

DEVICE AND METHOD FOR MONITORING A MECHANICAL JOINT

Technical Field

5 The present disclosure generally relates to a device and method for monitoring a mechanical joint. More particularly, the present disclosure describes various embodiments of a device and a method for monitoring a physical condition of a mechanical joint, such as a universal joint for cardan shafts.

10 Background

A mechanical joint can be defined as a section of a machine that is used to connect mechanical parts to each other. For example, mechanical joints may include ball-and-socket joints and universal joints. A universal joint can be defined as a joint that
15 connects shafts to each other, specifically rigid shafts whose axes are inclined to each other. For example as shown in Figure 1, a cardan shaft 100 may be coupled to other cardan shafts 100 via one or more universal joints 110. The universal joint 110 may also be referred to as a cardan joint that transmits rotary motion between the cardan shafts 100.

20

Movement of the cardan shafts 100 over time would result in wear and tear of the universal joints 110. However, there is current no feasible way to monitor the universal joints 110 other than through manual visual inspection for physical damages. Damages that are not visible externally may go unnoticed and the damaged universal
25 joint 110 would still continue to be in use. For example, cardan shafts 100 that move heavy loads may collapse if the damaged universal joint 110 suddenly breaks, potentially resulting in disastrous industrial accidents.

Therefore, in order to address or alleviate at least one of the aforementioned problems
30 and/or disadvantages, there is a need to provide an improved device and method for monitoring a mechanical joint.

Summary

According to a first aspect of the present disclosure, there is a device for monitoring a physical condition of a mechanical joint. The device comprises a set of sensors for disposing at the mechanical joint and configured for measuring physical parameters of the mechanical joint, the physical parameters comprising vibration parameters and temperature parameters. The device further comprises a control unit configured for: receiving the physical parameters from the sensors; and sending the physical parameters to an electronic device for the electronic device to subsequently process the physical parameters. The physical condition of the mechanical joint is determinable from said processing of the physical parameters including the vibration parameters and temperature parameters.

According to a second aspect of the present disclosure, there is a shaft assembly comprising: a shaft comprising a mechanical joint; and a device for monitoring a physical condition of the mechanical joint. The device comprises a set of sensors disposed at the mechanical joint, the sensors configured for measuring one or more physical parameters of the mechanical joint, the physical parameters comprising vibration parameters and temperature parameters; and a control unit disposed at the mechanical joint, the control unit configured for receiving the physical parameters from the sensors. The control unit is further configured for sending the physical parameters to an electronic device for the electronic device to subsequently process the physical parameters, wherein the physical condition of the mechanical joint is determinable from said processing of the physical parameters including the vibration parameters and temperature parameters.

According to a third aspect of the present disclosure, there is a computerized method for monitoring a physical condition of a mechanical joint. The method comprises: receiving, from a set of sensors disposed at the mechanical joint, one or more physical parameters of the mechanical joint that are measured by the sensors, the physical parameters comprising vibration parameters and temperature parameters; processing the physical parameters including the vibration parameters and temperature parameters to determine the physical condition of the mechanical joint; and generating a remedial message based on the physical condition of the mechanical joint, the

remedial message comprising a set of actions to remedy the physical condition of the mechanical joint.

A device and method for monitoring a mechanical joint according to the present disclosure are thus disclosed herein. Various features and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is an illustration of a cardan shaft with a universal joint.

Figures 2A to 2C are illustrations of a device for monitoring a mechanical joint.

Figure 3 is a flowchart illustration of a method for monitoring a mechanical joint.

Figures 4A and 4B are illustrations of physical parameters of the mechanical joint measured by the device.

Detailed Description

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a device and method for monitoring a mechanical joint, in accordance with the drawings. While parts of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present

disclosure may be practiced without specific details, and/or with multiple details arising from combinations of features of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure features of the embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment. As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions.

Representative or exemplary embodiments of the present disclosure describe a device 200 for monitoring a physical condition of a mechanical joint 110, with reference to Figures 2A to 2C. In many embodiments, there is a shaft assembly 120 including a shaft 100 having the mechanical joint 110. The shaft 100 may be a cardan shaft 100 and the mechanical joint 110 may be a universal joint.

The device 200 includes a set of sensors 210 for disposing or disposed at the mechanical joint 110. The sensors 210 are configured for measuring physical parameters of the mechanical joint 110, wherein the physical parameters include vibration parameters and temperature parameters.

The device 200 further includes a control unit 220 configured for receiving the physical parameters from the sensors 210. In some embodiments as shown in Figure 2B, the sensors 210 and the control unit 220 are separate components that are connected via a set of wires 230. For example, the sensors 210 are threaded into a bearing cap of the mechanical joint 110 and the control unit 220 is bolted to the mechanical joint 110. In some other embodiments as shown in Figure 2C, the sensors 210 and the control unit 220 may be integrated into a single unitary component. The device 200 may include a magnet 240 for mounting to the mechanical joint 110. The magnet 240 is preferably of industrial grade and has a strength of at least 5000 Gauss to prevent the device 200 from moving on the mechanical joint 110 during rotation of the shaft 100.

The control unit 220 is further configured for sending the physical parameters to an electronic device 250 for the electronic device 250 to subsequently process the physical parameters. The physical condition of the mechanical joint 110 is determinable from said processing of the physical parameters including the vibration parameters and temperature parameters.

The electronic device 250 may be, but is not limited to, a mobile phone or tablet device. The electronic device 250 includes one or more processors configured for executing instructions, codes, computer programs, and/or scripts. The processor includes suitable logic, circuitry, and/or interfaces to execute such operations or steps. Some non-limiting examples of the processor include an application-specific integrated

circuit (ASIC) processor, a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a field-programmable gate array (FPGA), and the like. While instructions may be executed by a processor, the instructions may be executed simultaneously, serially, or otherwise executed by one or multiple processors (e.g. in a multi-core configuration).

A mobile software application or app is installed and executable on the electronic device 250 for receiving the physical parameters from the control unit 220 and for processing the physical parameters. The control unit 220 and the electronic device 250 are configured to communicate the physical parameters via any wired / wireless communication protocol. Preferably, the communication is via a wireless communication protocol such as Bluetooth, NFC, or RFID. Alternatively, the communication may be via a wired communication protocol such as an Ethernet or USB cable.

In some embodiments, the control unit 220 is configured to send the physical parameters to the electronic device 250 in response to receiving a control signal from the electronic device 250. More specifically, the user operates the app on the electronic device 250 and sends the control signal to the control unit 220, such as via Bluetooth when they are in close proximity to each other. The control unit 220 then sends the physical parameters to the electronic device 250 in response to the control signal.

The control unit 220 may include a memory unit for storing the physical parameters for a predefined duration. For example, the memory unit stores the physical parameters for up to 100 or 150 days. After the control unit 220 receives the control signal, the control unit 220 sends all the stored physical parameters to the electronic device 250. For example, the user may be scheduled to collect the physical parameters every day, week, or month. The physical parameters may be erased from the memory unit after a predefined duration, such as 300 days.

The control unit 220 is not connected to any online system and the physical parameters are stored locally on the control unit 220 before sending to the electronic

device 250. This protects privacy of the physical parameters and allows for offline monitoring of the mechanical joint 110 using the electronic device 250 according to the appropriate schedule.

- 5 In some embodiments, the control unit 220 has a battery for powering the sensors 210. The battery may be chargeable by actuation of mechanical parts connected by the mechanical joint 110. For example, the control unit 220 includes piezoelectric components that can charge the battery using kinetic energy from motion of the cardan shaft 100 connected to the mechanical joint 110. Alternatively, the sensors 210 and
10 control unit 220 may be powered from an external power grid.

As described above, the physical condition of the mechanical joint 110 is determinable from processing of the physical parameters by the electronic device 250. Representative or exemplary embodiments of the present disclosure also describe a
15 computer-implemented or computerized method 300, performed by the electronic device 250, for monitoring a physical condition of a mechanical joint 110.

With reference to Figure 3, the method 300 includes a step 310 of receiving, from a set of sensors 210 disposed at the mechanical joint 110, one or more physical
20 parameters of the mechanical joint 110 that are measured by the sensors 210, the physical parameters including vibration parameters and temperature parameters. The method 300 includes a step 320 of processing the physical parameters including the vibration parameters and temperature parameters to determine the physical condition of the mechanical joint 110. The method 300 includes a step 330 of generating a
25 remedial message based on the physical condition of the mechanical joint 110, the remedial message comprising a set of actions to remedy the physical condition of the mechanical joint 110.

The sensors 210 may include a velocity sensor for measuring the vibration parameters.
30 For example, the velocity sensor is a piezoelectric velocity sensor or velocimeter. Velocity measurements are used to measure the magnitude and phase of vibrations from the mechanical joint 110 to provide an overall indication of the condition or health

of the mechanical joint 110. For example, the vibrations can indicate conditions such as low grease and misalignment.

The vibration parameters may be measured by the velocity sensor over a period of time, such as 100 or 150 days, and retrieved by the user every 1 to 2 months. Figure 4A shows the vibration parameters from the mechanical joint 110 in normal condition and faulty condition. The physical condition of the mechanical joint 110 may include a low grease level and/or a misalignment of the mechanical joint 110 that is determinable from said processing of the vibration parameters. For example as shown in Figure 4A, the vibration parameters show abnormal peaks 400 that are indicative of a faulty mechanical joint 110.

Figure 4B shows another graph of the vibration parameters measured by the velocity sensor. Various algorithms may be used to reduce unwanted noise from the vibration parameters, especially those caused by the abnormal peaks 400. For example, a root mean square algorithm may be used to reduce the noise.

The sensors 210 may include a thermal sensor for measuring the temperature parameters. The temperature parameters may include a current temperature of the mechanical joint 110 and the current temperature may be compared to a predefined temperature threshold of the mechanical joint 110. For example, the mechanical joint 110 has a temperature threshold of 80 °C, and if the current temperature is higher than the threshold, such as 120 °C, this may indicate a faulty mechanical joint 110. The temperature parameters may also include the number of days when the mechanical joint 110 had temperatures higher than the threshold. The temperature parameters complement the vibration parameters to determine the physical condition. For example, high temperature and high vibration noise usually mean high frictional forces in the mechanical joint 110, which can be caused by low grease level, misalignment of the mechanical joint 110, worn-off roller bearings, etc.

The software app on the electronic device 250 may be configured to analyse the physical parameters including the vibration parameters and temperature parameters to determine the physical condition of the mechanical joint 110, such as low grease

level or misalignment. The software app may be implemented with machine learning models to improve determination of the physical condition. Data collected from continual monitoring of various mechanical joints 110 may be used to train the machine learning models.

5

The software app is configured to generate a remedial message based on the physical condition of the mechanical joint 110. The software app may first perform a calibration process to establish the benchmark physical condition for the mechanical joint 110 under the normal working conditions for the mechanical joint 110. The current physical
10 condition of the mechanical joint 110 is determined from the physical parameters and compared with the benchmark physical condition. Recalibrations may be performed for the mechanical joint 110 if the sensors 210 are changed or new sensors 210 are added, or if the mechanical joint 110 is used for other working conditions.

15 The remedial message includes a set of actions to remedy the physical condition. For example, if the physical condition is low grease level, the remedial message may advise the user to add grease to the mechanical joint 110. If the physical condition is misalignment, the user may be required to stop operations of the shaft assembly 120 using the faulty mechanical joint 110 and to schedule the mechanical joint 110 for
20 maintenance and repairs. Other physical conditions include, but are not limited to, an rpm that is too high which causes excessive vibrations with abnormal peaks 400, and worn-out bearings in the mechanical joint 110.

In one example when the mechanical joint 110 is in an early stage of damage, the
25 current temperature may be 120 °C and this is higher than the temperature threshold of 80 °C. However, the vibration parameters may be normal based on the benchmark physical condition. The remedial message may suggest topping up grease during the next maintenance and/or monitoring the physical condition again in 1 to 2 months time.

30 In one example when the mechanical joint 110 is in an intermediate stage of damage, the current temperature may be 120 °C and this is higher than the temperature threshold of 80 °C. Additionally, the vibration parameters may show some abnormal peaks 400 in the lower frequency range compared to the benchmark physical condition.

The remedial message may suggest topping up grease immediately as the bearings have worn out and suggest replacing the bearings during the next maintenance.

5 In one example when the mechanical joint 110 is in a late stage of damage, the current temperature may be 120 °C and this is higher than the temperature threshold of 80 °C. Additionally, the vibration parameters may show some abnormal peaks 400 in the both the lower and higher frequency ranges compared to the benchmark physical condition. The remedial message may suggest stopping operation of the mechanical joint 110 immediately as the mechanical joint 110 is too damaged to be working properly and
10 this can cause safety problems.

In some embodiments, the sensors 210 may include an accelerometer configured to measure the rpm or rotation of the shaft 100 connected to the mechanical joint 110. The accelerometer may still show that the rpm is within 10% of the benchmark physical
15 condition when the mechanical joint 110 is in the early, intermediate, or late stage of damage. However, the accelerometer can be used to measure sudden impacts or shocks to the mechanical joint 110. In some embodiments, the sensors 210 may include a time-of-flight sensor to measure the distances between parts within the mechanical joint 110 to determine which parts are wearing out.

20 The device 200 and method 300 provide an improved way to monitor the physical condition of mechanical joints 110, particularly universal joints which are critical in shaft assemblies 120 with cardan shafts. Users can easily monitor the mechanical joints 110 using the electronic device 250 to detect any faults, such as due to wear
25 and tear or low grease levels, early on. Users can get early warnings about the physical conditions so they remedy actions can be taken before the mechanical joints 110 become more damaged. This can help to prevent unwanted operational shutdowns or losses that may occur from continued operation of faulty mechanical joints 110. Early detection of damaged mechanical joints 110 would result in timely
30 maintenance and repairs, thereby extending the lifespan of the mechanical joints 110.

In the foregoing detailed description, embodiments of the present disclosure in relation to a device and method for monitoring a mechanical joint are described with reference

to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned
5 problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the
10 scope of the following claims is not limited to embodiments described herein.

Claims

1. A device for monitoring a physical condition of a mechanical joint, the device comprising:
 - 5 a set of sensors for disposing at the mechanical joint and configured for measuring physical parameters of the mechanical joint, the physical parameters comprising vibration parameters and temperature parameters; and
 - a control unit configured for:
 - receiving the physical parameters from the sensors; and
 - 10 sending the physical parameters to an electronic device for the electronic device to subsequently process the physical parameters,
 - wherein the physical condition of the mechanical joint is determinable from said processing of the physical parameters including the vibration parameters and temperature parameters.
- 15 2. The device according to claim 1, wherein the sensors comprise a velocity sensor for measuring the vibration parameters.
3. The device according to claim 1 or 2, wherein the sensors comprise a thermal
20 sensor for measuring the temperature parameters.
4. The device according to any one of claims 1 to 3, wherein the control unit comprises a battery for powering the sensors.
- 25 5. The device according to claim 4, wherein the battery is chargeable by actuation of mechanical parts connected by the mechanical joint.
6. The device according to any one of claims 1 to 5, wherein the control unit is configured to send the physical parameters to the electronic device in response to
30 receiving a control signal from the electronic device.
7. The device according to any one of claims 1 to 6, wherein the control unit is configured to send the physical parameters to the electronic device via Bluetooth.

8. The device according to any one of claims 1 to 7, wherein the sensors further comprise an accelerometer and/or a time-of-flight sensor.

5 9. A shaft assembly comprising:

a shaft comprising a mechanical joint; and

a device for monitoring a physical condition of the mechanical joint, the device comprising:

10 a set of sensors disposed at the mechanical joint, the sensors configured for measuring one or more physical parameters of the mechanical joint, the physical parameters comprising vibration parameters and temperature parameters;

a control unit disposed at the mechanical joint, the control unit configured for receiving the physical parameters from the sensors; and

15 the control unit further configured for sending the physical parameters to an electronic device for the electronic device to subsequently process the physical parameters,

20 wherein the physical condition of the mechanical joint is determinable from said processing of the physical parameters including the vibration parameters and temperature parameters.

10. The shaft assembly according to claim 9, wherein the sensors comprise a velocity sensor for measuring the vibration parameters.

25 11. The shaft assembly according to claim 9 or 10, wherein the sensors comprise a thermal sensor for measuring the temperature parameters.

12. The shaft assembly according to any one of claims 9 to 11, wherein the control unit comprises a battery for powering the sensors.

30 13. The shaft assembly according to claim 12, wherein the battery is chargeable by actuation of the shaft.

14. The shaft assembly according to any one of claims 9 to 13, wherein the control unit is configured to send the physical parameters to the electronic device in response to receiving a control signal from the electronic device.

5 15. The shaft assembly according to any one of claims 9 to 14, wherein the control unit is configured to send the physical parameters to the electronic device via Bluetooth.

10 16. The shaft assembly according to any one of claims 9 to 15, wherein the mechanical joint is a universal joint.

17. The shaft assembly according to any one of claims 9 to 16, wherein the sensors further comprise an accelerometer and/or a time-of-flight sensor.

15 18. A computerized method for monitoring a physical condition of a mechanical joint, the method comprising:

20 receiving, from a set of sensors disposed at the mechanical joint, one or more physical parameters of the mechanical joint that are measured by the sensors, the physical parameters comprising vibration parameters and temperature parameters;

processing the physical parameters including the vibration parameters and temperature parameters to determine the physical condition of the mechanical joint; and

25 generating a remedial message based on the physical condition of the mechanical joint, the remedial message comprising a set of actions to remedy the physical condition of the mechanical joint.

19. The method according to claim 18, wherein the physical condition comprises a grease level and/or a misalignment of the mechanical joint.

30