# MEASURING TRANSDUCERS

## INSTRUMENTAL PLATFORMS FOR VIBRATION ANALYSIS IN PREDICTIVE MAINTENANCE

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**Abstract.** The article explores the benefits and importance of predictive maintenance in Industry 4.0. It is a revolutionary approach that analyzes data from cyber-physical systems to predict possible equipment failures before they occur and technology applied to detect early signs of a vibration problem on equipment. Thus, downtime is minimized and production continuity is ensured.

**Key words:** Accelerometer, Cyber-physical system, Predictive maintenance, Measurement of vibration parameters.

### 1. Introduction

At the heart of Industry 4.0, where machines and workers make decisions based on large volumes of data, a revolutionary approach to maintenance takes center stage: predictive maintenance. Unlike traditional, pre-planned preventive maintenance, predictive maintenance (PdM) uses capabilities to predict potential equipment failures before they occur, preventing downtime and ensuring permanent production [1], and also analyzes data generated by a cyber-physical system (CPS) [2], to create a smarter and more responsive production environment. Below are some of the benefits of predictive maintenance in Industry 4.0:

1. A proactive approach versus a reactive one. Traditional maintenance is based on scheduled inspections or responses to breakdowns. The PdM changes the script by taking a proactive approach. By constantly monitoring the state of the equipment with the help of sensor data analysis, potential problems are detected before they develop into serious malfunctions.

2. Data-driven solutions. PdM thrives on real-time data collected by sensors embedded in machines (industrial facilities). They include temperature, vibration, pressure, and other parameters that provide valuable information about the condition of the equipment. Advanced algorithms then analyze the data, identifying trends and patterns that signal the threat of a defect.

3. Minimized downtime. With the help of PdM, the system detects a problem early, while scheduling preventive maintenance during planned downtime. It minimizes production disruptions and ensures uninterrupted operations.

4. Reduced repair costs. Early detection of problems with PdM prevents catastrophic damage, provides fewer repairs, and lowers overall maintenance costs.

5. Improved efficiency. By keeping machines in working condition, the PdM helps reduce downtime, which increases productivity.

In the field of PdM for Industry 4.0, vibration analysis is a powerful and unobtrusive method. It becomes crucial in diagnosis of the equipment condition detecting potential problems early before they develop into serious malfunctions. This is why vibration analysis is so important in the context of Industry 4.0 [3-5]:

1. Early warning system. Each machine is characterized by unique vibration during operation. Vibration analysis focuses on detecting deviations from baseline. These abnormalities can serve as early warning signs of potential problems such as bearing wear, misalignment, or imbalance.

2. Continuous and unobtrusive monitoring. The deployed sensors strategically attached to the machine monitor the state without interrupting operations. This round-the-clock vigilance ensures that potential problems are detected as soon as they arise.

3. Statistics based on data. Vibration analysis seamlessly integrates with the core principle of Industry 4.0. Sensor data is fed into the CPS network, where advanced algorithms analyze it, identify abnormal vibration patterns, and correlate them with potential equipment problems.

4. Prediction of the future. By analyzing vibration data and historical trends, PdM systems equipped with vibration analysis can predict potential failures with a high degree of accuracy. Intelligent approach includes proactive maintenance planning, preventing downtime, and ensuring uninterrupted production.

5. Equipment reliability. Early detection of problems through vibration analysis prevents major breakdowns, resulting in increased equipment reliability and a more predictable production environment.

6. Reduced maintenance costs. By addressing problems early, companies can avoid costly repairs and replacements associated with catastrophic failures. Vibration analysis helps optimize maintenance costs by focusing resources on critical issues.

7. Improved security. Unknown equipment vibrations can pose a safety hazard. PdM with vibration analysis helps reduce these risks by proactively addressing potential problems before they become problems.

Vibration analysis is not the only method used in PdM, but it is a key one. By seamlessly integrating with the data-driven approach of Industry 4.0 [6] and offering continuous monitoring capabilities, vibration analysis enables companies to truly listen to their machines. This early warning system plays a vital role in maximizing the life of equipment, optimizing maintenance strategies, and ensuring a more efficient and reliable manufacturing environment within Industry 4.0.

## 1. Drawbacks

Vibration analysis is a common predictive maintenance technique applied to identify potential equipment failures. However, this method is characterized by the following disadvantages:

- Limited scope.
- Vibration analysis is not suitable for all types of damage. It is most effective for detecting problems related to rotating components such as bearings, gears, and shafts. Other types of defects, such as electrical problems or leaks, may not be detected.
- The need for sensors. Vibration analysis requires special sensors installed on the equipment.
- Complexity of interpretation of vibrometric data.
- Environmental noise can affect the received data and make it difficult to detect the real state of the machine.
- The importance of reference data. For the successful application of vibration analysis, it is necessary to obtain reference data on the vibration of the working equipment. These data are collected during the introductory testing and serve as a basis for comparison with the results of subsequent measurements.
- The need for regular maintenance of vibration sensors.

## 2. Goal

Study of vibration tools exploration for predictive maintenance, analysis, and identification of their specific, and technological applications.

## 3. Instrumental platforms for vibration analysis

### 3.1. VES004 diagnostic software for configuring vibration diagnostics

VES004 diagnostic software [7] in combination with accelerometers and diagnostic electronics of the VSE series is studied for vibration monitoring while maintenance of machines and installations. The diagnostic device can continuously and simultaneously analyze and evaluate signals from up to four accelerometers. To understand the capabilities of current software, you need to pay attention to key features.

1. Settings of Parameters

The software contributes to the definition of the critical parameters for vibration sensors, such as alarm thresholds, frequency bands of interest, and data filtering parameters. This configuration ensures that the system focuses on the specific vibration patterns that apply to your equipment.

2. Real-time data and historical data

VES004 provides a comprehensive view of the equipment state. You can monitor vibration data in real-time, identifying potential problems immediately.

3. Data analysis

The software includes built-in data analysis tools are applied to visualize vibration spectra and identify specific frequencies that may indicate developing problems.

4. Fieldbus integration

A key aspect of Industry 4.0 is seamless communication between devices. VES004 supports integration with various fieldbus protocols such as Profinet, EtherNet/IP, and Modbus TCP. Integration of vibrometric sensor data into the CPS network facilitates real-time monitoring and analysis.

### 3.2. Examples of object monitoring

The monitoring process begins with setting the object type. It can be a bearing, a fan, and others. At the next stage, you need to choose the value of the rotation frequency of the shaft or fan, which determines the state of the object.

### 3.3. Fan imbalance

Fig.1-2 shows the spectrum analyzer window. The band indicates the frequency at which the fan malfunction was detected. In Fig. 1. we can observe the absence of deviations from normal operation. In Fig. 2, a deviation has already been detected, which signals that the fan is unbalanced. The frequency at which the imbalance is detected is determined automatically after its pre-setting.

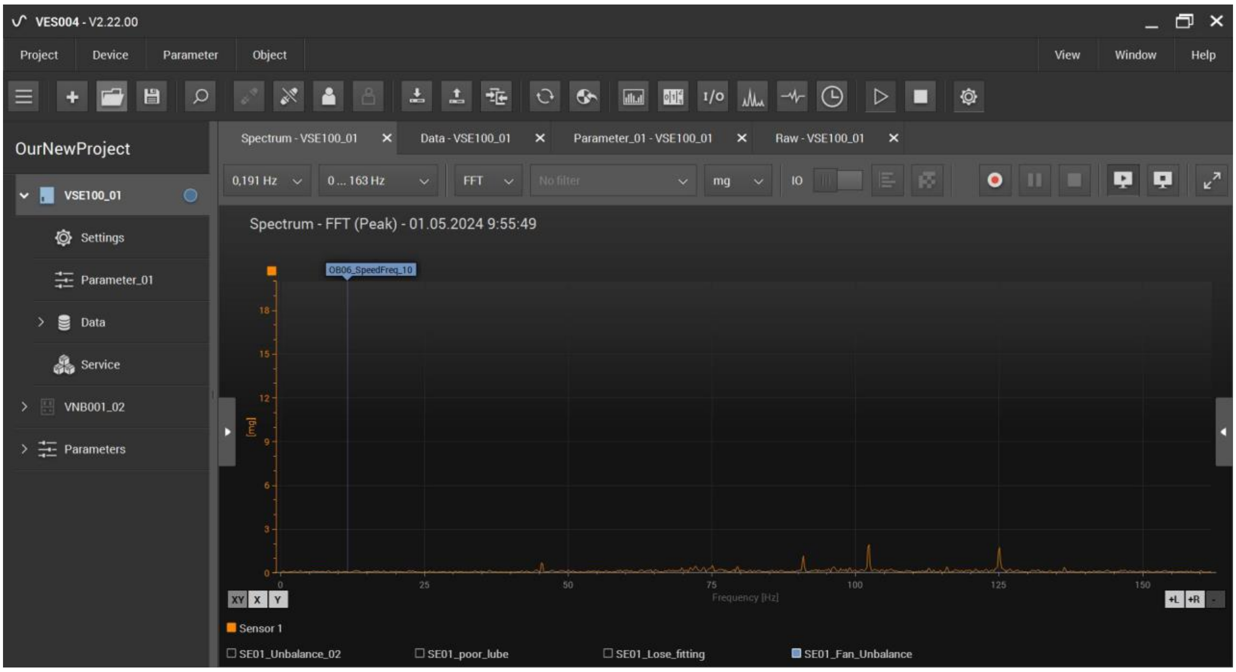


Fig. 1. Vibration graph of a working fan.


Fig. 2. Vibration graph of a faulty fan.

### 3.4. Imbalance of the rotation shaft

In addition to fan imbalance, the level of rotation shaft imbalance can be determined. Fig. 3-4 shows the levels of imbalance. In the first case, it can be determined that the vibration level reached the value of 9 mm/s because an asymmetric object is attached to the shaft. In Fig. 4 we observe the same imbalance, but with an amplitude of 2 mm, which means that the shaft is installed incorrectly. Such application of software and sensors may be realized before operation checking the equipment.

### 3.5. Bearing condition

Fig. 5-6 presents vibration graphs of two bearings - a working and a faulty. The blue bars indicate the damage frequencies for the three bearing elements (outer ring, inner ring, and the rolling element itself). Measurements were made at the same rotation frequency.

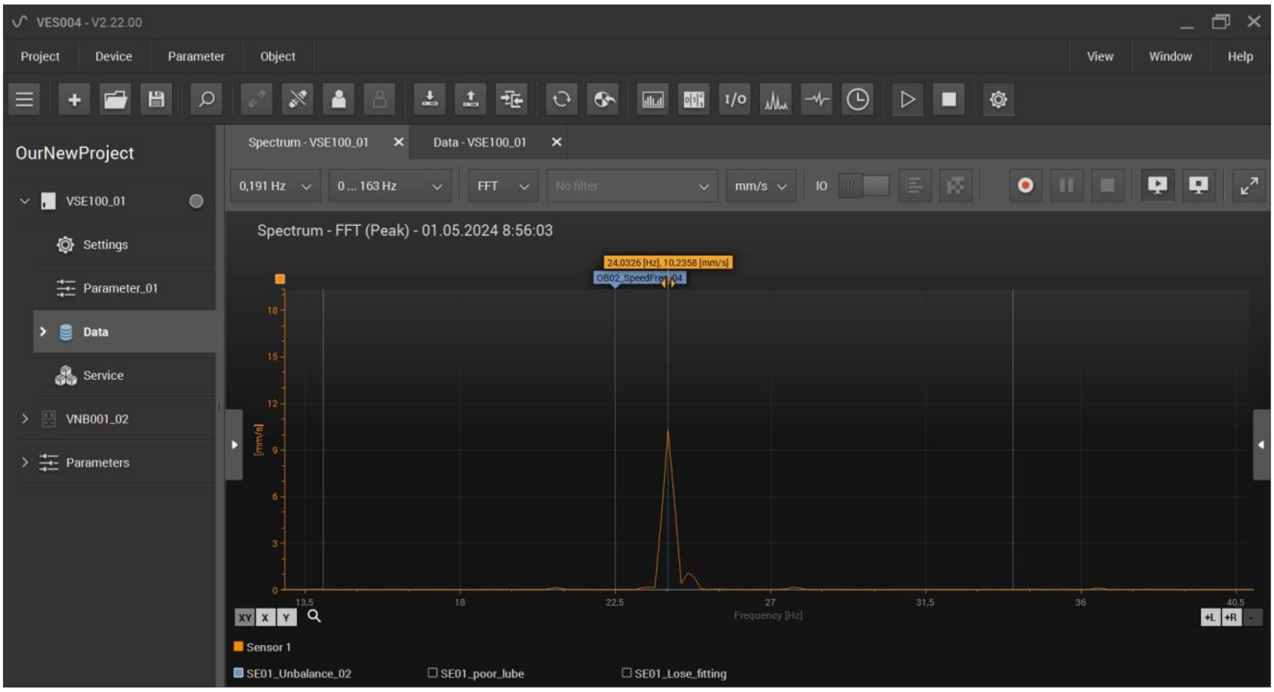


Fig. 3. Level of imbalance.


Fig. 4. The level of shaft imbalance at idle.

### 3.6. The condition of objects and their defects

It is possible to observe the state of objects by a special status window. The data in Fig. 7 is understandable even to users who have no experience in frequency spectrum analysis.

### 3.7. Disadvantages of VES004

The application of software for vibration analysis contains several disadvantages:

1. PC preset is possible.
2. The need to know the characteristics of equipment (engines, pumps, etc.) and other objects (bearings).
3. Lack of possibility to notify the operator using e-mail. The software can configure the device so that it can provide a visual signal when a threshold value is reached.
4. Lack of ability to send monitoring history to email. Only the option to export recorded data to a local computer is available.

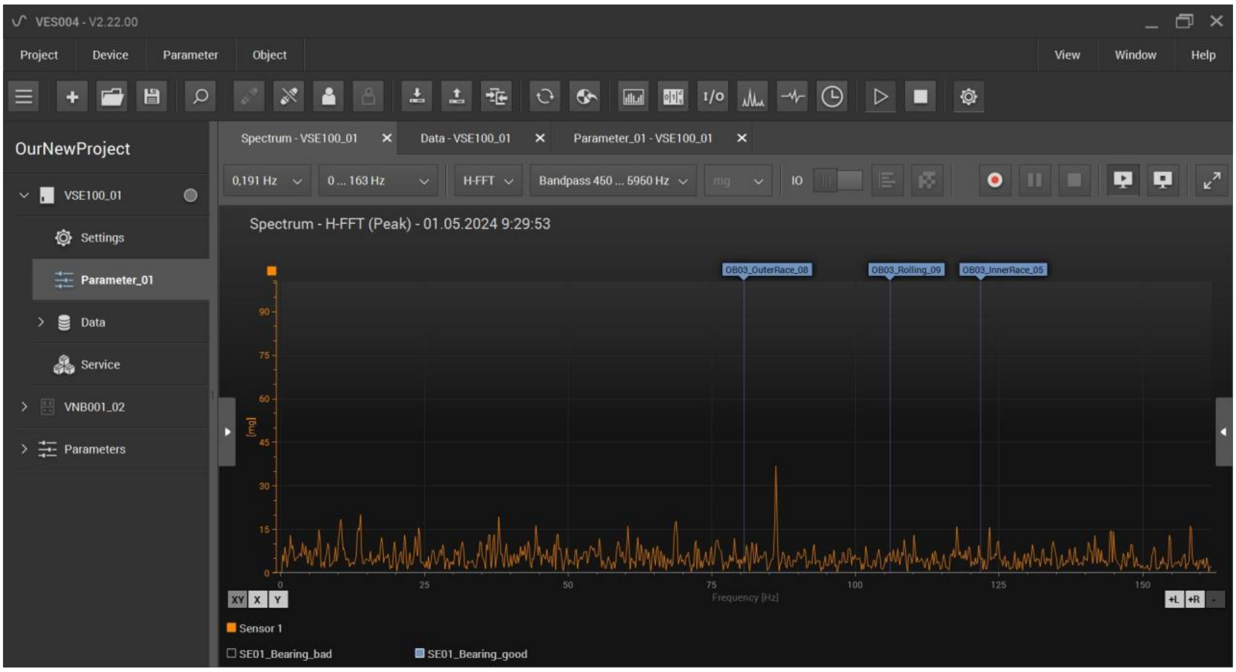


Fig. 5. Working bearing.

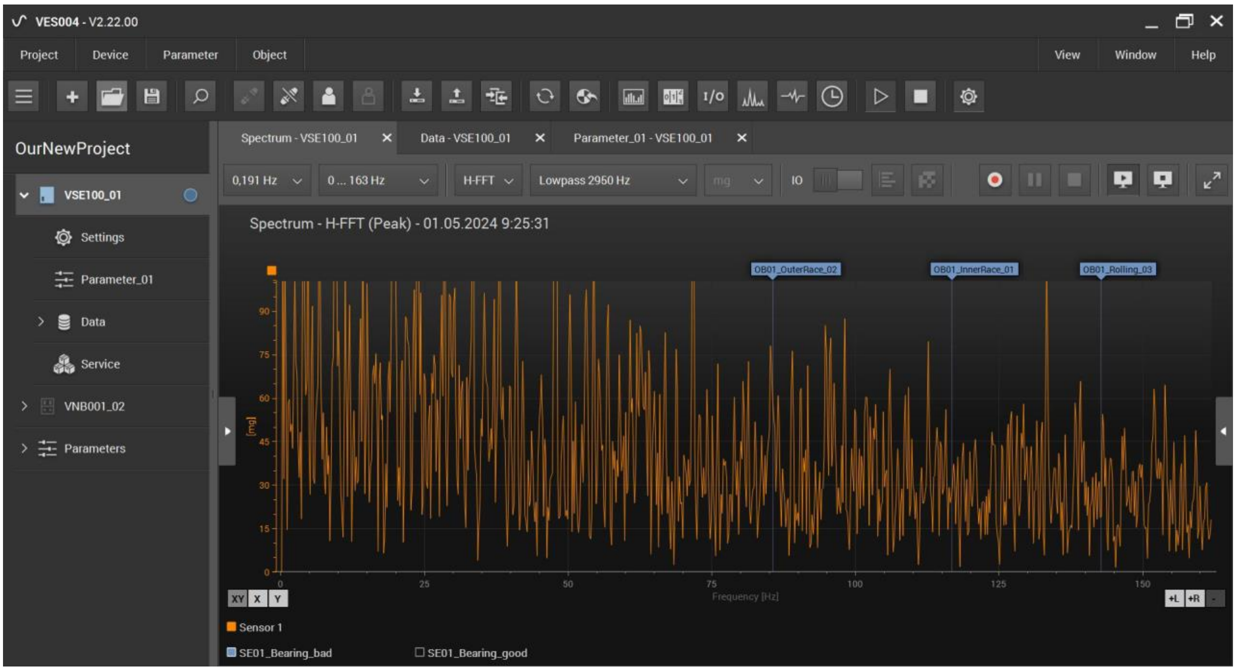


Fig. 6. Defective bearing.

5. Binding to certain types of devices.

For an untrained operator, it is quite difficult to understand the user's interface, including device settings.

### 3.8. moneo OS. Software for Industrial Internet of Things

The solution, that should eliminate the shortcomings indicated in VES004, is the software moneo OS [8]. It is a comprehensive software package for managing, analyzing, and optimizing industrial facilities. Software, unlike software limited to certain types of sensors, covers a wider perspective. So that it can configure, monitor, and diagnose the devices and sensors (temperature sensors, pressure gauges, vibration monitors, or even complex industrial controllers) in the network. moneo acts as a central hub for them. The possibility of connecting devices that support the IO-Link standard [9-10], is conjugated with an opportunity to choose a device for specific requirements.

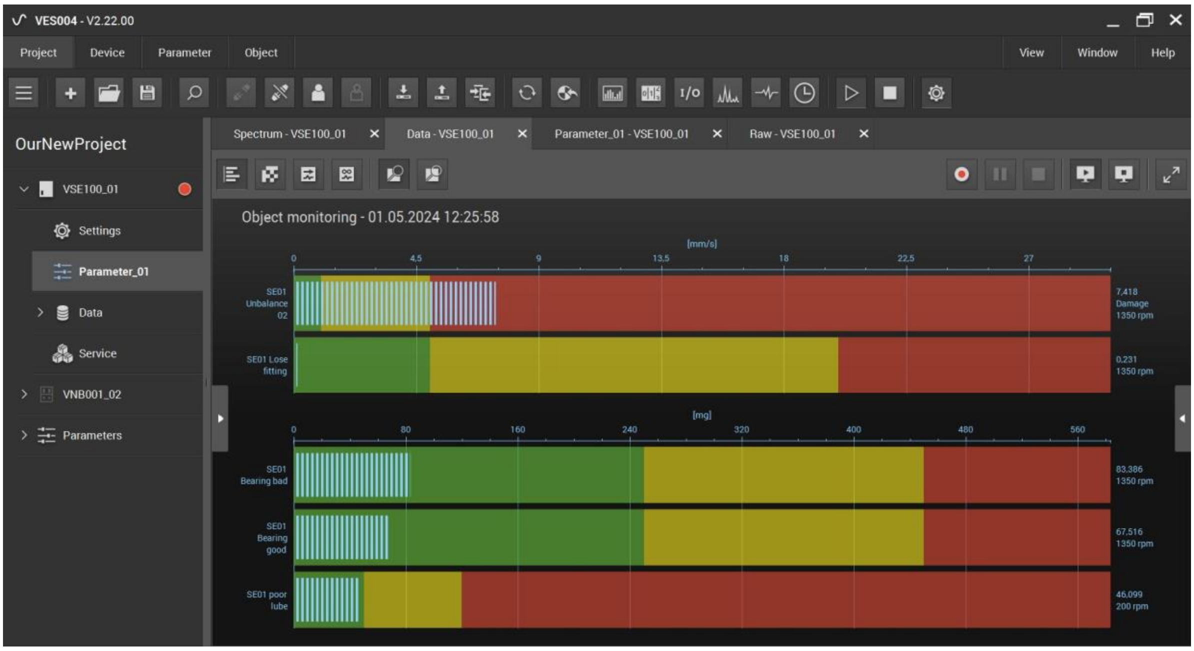


Fig. 7. List of objects.

moneo OS goes beyond vibration-focused software. It seamlessly integrates data from various sources, such as sensors for temperature, pressure, flow, energy consumption, etc. Such a holistic approach provides a complete picture of equipment health and performance, including real-time data visualization, history, and forecasting of future service needs. moneo OS presents the collected data in various formats, including tables, graphs, and charts, and is powerful in creating personalized dashboards that display key process values and equipment status in real time. It is possible to manage alarms based on preset threshold values for various parameters.

moneo OS is built with full integration in mind. It supports various industrial communication protocols such as Profinet, EtherNet/IP and Modbus TCP. This enables seamless data exchange between devices, sensors, and cloud platforms, contributing to the interconnected Industry 4.0 environment.

moneo OS simplifies vibration monitoring with minimal experience by following the ISO 10816-3 standardized approach [11]. It applies machine learning algorithms to analyze sensor data collected from machines. This analysis goes beyond simple threshold monitoring and identifies minor deviations from normal operating patterns.

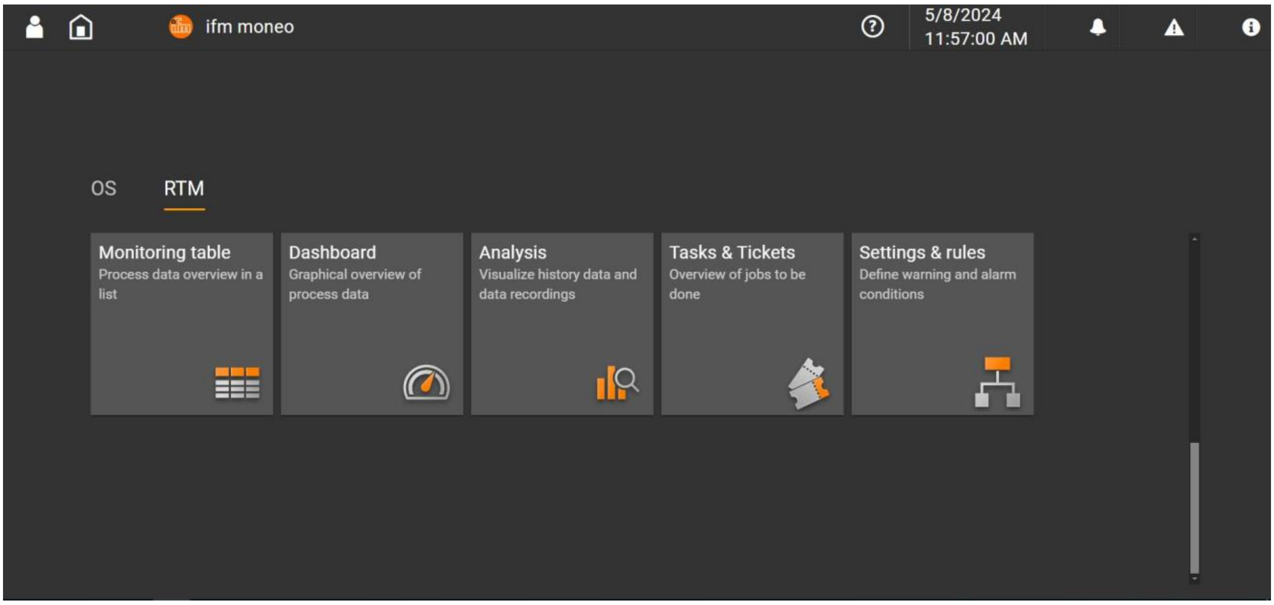


Fig. 8. Absence of functions for vibration analysis.

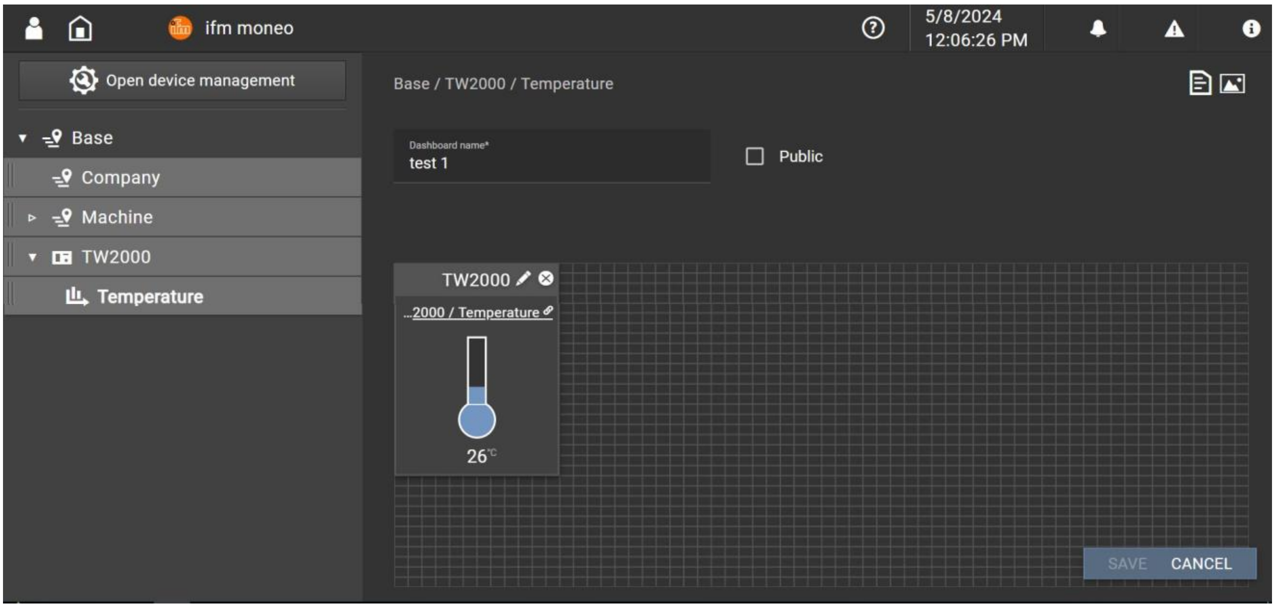


Fig. 9. Sensor data added to dashboard.

### 3.9. Drawbacks of moneo OS

There arise certain limitations while using moneo OS. First of all, it is designed for simple processes and simple industrial installations. Second, the proprietary moneo OS is closed software, which limits the flexibility to integrate with other industrial data platforms or custom software. Nevertheless, the test version does not give access to all software modules (Fig. 8) necessary for vibration monitoring.

In addition, the software does not save system settings. For example, sensor data added to the information panel (Fig. 9-10) are not saved if you leave the current window and switch to it again.

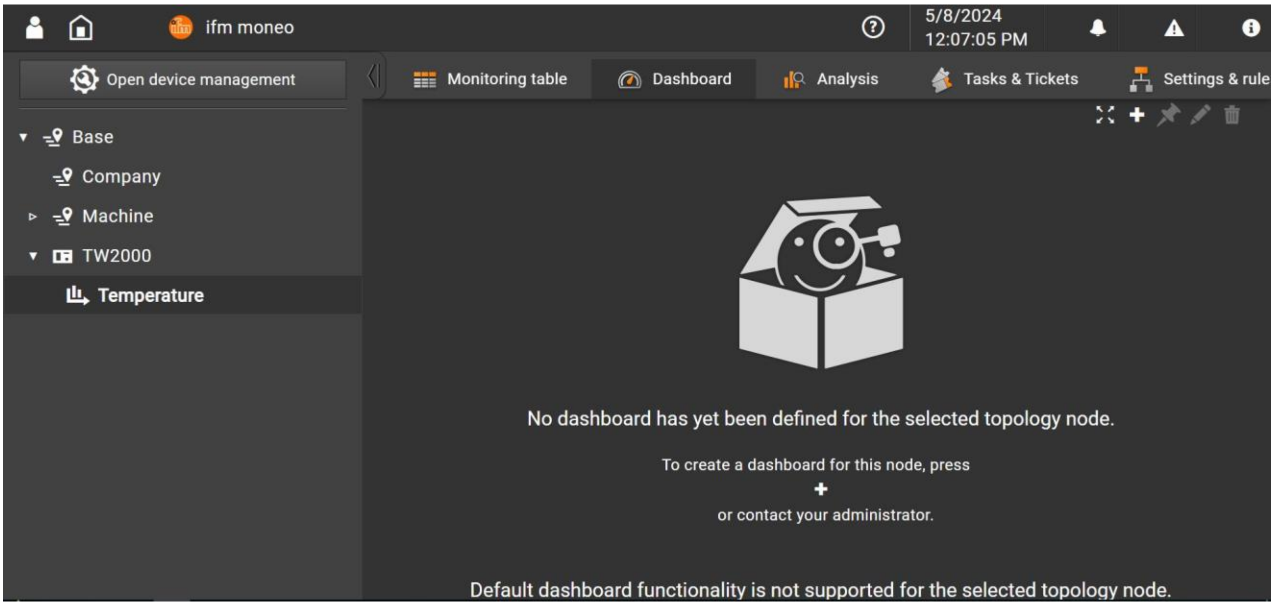


Fig. 10. The information panel is empty.

## 4. Conclusions

VES004 diagnostic software in combination with accelerometers and diagnostic electronics of the VSE series were studied for vibration monitoring while maintaining machines and installations. Several conducted experiments have demonstrated the possibility of assessing the condition of industrial facilities in terms of their vibration characteristics. Predicting a certain object's failure in the context of predictive maintenance needs further studies as well as optimization of VES004 diag- nostic software especially in exporting the received data. The ideal solution seems to be the automation of the proc- ess of recording and exporting data since in VES004 software it is manual.

## 5. Gratitude

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## 6. Conflict of Interest

The authors declare that there are no financial or other potential conflicts related to this work.

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