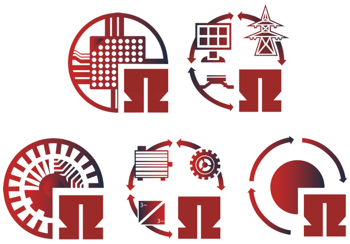
ELSYS Note



Machine diagnostics & Condition monitoring

Everyone, from students to experienced engineers, has likely encountered the concept of "Condition monitoring". This edition of the ELSYS Note provides a fundamental overview of "Machine diagnostics" and "Condition monitoring", offering readers a comprehensive introduction to the subject.

Motivation

The advancement of the digital age, specifically in the field of information processing and decision-making, has enabled significant improvements in efficiency and quality. With the help of digital tools, processes can be optimized and enhanced. However, a large collection of reliable data is required as a basis for accurate analysis. A key factor is measurement data, which provides information on the current status and intended use of a system. This results in enormous development potential, especially in the field of condition monitoring.

Terms & definitions

The term **machine diagnostics** describes the entire chain of effects of an undesirable symptom, starting from its origin **(cause)**, passing through the **error**, and resulting in its **(error consequence)**. The overarching goal is to monitor the current status of a system and to detect faulty functions, for example in the components in the system. In contrast, **machine monitoring** focuses on ensuring compliance with limit values and predefined tolerances.
As discussed by the authors in [1, 2], the technical term **"diagnosis"** was clearly divided into two sub-areas. This ELSYS Note primarily builds upon these references.

The **wear condition** clearly describes the cause of the fault, the type of damage and the resulting consequences for the component. This type of diagnosis offers advantages when the identification of corresponding modes within the detected signals and data records is required. If, on the other hand, the entirety of all possible diagnoses is to be systematically narrowed down, the focus is on the concept of **differential diagnosis**. In this case, all intact components are excluded according to the principle of the exclusion procedure until the damaged component is identified.
Condition diagnosis involves analyzing the current state of a system based on selected process and machine parameters, enabling a status comparison. This involves comparing the actual state with the target state of the system. The target state is defined neutrally in advance on the basis of clear process variables. With regard to the overarching keyword **"condition monitoring"**, limit values and time sequences are defined and monitored.
Compliance with the predefined limit values can be achieved through targeted monitoring of individual values or defined bands. Exceeding a warning threshold is usually due to a fault in the system. So called **symptoms** result with regard to the status detection or the target/actual comparison. These serve as input variables for further diagnosis and analysis. A schematic representation of this process is shown in the following Fig. 1. In this process, the results of the **condition comparison** are evaluated in order to localize the cause of the fault and where it originated. In addition, this method can be used to carry out a trend evaluation for early fault detection. Countermeasures can thus be initiated specifically to prevent faults. This process also reflects the basic principles of **predictive maintenance**. This procedure is also recognized as a quality assurance task, as described in [2], with applications that can be direct or indirect.

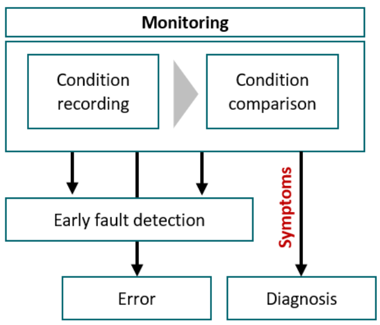


Fig. 1: Process monitoring

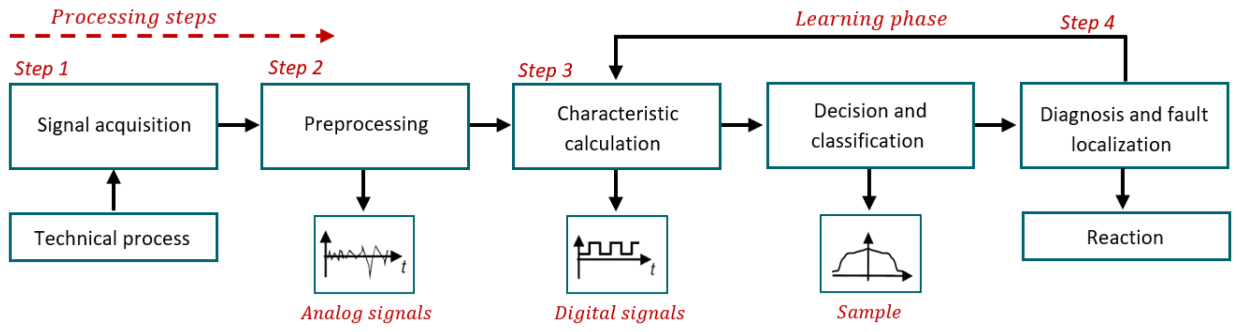


Fig. 2: Processing steps – signal processing to pattern recognition

Machine and monitoring parameters can thus be evaluated in terms of time, location, directly or indirectly via their respective effects using measurable variables.

Processing steps

In addition, the selected methodology for utilizing of physical signals will be adopted and applied to the principle of **machine monitoring**. This method specifically focuses on extracting the behavior and characterisitcs of the monitored system. However, this can only be done when the system is at a standstill and not during operation. In many cases, the indirect or in-process recording method is used as an alternative solution. In this case, measurable effects of the changing state variables and signals are detected.

The process of detecting physical signals and variables can be divided into individual processing steps, as shown in Fig. 2.

1. Signal Acquisition

First, the **signal acquisition** takes place using internal or external sensors, obtaining signals directly from actuators or the control loops.

2. Signal Preprocessing

To extract meaningful features, **signal preprocessing** follows, ensuring reliable insights into the process or status. Analog and digital preprocessing are essential:

- Analog preprocessing prepare signals for digitization without significant errors.
- Digital preprocessing focuses on correcting and filtering signals to extract relevant information.

3. Characteristic Calculation

Next, **characteristic calculation** determines key variables from processed signals. These are used in the decision-making process and classifying faults. A detailed fault pattern analysis, combined with prior system knowledge, allows for a precise assessment of the extracted characteristics.

4. Learning phase

The process then transitions into the **learning and parameterization phase**. During **learning phase**, appropriate limit values are defined to identify errors and anomalies reliably. The **parameterization phase** follows an iterative approach, using classification techniques such as target/actual comparisons to refine detection accuracy.

Conclusion

The outlined processing steps establish a structured approach to machine monitoring and diagnostics, enabling reliable fault detection and predictive maintenance. By systematically acquiring, preprocessing, and analyzing signals, as well as refining parameters through learning mechanisms, the system can effectively classify faults and optimize performance.

References

[1] Detlef Maier. *Sensorlose online Zustandserfassung von Vorschubantriebskomponenten in Werkzeugmaschinen*. Dissertation, ISBN 978-3-936100-58-7. Universität Stuttgart, 2015. DOI: 10.18419/opus-4595.

[2] Christian Brecher and Manfred Weck. *Werkzeugmaschinen und Fertigungssysteme 3. Mechatronische Systeme, Steuerungstechnik und Automatsierung*. 9th edition, ISBN 978-3-662-46569-1. Berlin: Springer-Verlag GmbH, 2021. DOI: 10.1007/978-3-662-46569-1.