and how they may be used to gain a competitive edge by minimizing machine tool downtime. It investigates which maintenance management methods are utilized and how they are chosen via a review. It relates to the authors' earlier work [1, 2], which presented a model to aid in the selection of the most cost-effective machine tool measurement strategy, as well as how to enhance the accuracy of calibration decision-making. Finally, this article addresses how to evaluate the effect of management methods on the strategic goal of preserving positional accuracy while minimizing machine downtime.

1.1 Predictive Calibration (PdC):

PdC[7] is a novel technique that has been suggested as being similar to, or perhaps a subset of, a PdM strategy. When properly applied, it may accomplish the same objective of maintaining machine precision while reducing the amount of time spent on period calibration. It is intended to be a formalized approach applied to machine tools to measure and monitor any degradation in mechanical parts in order to assist in maintaining the key performance indicator (KPI) of positioning accuracy while also revealing other maintenance issues such as wear in ball-screws, guide-ways, impending bearing failure, and so on. Analysis of the machine's historical data may be used to determine how the machine's condition has deteriorated over time. “Quick check” instruments like art fact probing, double Bulbar, or any other suitable measuring method may give such an inspection history. These tests may take anything from a few minutes to an hour to complete. The expense of downtime must be balanced against the richness of data and the need for daily performance tracking.

2. DISCUSSION

2.1 Total Productive Maintenance:

TPM is a method for organizing all personnel, from top management to shop floor staff. “When talking about quality control, people frequently believe that quality is determined by the process,” Nakajima claims. With the rise of robotics and automation, it may be more accurate to state that quality is determined by the equipment.” While this is true in highly automated sectors, manual or semi-automated production still accounts for a significant part of the manufacturing business. Modern CNC machine tools, on the other hand, are becoming more complicated, which must be taken into account.

For achieving TPM advantages, the following five key success factors have been identified:

- Get the most out of your equipment.
- Establish a thorough system of preventative. Throughout the life of the device, maintenance is required.
- Include everyone in the process (engineering, operations, and maintenance).
- All employees, from top management to shop floor workers, should be involved.
- Encourage TPM via self-directed small group activities.

All of these ideas may be applied to the problem of maintaining machine tool positioning precision. There are many instances of TPM success, including a 2% decrease in equipment failure, a 26% increase in equipment operating rates, a 90% reduction in process faults, and a 40-50% improvement in labor productivity. However, it has been claimed that achieving such significant improvements takes an average of three years after TPM is implemented. Because they do not support the whole staff or engage all levels of management, several businesses fail to achieve this stage. These efforts failed because they were implemented piecemeal, and as a result, individuals who did not own the integration were turned off. Restoring the equipment to its original state and training employees on how to use it are therefore important expenses that the business should consider.

2.2 The Eight Pillars of TPM:

As depicted in Figure. 2, the Japan Institute of Plant Maintenance (JIPM)[8] established an eight-pillar approach to TPM that focuses on achieving:

- There will be no accidents.
- There will be no breakdowns.
- There are no flaws

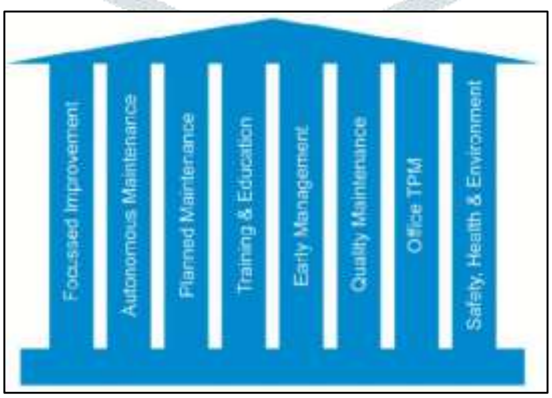

Figure: 2 Eight Pillar Approach to TPM.

Each pillar's mission is to reduce loss, with the ultimate goal of eliminating all losses. The whole process is a long-term structure that will support the industry's cultural shift. These pillars comprise a well-organized structure that bridges the gap in terms of change management, ensuring the industry's long-term success. The use of these pillars to machine tool calibration is described in detail below.

A. Improvement with a Purpose:

TPM's first pillar is targeted improvement, which is founded on the idea that "things can always be better." A new approach from the conventional notion of maintenance management is required for an industry to retain maximum efficiency and availability of all of its equipment. This must be done in the context of the whole organization as a man-machine system. It must also take ongoing steps to avoid any losses while also enhancing maintenance procedures. In order to minimize losses in any process, this pillar offers a systematic, team-based approach.

By increasing the skills of teams to be self-sufficient in applying suitable issue solutions, as well as enhancing safety performance via loss elimination, the focused improvement pillar may decrease defects and machine inaccuracy. It also guarantees that the method used are reproducible and consistent, ensuring long-term viability.

B. Autonomous Maintenance:

Autonomous maintenance is the second of TPM's eight pillars. This pillar seeks to enhance maintenance personnel's skill levels so that they may better understand, manage, and improve their equipment and the manufacturing process. The goal is to shift employees from a reactive to a proactive mindset, resulting in optimum circumstances that minimize pauses while also lowering the output of non-conforming components, rejects, and machine failures.

For example, a CNC machine tool operator would typically respond to component errors by making a small change to the machine's setup or a program offset. An operator may also “override” a feed-rate order to boost production rates, or a spindle speed command if the machining process “sounds” incorrect. When done alone, though, such a course of action may have severe consequences. While a change in technique may improve one work, it may make other occupations worse, or at the very least conceal an underlying issue. As part of autonomous maintenance, these unrecorded reactive actions should be removed. Instead, the operator's expertise and experience should be used to alert the maintenance staff to any possible machine problems.

C. Training and education:

Workers must be trained and educated in order to alter the company's culture. When changes are suggested, employees with good education will respond differently. Maintenance specialists' expertise and abilities, for example, may be helpful in improving the detail of the maintenance plan. This wealth of expertise, however, can only be tapped into if all parties have a similar language and frame of reference. This pillar guarantees that workers are educated in the skills recognized as essential for their personal growth as well as the successful deployment of TPM; without enough education, the other pillars' influence would be short-lived.

The precision of machine tools is influenced by a complex interplay of numerous variables. As a result, prior to implementing modifications to maintenance processes, education in the foundations of the problem and training in particular maintenance duties are required. Maintenance professionals should get comprehensive training to prevent misinterpretation, erroneous readings, and, as a result, false reactions. Machine operators should be fully informed about why maintenance personnel are conducting measurements on their equipment so that they may contribute to any root cause investigation. Product designers must grasp the actual capabilities of machines in order to adapt their ideas to existing assets or request that new equipment be purchased to fulfill their stringent requirements.

D. Quality Maintenance:

This pillar emphasizes that maintaining optimum quality conditions and aiming for zero faults is everyone's responsibility. Operators and maintenance personnel must be able to maintain the quality of machine conditions in order to correct any machine degradation and remove any process issues[9].

The requirement for appropriate measuring action is critical to the effectiveness of sustaining machine tool precision. Measurement instruments must be protected, clean, and neat to a degree that isn't usually seen with other types of maintenance equipment. Some maintenance personnel, for example, store dial/digital test indicators, which can measure with a ten micron precision, in their toolboxes unprotected among spanners and screwdrivers. In this scenario, no future measurement could be depended upon without appropriate usage and storage.

E. Office TPM:

Office TPM is a critical pillar that focuses on all sectors of the industry that offer administrative and support services. This is useful for scheduling measuring activities, aggregating and securely storing data, and so forth. This feature enables a single measurement to be used as part of a company-wide inquiry, maximizing the measurement time's value.

F. Health, Safety, and Environment:

The pillar of safety, health, and the environment seeks to remove the underlying causes of accidents and minimize the likelihood of future occurrences. It focuses on employee behavior, machine conditions, and management systems. It has the potential to prevent lost time events from recurring and to decrease the frequency of minor occurrences. The advantage is a financial savings in inquiry and compensation costs, as well as a reduction in reputational risk.

Recent trends in the distribution of measuring duties for machine fast checks have resulted in increased health and safety requirements. The double ball bar, for example, is a tool that machine tool operators may use, but it previously required that the machine doors be opened in order for the data capture cable to be linked to a PC. Renishaw plc has created a wireless version of the gadget (QC- 20w) that may be operated without the requirement to open the safety doors.

Using the machine doors closed, more complex measurements, such as those performed with a laser interferometer, are now more difficult to accomplish. Expert people operate them in specific maintenance modes. However, by changing the machine tool to enable access for the laser without interfering with the safety measures, this may be improved.

3. PREDICTIVE CALIBRATION PROCESS

If the machine is producing the desired quantity of parts within their nominal tolerance, a strong case must be made to justify the period of downtime for machine tool calibration. It is necessary to develop a new method for maintaining machine tool accuracy that is compatible with the predictive maintenance paradigm. This approach, known as predictive calibration, is a system that relies on the prediction of machine tool accuracy deterioration based on frequent data collection. Figure 3 depicts the situation.

Predictive calibration[10] is a methodology that relies on regular data capture to predict the degradation in machine tool accuracy. It's a brand-new technique for determining the indirect limits of machine tool operating tolerance. These limits indicate the degree of deterioration associated with manufacturing capabilities, as well as the resulting impact on component quality. Although implementing such a strategy would add a new cost, the goal is to offset this investment by improving operational efficiency and lowering total downtime costs owing to unforeseen and unanticipated machine quality problems. Furthermore, by being in control of machine precision, a manufacturing facility's total downtime will be reduced by being able to exclude the machine as the main cause of any problem later in the production process.

The primary goal is accomplished by collecting data utilizing fast check measurement methods or monitoring post-process quality data to monitor the state of the machine tool. As a result, data from either the machine or the component should be used to drive calibration. Building a database of inspection history by regularly measuring the equipment using relatively non-invasive techniques would be beneficial.

4. CONCLUSION

In high-value manufacturing, maintenance is a strategic issue. Analysis of failures, as well as the creation and application of appropriate mathematical cost methods, are required to create an optimum, cost-effective maintenance strategy. A machine tool's or a set of machine tools' performance is determined not only by its design, layout, and operation, but also by the machines' successful calibration and maintenance throughout their operating lifespan. When evaluating maintenance effectiveness, advanced manufacturing technologies and contemporary metrology weigh in important variables like downtime and product quality. Manufacturing facility safety and environmental sustainability have also become more significant considerations. Manufacturing waste, discarded raw materials, energy, and consumables used for re-machining all come at a high cost and have a negative environmental effect. Many reasons contribute to product inaccuracy. The machine tool on which the component is manufactured is one of these. Many reasons may result in machine errors. During the machine's early life, they may be the worst. Machine inaccuracy or erroneously attributing product inaccuracy to the machine may occur due to design, installation, and operating issues, bad measurement methods, inadequate measuring equipment, and misunderstanding of measuring data. In order to reduce uncertainty and improve decision-making, a scientific approach to measurement is required. Without appropriate installation in a way tailored especially to suit the machine's needs, the performance, repeatability, and accuracy built into today's advanced machine tools cannot be provided. Predictive calibration is a method that aids in the management of production accuracy problems as well as the identification of the source of components that are out of tolerance. As a result, there is a decrease in the number of people who smoke. Increases total efficiency by reducing machine tool downtime and facilitating traceable inspection on the machine.

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