WHITE PAPER

PREDICTIVE MAINTENANCE THROUGH DIGITAL TWINNING

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How can a Digital Twinning enhance maintenance activities?

This white paper looks at the need for maintenance of complex machines and specifically the role of Digital Twinning in advancing maintenance of complex machines, and why it’s a great strategy to consider. It will discuss in-depth how a digital twin is implemented and give tips on how and where to get started when looking to implement this strategy.
## Contents

- Introduction 1
- Role of a Digital Twin in Advanced Maintenance 3
- Implementation 4
- Get Started Today 7
- Conclusion 9
- References 9
Introduction

Industries have started using complex machines to a large extent leading to new challenges from unexpected failures that arise. Unexpected failures of the machines can have a great impact resulting in high costs. Therefore, there is a need for proper maintenance for these machines and their components to reduce downtime costs and avoid unexpected failures. Sophisticated methodologies have now been developed to improve maintenance.

One of these methodologies is the Failure Mode and Effect (and Criticality) Analysis (FME(C)A). It enables the identification of possible errors and focuses on them until corrective actions are taken. Unfortunately, most maintenance actions today are performed after the error has already occurred. This means that downtime is not prevented. To avoid this, there is a need to shift from the traditional fix-it-when-broken (diagnostics) to a predict-and-prevent (prognostics) methodology. That way, the industry is aware of the state of the machines and their components at all times.

Prognostic and Health methodology is one of the predictive maintenance methodologies that predicts the time a machine will no longer be useful. One important measure for decision-making of maintenance actions is the Remaining Useful Life (RUL) measure. It analyzes the information about the state of the machine or component that is being assessed. This is estimated by comparing sensor data and historical data using a prediction algorithm to predict the future health of the machine and its components.
Implementing a prediction algorithm requires a huge amount of data. Therefore, acquiring these data can take a long time and requires a large storage space. Also, it’s not feasible to measure all aspects of a component for example temperature and pressure. Thus, a prediction system based on these sensors rarely captures the complete overview of all possible correlations among the failure modes. The focus should be put on some components and not the machine as a whole. Therefore, the utilization of all the components of the machine is still restricted by the lack of solutions to collect, connect, control, and combine the obtained information for predictive maintenance.
Role of a Digital Twin in Advanced Maintenance

Digital twinning is a technology that has come up along with the evolution of Industry 4.0. A Digital Twin is a real-time virtual representation of a physical asset. It is done by analyzing data and visualising information using the mathematical representation of the machine to gain useful insight into its behavior. The data is gathered by sensors embedded in the machine. A digital twin can analyse the condition, efficiency, and real-time status of the machine. The detailed mathematical models of components of machines and their interaction allow the user to monitor and gather data from each separate component or of a complete system.

Digital Twinning technology does not only support in the better prognosis of the RUL but also, by representing the machine virtually and visually, it can promote a better understanding of the machine and the complex mechanisms it has inside. Another benefit is that it enables the development of new opportunities and planning the future using simulations.1

Implementation

A successful implementation of a Predictive Maintenance is much more complicated than only extracting data from the asset. Besides the modelling, tuning to the actual condition is required, and the prediction model, the implementation in the enterprise IT/OT system should be such that the correct maintenance decisions can be made.

The following steps should be followed when implementing the digital twinning strategy:

[Diagram showing the steps of implementing Predictive Maintenance]
The heart of all predictive maintenance strategies is data. This data is extracted from the asset and meaningful features are extracted in a machine learning algorithm to predict the future behavior. However, it is not always possible to acquire all possible fault data. Permitting faults in machines may be unfeasible, since it can lead to catastrophic failures and destroyed equipment.

The development of a digital representation of the actual asset provides a solution to the development of a predictive maintenance strategy. The model is based on the modelling of the mechanical, electrical, and all other functions of the machine. Through simulations all possible fault combinations and varying severity can be generated, without applying faults to the actual machine.

The second step is the tuning of the Digital Twin. The calibration requires actual data from the machine. Not all data is relevant and can be used as an input in the simulation model. The obtained data should therefore be analysed and processed such that large amounts of unnecessary data are avoided. The processed data are compared to those of the actual machine. To eliminate the error of the comparison, an estimation of the modelling parameters should take place periodically and updated in the Digital Twin. This tuning procedure is based on the comparison of the actual machine’s component behaviour and the predicted simulation outcome. Critical components have to be updated more frequently than others that have less impact on functionality.
After the modelling of the machine and tuning during operation, the main objective is to utilize Digital Twin. Simulations of the outcome of the performed tasks are compared to the output of the real machine in operation. A comparison is made, and the results are used to calculate the RUL. Later, a validation of the usefulness of the information and the representation of the information for the user should be reviewed.

The RUL is calculated by considering the data gathered from the sensors and controllers on the machine and the results from the simulation of the physics-based model. The collected sensor data are not always adequate to estimate RUL due to the change of the functionality in the machine over time. Thus, the necessity to use the Digital Twin arises. The virtual sensors are used to capture any abnormal behavior of the real machine. When calculating the RUL, factors like future operation plan and the model of physical degradation are analyzed and the simulation outcome is compared with the real output of the machine.

The final step in the development of a prognostic maintenance planning is the time to perform maintenance actions. Financially valuable considerations should be made on whether and when to perform maintenance actions based on the RUL. This can only be successful if the Predictive Maintenance strategy can be implemented in the enterprise IT/OT system. This step is crucial to make the
Imagine the Possibilities

Have a focused ideation session with business, operational, and technical leadership team members to imagine and shortlist some scenarios that can benefit from having a digital twin. The right scenario will most likely have the following characteristics:

- The manufacturing process or product is valuable enough to consider investing in building a digital twin.
- There are product-related issues or outstanding processes that could unlock some value for the enterprise or the customer.

Once the shortlist is created, it is important for each situation to be assessed to determine which processes can provide quick benefits when using a digital twin.

Identify the Process

The next step is identifying the pilot digital twin with the highest possible value and the highest chance to be a success. Business and organizational change factors and stakeholders should be considered in identifying the best configurations for the pilot. Also, focus on areas with a high potential to scale across technologies and sites. The ability to deploy broadly and not too deeply across the organization drives the most value and support. So, the focus should be on broad rather than deep deployment.
Pilot a Program

Move into a pilot program by using iterative and agile cycles that speed up learning, manage risk, and maximizes profits. This pilot could be a set of business divisions, or products, with the ability to show value to the customer, enterprise and stakeholders. The implementation team must support adaptability at all stages of the development for easy integration with new data and technologies. With the achievement of the initial value, build on this momentum to drive greater results, and then communicate this value to the larger enterprise.

Monitor and Measure

Changes should be monitored regularly to measure the value delivered by the adoption of the digital twin. Tangible benefits that can be measured include yield throughput, quality, cycle time, and cost per item but also effectiveness of decision support. Make iterative changes to the digital twin processes to measure results and identify the best configuration. The most important thing to note is that this project shouldn’t just end when the value is achieved, implemented, and measured. It should be improved continuously with the changing company needs.
Conclusion

Adoption of the proposed digital twin based prognostic maintenance strategy can change end-to-end business, optimizing maintenance actions, and considering predictive maintenance tools to reduce downtime, improve safety, and increase profit. In other words, Digital Twins drive innovation and performance.

With the physics-based model, the ability arises to implement prognostic maintenance strategies using little data and almost no historical data. The calculation of the RUL can help to instantly check the condition of a machine as well as the future prediction of the condition of its components.

References
