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(54) Title: SELF-LEARNING MALFUNCTION MONITORING AND EARLY WARNING SYSTEM

(57) Abstract: The present invention relates to a malfunction monitoring and early warning system (1) which can learn the determined malfunction data, is used in engines of different fields such as industrial engines, wind turbine engines, rail transport engines, and ensures malfunction, maintenance, and early warning determination by monitoring the temperature, vibration, and speed information of the engine on which it is used.



SELF-LEARNING MALFUNCTION MONITORING AND EARLY WARNING SYSTEM

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Technical Field

The present invention relates to a malfunction monitoring and early warning system which can learn the determined malfunction data, is used in engines of
10 different fields such as industrial engines, wind turbine engines, rail transport engines, and ensures malfunction, maintenance, and early warning determination by monitoring the temperature, vibration, and speed information of the engine on which it is used.

15 State of the Art

Engines are used in almost all fields in the industry for performing various works. In industry, operation of all types of machines is usually ensured by engines. Engines generate power and said power is used for operation of machines.
20 Different types of engines are used according to the characteristics and application areas of machines, and operation of the machines is ensured by means of said engines.

Some of the sectors where engines are commonly used are as follows: wind
25 turbines, railway rail system transportation, manufacturing, ship transportation, petroleum platforms, and aviation and aircraft sector and so on.

In areas where an engine is used, it is quite important that the engine used is suitable for the work to be done, the engine is used efficiently, the engine
30 maintenance is done on time, and malfunctions occurring in the engines are detected and timely intervened. As all machines, engines also have service lives.

The service life of an engine can vary depending on its usage conditions, operating temperature, the level of vibration they get exposed to, their operating speed, and compliance with their periodic maintenance. Timely maintenance is required for engines to ensure their efficient and problem-free use. Usage
5 conditions of engines should be monitored so as to plan their maintenance periods according to the usage conditions, and their maintenance should be made on time.

Today, there are systems used for monitoring the conditions of use of engines and detecting their malfunction situations. In said systems, vibration, temperature, and
10 speed parameters of engines are recorded by non-smart devices that cannot perform interpretation, and are reported by human-dependent systems. The most significant technical problem encountered in recording and monitoring systems used in the state of the art applications is that engine data are only recorded and reported by human-dependent systems. Not being able to monitor engine
15 operation data while recording the data with a dynamically learning structure, and not being able to dynamically estimate the malfunction and maintenance times according to engine operating conditions are significant technical problems. In systems known in the state of the art, there is no procedure for predicting engine malfunction or maintenance times, estimating maintenance times by means of
20 monitoring the use of the engine. Lots of mistakes are made with the state of the art malfunction determinations and manual maintenance times.

In the Chinese patent document No. CN 102706572 encountered in the known status of the art, an error detection and repair system operating while a train is on
25 the move is disclosed. In said patent document, vibration sensors are used, data collection is made, and a real-time analysis unit is found. However, in the patent according to the present application, temperature, speed, and vibration data of the engine are measured, said data are recorded, and estimations are made for engine malfunction and/or maintenance times according to the obtained data. In the
30 patent according to the present application, a self-learning system is disclosed, in which the malfunctions encountered, the reasons of the malfunctions,

maintenance results according to maintenance periods are recorded and learnt by the system, and used for determining the maintenance time in the next malfunction determination.

- 5 The German patent document DE 19919604 encountered in the known status of the art discloses a system for analyzing and detecting failures and malfunctions that occur while a vehicle is moving. In the said system, malfunctions and failures of the vehicle are detected. However, in the patent according to the present application, operation of the engines is monitored, recorded, and maintenance and
10 malfunction estimation are made according to the usage conditions of the engine.

- In the Chinese utility model document No. CN 202885861 encountered in the known status of the art, a dynamic sensing system for railway is disclosed. Data detection, data collection, and processing units are found in said system. With the
15 said system, unstable turns and improper turns of the train are determined in real time. On the other hand, the patent according to the present application has a completely different operating logic. In the patent according to the present application, the operating conditions and times of the engine are monitored by means of sensors. A possible malfunction estimation and maintenance time
20 estimation are performed according to the engine operating time and operating conditions. The system has a self-learning structure. The results of all malfunctions, errors, and failures that occur during use of the system can be learnt by the system, and determination can be made for the next similar situation.

- 25 In the Chinese utility model document No. CN 2124173 encountered in the known status of the art, an infrared thermal shaft sensor is disclosed for trains. Determination of excessive shaft heating by means of said thermal sensor, and thus ensuring safe drive are disclosed. In the patent according to the present application, temperature, speed, and vibration data of the engine are monitored so
30 as to determine the operating conditions of the engine and make maintenance and malfunction time estimation (prediction) according to said data.

With the patent according to the present application, operation of engines is monitored continuously and instantaneously. The operating conditions of the engine are monitored by measuring the vibration, temperature, and speed
5 information during operation of the engine. Since maintenance and malfunctions of engines are dependent on their operating conditions and operating times, the maintenance periods of engines are determined according to their actual operating conditions, and a possible malfunction is previously estimated to inform relevant people. The patent according to the present application also has a self-learning
10 structure. By means of the patent according to the present application, a system that can learn, can improve itself as the system works, and can automatically digitalize all kinds of malfunctions is obtained. In this way, maintenance times can be predicted, maintenance can be determined in a planned way, and significant cost advantages can be achieved in terms of maintenance costs.

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Purposes of the Invention

The purpose of the invention is to develop a self-learning malfunction monitoring and early warning system which can predetermine engine malfunction and
20 maintenance times by continuously measuring engine operating conditions, engine temperature, speed, and vibration.

Another purpose of the invention is to develop a malfunction monitoring and early warning system which can self-learn about encountered malfunctions according to
25 engine operating conditions, and develop new malfunction conditions according to the malfunctions learnt.

Another purpose of the invention is to develop a malfunction monitoring and early warning system which updates maintenance scheduling according to the learnt
30 new engine malfunctions, and then perform new estimations according to the updates.

Another purpose of the invention is to develop a malfunction monitoring and early warning system which performs malfunction maintenance estimation beforehand, and can provide a common malfunction maintenance program for engines that are
5 found close to each other.

Brief Description of the Invention

10 The malfunction monitoring and early warning system developed in order to achieve the purposes of the present invention, which is defined in claim 1 and the other claims dependent to claim 1, comprises: sensors placed on the engine and measuring the speed/revolution, vibration, and temperature values of the engine, a
15 malfunction monitoring module to which the sensors are connected, and a malfunction monitoring module showing the engine operation, malfunction and maintenance situations according to the information received from the malfunction monitoring module. The malfunction monitoring module records the measurement values received from the sensors and determines whether the measured values meet the conditions of use and whether they indicate a
20 malfunction or not by comparing the same with the values in the database. The malfunction monitoring module not only detects malfunctions but also monitors the engine usage conditions and estimates the maintenance periods according to the usage conditions, and transmits said data to the malfunction display module. The malfunction display module is a web based application or an application that
25 can be used in smart devices. It visually displays the information received from the malfunction monitoring module and the usage values of the engine, and allows the user to monitor the operation of the engine. The patent according to the present application has a self-learning, self-improving system structure. The malfunction monitoring module comprises the experience database, and the
30 experienced malfunctions are recorded into said database together with the information including the reason of malfunction, usage conditions before the

malfunction, type of the engine, and characteristics of the engine etc. In this way, the system continuously improves itself and learns about new malfunctions and their reasons, and gives malfunction and maintenance warnings by comparing with new malfunctions while performing malfunction monitoring.

5

With the malfunction monitoring and early warning system according to the present application, usage conditions and malfunctions of engines are monitored, prediction is made about malfunction and maintenance times according to these usage conditions, and notification is provided to users or operators about the predictions.

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Detailed Description of the Invention

15 A malfunction monitoring and early warning system developed in order to achieve the purposes of the present invention is shown in the attached figures, among which:

Figure 1. Is a schematic view of the malfunction monitoring and early warning system.

20

The components given in the figures are enumerated individually, and the meanings of these numbers are given below.

- 25 1. Malfunction monitoring and early warning system
 2. Speed sensor
 3. Temperature sensor
 4. Vibration sensor
 5. Malfunction monitoring module
30 5.1. Processor
 5.2. Memory

5.3. Communication unit

5.4. Signal converter

5.5. Filter

5.6. Experience database

5 5.7. Amplifier

6. Malfunction display module

The malfunction monitoring and early warning system (1) according to the invention is a system which performs malfunction monitoring and gives warning
10 in dangerous situations for all rail systems, manufacturing, ship transportation, wind turbine, oil platforms, and aviation sector. The malfunction monitoring and early warning system (1) ensures estimation (prediction) of malfunction situations and maintenance times of engines having different characteristics and being used in different areas in industry, according to their usage conditions. The malfunction
15 monitoring and early warning system (1) according to the invention has a self-learning structure, and records engine malfunctions together with the engine usage conditions during and before occurrence of the malfunction, and thus expands malfunction information and uses the new information in malfunction analysis and comparison. An electronically embedded smart card and a cloud based
20 software signal mechanism algorithms are used in the malfunction monitoring and early warning system (1). The malfunction monitoring and early warning system (1) is placed in rotating and moving accessories of all of the above said machines in industry, and early malfunction estimation is made by examining mechanical vibration wave forms during operation of the engine by means of a high frequency
25 accelerometer vibration sensor (4). In this way, operational maintenance activities and maintenance costs are reduced in machines where the malfunction monitoring and early warning system (1) is used.

The malfunction monitoring and early warning system (1) which is used in
30 industrial engines, and ensures malfunction, maintenance, and early warning determination by monitoring the temperature, vibration, and speed information of

the engine on which it is used, and can learn the determined malfunction data, comprises the following components:

- at least one speed sensor (2) placed in the engine to detect the engine revolutions or speed via the engine rotor,
- 5 - at least one temperature sensor (3) placed on or in the engine to measure the operating temperature of the engine,
- at least one vibration sensor (4) placed at the engine or at the place where the engine is fixed, to measure the level of vibration generated during operation of the engine or the engine is subjected to,
- 10 - at least one malfunction monitoring module (5) comprising at least one processor (5.1), at least one memory (5.2), at least one communication unit (5.3), and at least one experience database (5.6), receiving measurement values by communicating with a speed sensor (2), a temperature sensor (3), and a vibration sensor (4), and adapted to perform engine malfunction
- 15 estimation by interpreting said measurement values according to ideal engine usage conditions using the processor (5.1) and the experience database (5.6) found therein, predetermine the malfunction and engine maintenance times, and ensure determination of each malfunction together with its reasons by means of recording encountered malfunctions and the speed, temperature, and
- 20 vibration values at which the malfunction occurs,
- at least one processor (5.1) which is adapted to ensure that the experience database (5.6) learns about malfunctions by being continuously updated by recording, in the experience database (5.6), malfunctions that are not
- 25 previously recorded in the experience database (5.6), together with the information of the engine type and measurements of engine usage such as temperature, speed, and vibration, before the malfunction is encountered,
- an experience database (5.6) which is adapted to record, via the processor (5.1), the malfunction and its reasons, when an engine malfunction that is not
- 30 previously recorded is encountered, and to ensure that malfunction control and estimation is performed using the updated malfunction list while a new malfunction analysis is being made,

- at least one malfunction display module (6) which communicates with the malfunction monitoring module (5) via wired, wireless, Ethernet, or can bus connection, can be operated through the internet or a smart device, comprises visual graphics of the monitored engine, and allows the user to see the engine malfunction, the reason of malfunction and suggestions, and the engine maintenance time according to the data received from the malfunction monitoring module (5).

The malfunction monitoring and early warning system (1) consists of three main structures. The first structure is the structure where the sensors used for monitoring the operation of the engine on which malfunction and maintenance monitoring will be made. The second structure is the malfunction monitoring module (5) where malfunction determination and early malfunction determination are made according to the data received from the sensors. The third structure is a malfunction display module (6) allowing the user to visually see the malfunctions according to the data received from the malfunction monitoring module (5), and preferably operating on cloud in a web based and/or smart device based manner.

The operation of the engine is preferably detected by the speed sensor (2), the temperature sensor (3) and the vibration sensor (4) positioned on, in, or around the engine. In an embodiment of the invention, an encoder or a tachometer is used as the speed sensor (2), and the speed data is detected by means of said sensors. The speed sensor (2) preferably measures the rotation of the rotor or the engine shaft so as to calculate the revolution or rotation speed of the engine. For example, in a malfunction monitoring and early warning system used in engines of vehicles such as trains, the speed of the engine is measured. In engines used for tasks such as starting, rotating, or pushing a machine on industrial sites, the revolution of the engine shaft or rotor is measured.

The speed sensor (2) has a wired or wireless connection with the malfunction monitoring module (5). The speed sensor (2) continuously measures the speed

and/or revolution of the engine and immediately transmits the measurement results to the malfunction monitoring module (5). The speed sensor (2) transmits the measurement values in a digital or analogue way.

- 5 A temperature sensor (3) is used in the malfunction monitoring and early warning system (1) according to the invention to measure the temperature of the engine. The temperature sensor (3) has a wired or wireless connection with the malfunction monitoring module (5). The temperature sensor (3) is mounted on the engine or in the engine, so that it measures the temperature of the engine during
10 operation. The temperature sensor (3) transmits the measurement values in a digital or analogue way. The malfunction monitoring module (5) controls the operating temperature of the engine according to the value received from the temperature sensor (3).
- 15 Another factor that directly affects the expected life, malfunctioning, and maintenance periods of the engine is the vibration of the engine. In the malfunction monitoring and early warning system (1) according to the invention, the vibration level of the engine is measured by means of the vibration sensor (4) positioned at the engine or at the place where the engine is inserted. In an
20 embodiment of the invention, piezo electric vibration sensor is used as the vibration sensor (4). The vibration sensor (4) has a wired or wireless connection with the malfunction monitoring module (5). The vibration sensor (4) can transmit the measurement values to the malfunction monitoring module (5) in a digital or analogue way. The malfunction monitoring module (5) controls the level of
25 vibration that the engine is subjected to, according to the value it obtains from the vibration sensor (4).

In an embodiment of the invention, the speed sensor (2), the temperature sensor (3) and the vibration sensor (4) have an integrated structure. The speed,
30 temperature, and vibration of the engine can be detected by means of a single integrated detection unit placed on the engine.

In the malfunction monitoring and early warning system (1) according to the invention, the operating conditions of the engine are measured by the speed sensor (2), temperature sensor (3), and vibration sensor (4), and then transmitted to the malfunction monitoring module (5). The malfunction monitoring module (5) is adapted to track and monitor the operating conditions of the engine according to the measurement values obtained from the sensors (3, 4, 5). In an embodiment of the invention, the malfunction monitoring module (5) comprises a processor (5.1), a memory (5.2), a communication module (5.3), a signal converter (5.4), a filter (5.5), an experience database (5.6), and preferably an amplifier (5.7).

In an embodiment of the invention, the malfunction monitoring module (5) has signal inputs for connection of the speed sensor (2), temperature sensor (3), and vibration sensor (4). In an embodiment of the invention, the temperature sensor (3) and the vibration sensor (4) transmit the measurement results to the malfunction monitoring module (5) as analogue signals, and the signal converter (5.4) found in the malfunction monitoring module (5) converts said analogue signals into digital signals. The signal converter (5.4) preferably transmits the measured values of the engine to the processor (5.1) as a digital signal.

20

In an embodiment of the invention, the speed sensor (2) and the temperature sensor (3) are connected to the amplifier (5.7). The amplifier (5.7) can either be positioned within the malfunction monitoring module (5) or be positioned in an independent structure outside the malfunction monitoring module (5). The speed sensor (2) and the temperature sensor (3) enter the values to the amplifier in the form of analogue signal (5.7), and the amplifier (5.7) amplifies said signals and transmits thereof to the malfunction monitoring module (5). In an embodiment of the invention, the amplifier (5.7) amplifies analogue signals directly or in an isolated manner.

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In an embodiment of the invention, the signal converter (5.4) and/or sensors (2, 3, 4) are connected to the filter (5.5). The signals received from the signal converter (5.4) are filtered by the filter (5.5) to eliminate unclear signals, and the signals are enhanced by the filter (5.5). With the filter (5.5), noise is eliminated from the signals received from the speed sensor (2), temperature sensor (3), and vibration sensors (4), and the values are read more clearly.

In an embodiment of the invention, the signals received from the speed sensor (2) and/or temperature sensor (3) and/or vibration sensors (4) that perform analogue measurement are separated by the filter (5.5). Said signals are filtered (5.5) separately to receive each sensor value after they come out from the signal converter (5.4).

The malfunction monitoring module (5) preferably comprises a communication unit (5.3) which can perform wired or wireless communication. Remote access is ensured to the malfunction monitoring module (5) by means of the communication unit (5.3). Data transmission between the malfunction monitoring module (5) and the malfunction display module (6) is ensured via the communication unit (5.3). The communication unit (5.3) can perform 3G connection, Ethernet connection, CAN BUS (A Controller Area Network) connection, or Bluetooth connection, and can transmit data through said connections.

The malfunction monitoring module (5) is positioned on or close to or relatively far from the engine to be monitored. The speed sensor (2), temperature sensor (3), and vibration sensor (4) placed on the engine are connected to the malfunction monitoring module (5). In this way, the operating conditions and malfunction situation, the speed, temperature, and vibration measurements of the monitored engine are transferred to the malfunction monitoring module (5). The malfunction monitoring module (5) processor (5.1) processes the speed, temperature, and vibration measurement values for the engine to monitor the operating situation of

the engine. The processor (5.1) ensures recording of the analogue measurement values obtained from the vibration sensor (4) and the temperature sensor (3) into the memory (5.2), directly or after coming out of the signal converter (5.4). The speed data for the engine is preferably taken digitally from the speed sensor (2) and recorded directly in the memory (5.2). The speed, temperature, and vibration measurement values are recorded in the memory (5.2) together with the hour, minute, and second information.

In an embodiment of the invention, the measurement values received from the speed sensor (2), the temperature sensor (3), and the vibration sensor (4) are filtered by the filter (5.5), before being recorded in the memory (5.2) or after being recorded in the memory (5.2). With the filter (5.5), frequency components of digital signals such as speed and vibration are found. At the same time, noise filter is applied on said digital signals via the filter (5.5) so that the noise pollution on the signal is reduced, and the vibration value is determined from the signal value.

The malfunction monitoring module (5) processor (5.1) determines, according to the measurement values recorded in the memory (5.2), whether there is vibration or not during operation of the engine. The processor (5.1) is adapted to determine whether there is vibration or not in operation of the engine, whether the vibration causes resonance or not, and to perform vibration classification according to the filtered measurement value received from the vibration sensor (4). The processor (5) preferably compares the measured vibration value with the vibration values found in the experience database (5.6). In the experience database (5.6), the vibration values, and whether the vibration is circular or linear according to the vibration values are recorded. The processor (5.1) compares the measured vibration value and the vibration value found in the experience database (5.6) so as to determine whether there is resonance or not during operation of the engine, and whether the vibration is circular or linear, and then records said information

and/or transmits thereof to the malfunction display module (6) through the communication unit (5.3).

In a preferred embodiment of the invention, characteristics of different types of engines are recorded in the experience database (5.6) and/or new recordings can be made by a user or operator according to the engine to be monitored. For example, in a system where the malfunction and maintenance situation of a train is to be checked, first of all the manufacturer company of the train, the type of ball bearing used and the type of mechanical parts used by the manufacturer company, the operating conditions of the ball bearing or materials, and usage threshold values are recorded in the experience database (5.6). Parts maintenance information is also entered in the experience database (5.6) together with the said data. In this way, the replacement periods of different parts of the engine and their maintenance periods can be determined by the processor (5.1). Since usage and malfunction maintenance instructions of engines are not followed closely enough by operators, there may be situations where malfunctions occur or maintenance is needed earlier than the required period due to the expected lives of engines, and such situations can be monitored by the malfunction monitoring module (5). After the maintenance, malfunction, and parts information about the engine are entered, early warning determination is made according to the temperature, speed, and vibration values of the engine, so that the user can be informed about malfunction and maintenance due to usage.

The malfunction monitoring module (5) processor (5.1) determines, according to the measurement values recorded in the memory (5.2), the operating temperature of the engine. According to the filtered measurement values received from the speed sensor (2) and the temperature sensor (3), the processor (5.1) compares the operating speed and temperature of the engine with the values found at the experience database (5.6) of the engine so as to monitor the operating conditions of the engine. The processor (5.1) records the operating conditions and periods of the engine with regard to the temperature, speed, and vibration of the engine,

starting from the moment when the engine is started. The processor (5.1) records the measured temperature and speed values and/or transmits thereof to the malfunction display module (6) through the communication unit (5.3).

5 The processor (5.1) monitors and records the vibration, temperature, speed, and usage period data of the engine during engine operation. The processor (5.1) performs malfunction and maintenance prediction for the engine according to said usage conditions. The processor (5.1) compares the engine usage values with the values found in the experience database (5.6), and calculates, according to the
10 operating condition values, when the engine will need maintenance. The processor (5.1) calculates the probability and expected time of a possible malfunction according to the usage conditions of the engine. The processor (5.1) is adapted to transmit said calculated values to the malfunction display module (6) through the communication unit (5.3).

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When there is a malfunction in the engine, the malfunction monitoring module (5) determines the type of the malfunctioning engine, at which temperature, speed, and vibration values the engine had been used before the malfunction, and the reason of occurrence of the malfunction, and then records the same to the
20 experience database (5.6). In this way, encountered malfunctions and malfunction conditions are recorded in the experience database (5.6) so that the malfunction monitoring module (5) can continuously learn about the malfunctions.

In an embodiment of the invention, malfunction monitoring and early warning
25 systems (1) used for different engines in different places can be integrated to each other. Each malfunction monitoring and early warning system (1) malfunction monitoring module (5) shares, via the communication unit (5.3), the newly obtained malfunction and malfunction reason information with the malfunction monitoring modules (5) and experience databases (5.6) found at different places.
30 The processor (5.1) records the new malfunction recordings received from external systems to the experience database (5.6). In this way, the malfunction

monitoring and early warning systems (1) learn by themselves and are converted into a structure that can improve their own experience databases (5.6).

5 Since the malfunction monitoring module (5) monitors the mechanical behaviour of the engine according to the measurement values received from the sensors (2, 3, 4), it can provide information about mechanical fatigue and warning about malfunction in early stages.

10 In an embodiment of the invention, operation of more than one engine can be monitored via the malfunction monitoring module (5). Individual sensors (2, 3, 4) are used for each engine and the malfunction monitoring module (5) monitors the operating, maintenance, and malfunction conditions of all engines. When there are malfunctions or maintenance is required for more than one engine, the malfunction monitoring module (5) forms the optimum maintenance intervention map so that the user can follow, from the malfunction monitoring module (5) or
15 the malfunction display module (6), by which order the engines should be dealt.

The malfunction display module (6) is the part that visually informs the user about the operating conditions, operating temperature, and malfunction situation of the
20 engine. The malfunction display module (6) can be a smart device, a phone, an indicator panel, a display screen, or a web based application.

In an embodiment of the invention, graphs containing the drawings and schematic images of the engine(s) are found on the malfunction display module (6). Areas
25 are found on said engine drawings where temperature, speed, and vibration values can be shown, and the measurement values received from the malfunction monitoring module (5) are shown on said areas. The malfunction display module (6) allows the user to monitor the operating conditions, malfunction and maintenance predictions, and malfunction situations of the engine. The user can
30 monitor the situation(s) of the engine(s) used, on a display screen via the malfunction display module (6).

In an embodiment of the invention, when the malfunction and maintenance periods of the engines come, warning can be given via the malfunction display module (6). By means of the malfunction display module (6), the user can see the engine which already has a malfunction or will have a malfunction soon, the reason of the malfunction, and the way to deal with the malfunction.

Malfunction monitoring of more than one of the engines found at the same place or at different places can be made via the malfunction display module (6). Moreover, when it is required to access to more than one of the engines, an access and intervention map can be found at the malfunction display module (6) for the engines that are malfunctioning or need maintenance.

In the malfunction monitoring and early warning system (1), the measurement values received from the speed sensor (2), temperature sensor (3), and vibration sensor (4) are interpreted by the malfunction monitoring module (5). Sudden changes in temperature, speed, or vibration during operation of the engine are interpreted by the malfunction monitoring module (5) processor (5.1) by means of comparing the same with the values found in the experience database (5.6). For example, when a malfunction occurs at the measured temperature of 70 °C, vibration of 4.6 G value, and speed of 1450 revolution/minute value, the processor (5.1) determines said malfunction as an engine balance defect (imbalance). If the malfunction detected by the processor (5.1) is not recorded in the experience database (5.6), it records said malfunction in the experience database (5.6). Moreover, said malfunction is communicated via the malfunction communication unit (5.3) to the malfunction display module (6) together with the malfunction and the solution proposal. In the malfunction display module (6), said data are simulated and allow providing visual reporting. The user can also receive a retrospective report according to the date range to be entered from the malfunction display module (6).

The operation of an embodiment of the malfunction monitoring and early warning system (1) according to the invention is as follows. The speed sensor (2), temperature sensor (3), and vibration sensor (4) are mounted on the engine(s). Said sensors (2, 3, 4) are connected to the signal input lines of the malfunction monitoring module (5). If technical data is not found in the experience database (5.6) about the engine to be monitored for malfunction and maintenance, the type, mechanical parts, ball bearings, maintenance times of the parts, and usage conditions of the parts are entered into the experience database (5.6). In this way, the malfunction and maintenance monitoring operations are started. Whenever the engine is used, the malfunction monitoring module (5) receives the engine speed, temperature, and vibration usage information. Analogy signals taken from the engine speed, temperature, and vibration measurements are converted to digital signals by the signal converter (5.4). Afterwards, the speed, temperature, and vibration measurements of the engine are digitally recorded in the memory (5.2). The engine speed, temperature, and vibration measurements are filtered by the filter (5.5) before or after being recorded in the memory (5.2). The vibration value at which the engine operates is quite important especially for engine malfunction and maintenance. The pressure force applied on the parts due to engine vibration and the circular or linear type of said force is faultlessly monitored during malfunction and maintenance operations. The processor (5.1) preferably calculates the measured engine vibration value as vibration G force, makes a classification for vibration as linear or circular vibration, and determines if the result would cause resonance or not, and records this determination in the experience database (5.6). The speed, temperature, and vibration measurements made at the engine are compared by the processor (5.1) with the engine-specific mechanical part usage values found in the experience database (5.6) so as to determine whether a malfunction is found or not found at that moment, and the measured values are recorded in the experience database (5.6). The processor (5.1) is adapted to control the use of the engine over time. Whenever the engine is used, the processor (5.1) monitors the total duration of use and the conditions under which the engine is used, and estimates which parts need maintenance and

when they need maintenance by calculating the forces and temperatures applied on the mechanical parts according to the usage conditions. The processor (5.1) communicates all these estimates, malfunction, maintenance, and usage information to the malfunction display module (6) via the communication unit (5.3). The malfunction display module (6) displays the information taken from the malfunction monitoring module (5) to the user in a web-based or a smart device-based manner. The user can preferably monitor the usage status of the engine via the malfunction display module (6), and notifies the user about malfunction notifications and maintenance notifications coming from the malfunction monitoring module (5), and about operations to be performed. Each malfunction that occurs is recorded into the experience database (5.6) by the processor (5.1). The processor (5.1) can use the new malfunction and advice information recorded in the experience database (5.6) for the next troubleshooting comparison. In this way, information about new malfunctions, sources of malfunctions, and ways of solving malfunctions are kept in a continuously learning experience database (5.6), and new data are added into the system as the number of malfunctions increases.

CLAIMS

1. A malfunction monitoring and early warning system (1) used in industrial engines for ensuring malfunction, maintenance, and early warning determination by monitoring the temperature, vibration, and speed information of the engine on which it is used, and can learn the determined malfunction data, comprising:
- at least one speed sensor (2) placed in the engine to detect the engine revolutions or speed via the engine rotor,
 - at least one temperature sensor (3) placed on or in the engine to measure the operating temperature of the engine,
 - at least one vibration sensor (4) placed on the engine or on the place where the engine is fixed, to measure the level of vibration generated during operation of the engine or the engine is subjected to, and **characterized by:**
 - at least one malfunction monitoring module (5) comprising at least one processor (5.1), at least one memory (5.2), at least one communication unit (5.3), and at least one experience database (5.6), receiving measurement values by communicating with a speed sensor (2), a temperature sensor (3), and a vibration sensor (4), and adapted to perform engine malfunction estimation by interpreting said measurement values according to ideal engine usage conditions using the processor (5.1) and the experience database (5.6) found therein, predetermine the malfunction and engine maintenance times, and ensure determination of each malfunction together with its reasons by means of recording encountered malfunctions and the speed, temperature, and vibration values at which the malfunction occurs,
 - at least one processor (5.1) which estimates which parts of the engine are required to be replaced in which time period by comparing the measured engine data with the usage data found in the experience database (5.6), and when a malfunction that is not recorded in the experience database (5.6) is encountered, which is adapted to determine at which total temperature, speed, and vibration values and how the engine had been used before the

malfunction, and the reason of the malfunction, and records thereof in the experience database (5.6) together with the engine type information so as to ensure that the experience database (5.6) is continuously updated with new malfunctions and learns about these malfunctions,

- 5 - an experience database (5.6) which is adapted to record, via the processor (5.1), the malfunction and its reasons, when an engine malfunction that is not previously recorded is encountered, and to ensure that malfunction control and estimation is performed using the updated malfunction list while a new malfunction analysis is being made,
- 10 - at least one malfunction display module (6) which communicates with the malfunction monitoring module (5) via wired, wireless, Ethernet, or can bus connection, can be operated through the internet or a smart device, comprises visual graphics of the monitored engine, and allows the user to see the engine malfunction, the reason of malfunction and suggestions, and the engine
- 15 maintenance time according to the data received from the malfunction monitoring module (5).

2. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a speed sensor (2), a temperature sensor (3), and a vibration sensor (4), which have an integrated structure to each other and

20 allow detection of the engine speed, temperature, and vibration by means of a single integrated sensor placed on the engine.

3. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a malfunction monitoring module (5) which comprises

25 signal ports where the speed sensor (2), temperature sensor (3), and vibration sensor (4) are connected, a signal converter (5.4) which converts analogue signals into digital signals, a filter (5.5), and an amplifier (5.7) which amplifies analogue signals.

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4. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** an amplifier (5.7), which is either found within the malfunction monitoring module (5) or has an independent structure outside the malfunction monitoring module (5), is connected to the speed sensor (2) and temperature sensor (3) outlets, and amplifies the signals received from the speed sensor (2) and the temperature sensor (3).
5. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a communication unit (5.3) which ensures remote access to the malfunction monitoring module (5), and ensures data transmission between malfunction monitoring module (5) and the malfunction display module (6) via 3G connection, Ethernet connection, CAN BUS connection, or Bluetooth connection.
6. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** an experience database (5.6), in which information such as the characteristics of different types of engines, the manufacturer company of the engines, the type of ball bearings used by the manufacturer company, the type of mechanical parts used, the operating conditions of the ball bearing or materials used, usage threshold value data, and parts maintenance information are recorded.
7. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a processor (5.1) adapted to record, in the memory (5.2), the analogue measurement values obtained from the vibration sensor (4) and the temperature sensor (3), directly or after the values are passed through the signal converter (5.4), and directly record the digital values received from the speed sensor (2) into the memory (5.2), monitor the operating condition of the engine by processing said data, and record the speed, temperature, and vibration measurement values into the memory (5.2) together with the time information in hours, minutes, and seconds.

8. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a processor (5.1) adapted to determine whether there is vibration or not during operation of the engine, whether the vibration causes resonance or not, and to perform vibration classification according to the measurement values recorded in the memory (5.2) and the measurement value received from the vibration sensor (4).
9. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a processor (5.1) which is adapted to compare the measurement value received from the vibration sensor (4) with the vibration values found in the experience database (5.6), determine, according to the result of the comparison, whether the vibration is circular or linear, whether there is resonance or not during operation of the engine, and record said information and transmit th information to the malfunction display module (6) via the communication unit (5.3).
10. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a processor (5.1) adapted to monitor and record the engine vibration, temperature, and speed information during operation of the engine, compare the usage values of the engine with the values found in the experience database (5.6), calculate and estimate the maintenance time of the engine according to the engine usage condition values, the possibility of malfunction occurrence according to the engine usage conditions, mechanical fatigue, and provide possible early malfunction notification and times, and transmit the same values to the malfunction display module (6) through the communication unit (5.3).
11. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a processor (5.1) which is adapted to determine, when there is a malfunction in the engine, the type of the malfunctioning engine, at which temperature, speed, and vibration values the engine had been used before the malfunction, and the reason of occurrence of the malfunction, and

record the same to the experience database (5.6), and allow the malfunction monitoring module (5) to continuously learn about malfunctions by automatically recording each engine malfunction and malfunction conditions in the experience database (5.6).

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12. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a malfunction monitoring module (5) adapted to communicate, through the communication unit (5.3), with other malfunction monitoring modules (5) and experience databases (5.6) found at different places, share the newly encountered engine malfunctions and their reasons with experience databases found at different places, and record, in the experience database (5.6), new malfunction records received from other external systems.

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13. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a malfunction monitoring module (5) comprising more than one speed sensor (2), temperature sensor (3), and vibration sensor (4) inlet, and adapted to monitor operation of more than one engine, individually monitor the operation, maintenance, and malfunction conditions of all of the connected engines, provide the most ideal maintenance intervention map to the user when malfunction occurs in or maintenance time comes for more than one engine, and inform the user, via the malfunction display module (6), about which order he/she should follow to reach the engines.

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14. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a malfunction display module (6) comprising graphics thereon including the drawings and schematic views of the engine(s), comprising areas on the drawings where temperature, speed, and vibration values can be shown, and displaying the measurement values received from the malfunction monitoring module (5) in said areas, and displaying the engine that has a malfunction or will have a malfunction, the reason for the malfunction, and the way to intervene in the malfunction.

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15. The malfunction monitoring and early warning system (1) according to claim 1, **characterized by** a malfunction display module (6) which allows malfunction monitoring of more than one engine found at the same place or at different places, and which is adapted to provide an access and intervention map to the engines when it is required to access more than one engine for repairing malfunctions or doing maintenance.

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Figure 1

