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# (54) RAILROAD SWITCH ACTUATION SYSTEM, RAILROAD SWITCH AND METHOD FOR RECORDING DATA FOR DETERMINING A STATE OF WEAR OF SUCH A RAILROAD SWITCH ACTUATION SYSTEM AND/OR RAILROAD SWITCH

(57) The invention relates to railroad switch actuation system (1) comprising a component (10) selected from the group consisting of: at least one point machine assembly (20), at least one end position detection assembly (30);
wherein the component (10) is configured to be attached to a railroad switch (2), characterized in that a sensor unit (3) is mounted in or on said component (10), wherein the sensor unit (3) is configured to record a motion of the component (10) caused by a railroad vehicle passing the railroad switch (2) for evaluating the recorded motion to determine an indication of a state of wear of the component (10) and/or the railroad switch (2).

The invention further relates to a railroad switch (2) comprising such a railroad switch actuation system (1) as well as a method for recording data for determining a state of wear of the railroad switch actuation system (1) and/or the railroad switch (2).

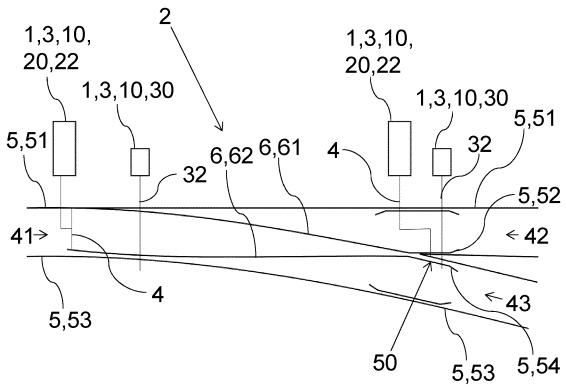


Fig. 1

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## Description

**[0001]** The present invention relates to a railroad switch actuation system, a railroad switch and a method for recording data for determining a state of wear of such a railroad switch actuation system and/or railroad switch.

**[0002]** Railroad systems are of increasing importance for modern mobility. As relatively cost-intensive systems with respect to their assembly, existing railroad systems are nowadays heavily stressed by more and more railroad vehicles such as trains utilizing the railroad system and its associated infrastructure. Consequently, the existing railroad infrastructure needs to be maintained on a regular basis for safety of trains and passengers. The maintenance particularly concerns railroad switch, which are key constituents of railroad systems. Railroad switch are particularly vulnerable as they are subjected to heavy mechanical loads while necessarily comprising movable structures by means of point machine assemblies that move switch rails and/or movable frogs with respect to stock rails so as to change the setting of the railroad switch. Monitoring of the position of the switch rails or movable frogs with respect to the stock rails is typically realized by end position detection assemblies with end position detectors. A correct functioning of railroad switch systems and railroad switch is mandatory at all times to guarantee the safety of railroad systems. For maintenance, railroad switches are typically investigated by authorized personnel in regular maintenance intervals. However, maintaining railroad switch in intervals provides only limited information on the state of wear of the railroad switch as the state of wear between the investigations remains unknown. Consequently, potentially dangerous, increasing wear occurring between the maintenance intervals stay hidden. Other approaches use sensors mounted to railroad elements such as sleepers of a rail or of a railroad switch, a rail or a railroad switch to determine element characteristics of the respective railroad element. However, this approach is disadvantageous in that the assembly or integration of the sensors onto the railroad element is relatively complex and potentially dangerous due to the close proximity of the sensors to the passing trains. At the same time, the determined characteristics remain limited to the rails or sleepers. Moreover, by mounting the sensors on the point machines or end position detectors, signal noise is reduced as the assembly units act as filter which results in an improved signal to noise ratio of the signal.

**[0003]** Based on the above, it is subject of the present invention to provide a railroad switch actuation system, a railroad switch, as well as a method for determining a state of wear of the railroad switch actuation system and/or the railroad switch that allows for an improved determination of said state of wear to improve the safety of railroad systems.

**[0004]** This task is solved by a railroad switch actuation system with the features of claim 1 as well as a railroad switch with the features of claim 8 and a method for recording data for determining a state of wear of a railroad switch actuation system and/or railroad switch with the features of claim 10.

**[0005]** Advantageous embodiments of the invention are given in the corresponding dependent claims and described in the following.

**[0006]** A first aspect of the invention relates to a railroad switch actuation system. The railroad switch actuation system comprises a component selected from the group consisting of: at least one point machine assembly, at least one end position detection assembly; wherein the component is configured to be attached to a railroad switch, wherein a sensor unit is mounted in or on said component, wherein the sensor unit is configured to record a motion of the component caused by a railroad vehicle passing the railroad switch for evaluating the recorded motion to determine an indication of a state of wear of the component and/or the railroad switch.

**[0007]** A railroad switch according to the present invention comprises at least portions of switch rails and stock rails, as well as at least one frog, i.e. at least one crossing between switch rails and/or stock rails.

**[0008]** The point machine assembly and the end position detection assembly are core components of the railroad switch actuation system and the railroad switch as they control and monitor the setting of the railroad switch. Since according to the invention, the sensor unit is mounted in or on the component, the motion recorded by the sensor unit directly reflects mechanical properties of the component and thus allows to determine the indication of the state of wear of the component. Moreover, with the component being configured to be attached or attached to the railroad switch, the invention also advantageously permits to determine an indication of the state of wear of the railroad switch. In particular, due to the mechanical connection between the component and the railroad switch, the invention allows to determine an indication of a combined state of wear of the component and the railroad switch. At the same time, mounting the sensor unit on the point machine assembly and/or the end position detection assembly instead of a railroad element such as the rails or sleepers simplifies the assembly and the safety of the railroad switch actuation system, since existing fastening structures may be used.

**[0009]** The point machine assembly preferably comprises a point machine configured to switch the railroad switch between at least two settings, such that a railroad vehicle passing the railroad switch may be guided onto one of at least two tracks depending on the setting of the switch. To this end, the point machine may for example drive a switch rail arranged next to an associated stock rail between at least two positions, wherein the railroad vehicle is guided according to the position of the stock rail controlled by the point machine. For example, in a first of the two positions, the switch rail is in contact with its respective stock rail, such that a railroad vehicle passing the switch is guided from the stock rail onto the switch rail so as to leave the track with the respective stock rail. In a second of the two positions, the switch rail

may be arranged in a predetermined distance away from the stock rail, such that a railroad vehicle passing the railroad switch remains on the stock rail and is thus not guided onto the track of the switch rail. The point machine may also drive two switch rails arranged between respective stock rails. The driving of the switch rails may for example be realized by a shifting element connecting the switch rails with the point machine, wherein the shifting element transmits a force exerted by the point machine.

**[0010]** The end position detection assembly preferably comprises an end position detector configured to detect a position of a switch rail with respect to its associated stock rail. In particular, the end position detector is configured to determine whether the switch rail is in contact with or arranged within a predetermined distance to its associated stock rail. For example, the position of the switch rail with respect to its associated stock rail is secured with a lock that closes once the switch rail has been moved to a predetermined position with respect to the associated stock rail, particularly wherein the switch rail is in contact with or arranged within a predetermined distance to its associated stock rail, such that the switch rail is securely kept in the predetermined position. The end position detector may be configured to monitor the lock and whether the lock is closed, particularly using a switch mechanism based on an electrical or mechanical switch that switches between two states once the lock is locked or unlocked. As such, the end position detector is configured to detect the position of the switch rail with respect to its associated stock rail according to the state of the switch mechanism.

**[0011]** In the same fashion, the end position detection assembly may be configured to detect a position of a first switch rail with respect to a second switch rail, wherein the first and second switch rails are part of a frog forming a crossing particularly between the first and second switch rails.

**[0012]** Wear on the railroad switch typically causes increasing mechanical vibrations, which may cause the switch mechanism to switch between the states even though the lock is securely closed, causing a false alarm that may result in a full track closure. As such, equipping the end position detection assembly with a sensor unit is particularly advantageous as it allows to monitor indications of the state of wear of the railroad switch actuation system as well as the railroad switch before the wear results in track closures due to false alarms.

**[0013]** Depending on the size and type of railroad switch, multiple point machine assemblies and/or end position detection assemblies may be used.

**[0014]** The motion of the component caused by a railroad vehicle passing the railroad switch may be or may comprise a vibration of the component. In particular, the vibration of the component may be described with respect to a reference position of the component. For example, the reference position corresponds to the position of the component in the absence of forces causing motion of the component, i.e., when no railroad vehicle is moving towards or away from the component. The vibration of the component may be described as time-dependent deflections of the component compared to the reference position. Particularly, the vibration may comprise deflections along three spatially linear independent, particularly orthogonal directions with corresponding amplitudes with respect to the reference position.

**[0015]** According to an embodiment, the sensor unit is mounted in or on the component by way of a mechanically rigid connection, such that the motion of the component is transmitted essentially undamped to the sensor unit. In the context of the present invention, such a mechanically rigid connection between the sensor unit and the component is to be understood such that the sensor unit mounted in or on the component follows the motion of the component in a way that deflections of the sensor unit coincide with deflections of the sensor unit or coincide with deflections of the sensor unit up to a spatial offset due to different reference positions of the component and the sensor unit. Hence, the motion recorded by the sensor unit directly reflects the motion and thus the mechanical properties of the component and/or the railroad switch connected with the component, allowing to determine indications of their state of wear.

**[0016]** The sensor unit may be or comprise a transducer configured to convert mechanical vibrations into a signal, particularly an electrical signal, encoding the mechanical vibrations.

**[0017]** For example, such a mechanically rigid connection may be realized by means of a screw connection but also may be realized by clamping, gluing, welding or by using magnets.

**[0018]** In another embodiment, the sensor unit comprises one or more sensors selected from the group consisting of:

- a motion sensor, configured to record the motion of the component and to generate motion data comprising information on a corresponding motion direction along three spatial dimensions of the recorded motion, as well as a motion amplitude associated to the motion direction,
- a temperature sensor, configured to record a temperature of the component and to generate temperature data comprising information on the temperature of the component,
- a humidity sensor, configured to record a humidity of air surrounding the railroad switch actuation system and to generate humidity data comprising information on the humidity of air surrounding the railroad switch actuation system,
- a sound sensor, particularly a microphone, configured to record a sound from a passing railroad vehicle and/or from the railroad switch and to generate sound data comprising information on the sound recorded from a passing railroad vehicle and/or the railroad switch,
- an optical sensor, configured to record a velocity of a passing railroad vehicle and to generate velocity data comprising

information on the velocity of the passing railroad vehicle.

**[0019]** The motion amplitude or -direction may be based on or consist of the deflection amplitude or direction defined above.

**[0020]** In yet another embodiment, the sensor unit is configured to process at least some of the generated data, particularly the generated motion data, so as to determine the velocity and/or a weight of a passing railroad vehicle.

**[0021]** As such, the recorded motion, temperature, humidity, and/or sound, velocity and/or weight of a passing railroad vehicle and the corresponding generated data additionally deliver valuable information that may be used to determine the indication of the state of wear of the component and/or the railroad switch.

**[0022]** According to another embodiment, the railroad switch actuation system comprises a plurality of sensor units, wherein each sensor unit is mounted at a different location in or on the component, wherein the data recorded by the plurality of sensor units comprises datasets associated to the individual sensor units, such that the indication of the state of wear can be determined from the data recorded by the plurality of sensor units, particularly from weighting the datasets associated to the individual sensor units. As such, multiple sensor units may for example deliver motion data recorded at different locations or portions in or on the component. In other words, every sensor unit delivers a dataset corresponding to a specific location or portion of the component, which advantageously allows to more accurately determine indications of the state of wear of the component and/or the railroad switch.

**[0023]** The individual datasets associated to the individual sensor units may be related to each other to determine the indication of the state of wear. For example, individual datasets associated to the individual sensor units may be weighted, particularly according to their spatial distribution with respect to the railroad switch actuation system, particularly with respect to the component. For example, datasets of sensor units located in or on portions of the component with a lower spatial density of sensor units may be weighted stronger compared to datasets located in or on portions with a higher spatial density of sensor units. This measure prevents that datasets associated to sensor units that are arranged in close proximity on one and the same component distort the determined indication of the state of wear by means of similar, particularly redundant datasets due to sensor units that record similar, particularly redundant data as a consequence of their arrangement in close proximity on one and the same component.

**[0024]** In particular, individual datasets may be related to each other for different conditions, that is for different temperature, humidity, and/or sound, velocity and/or weight of a passing railroad vehicle and/or for different settings of the switch, so as to determine the indication of the state of wear.

**[0025]** According to another embodiment, the railroad switch actuation system comprises a sensor unit with multiple redundant sensors such that if one of the multiple redundant sensors fails, their function is maintained by at least one of the other multiple redundant sensors. Particularly, the railroad switch actuation system may be configured such that a warning is sent to an external server in case at least one of the multiple redundant sensors fails.

**[0026]** In another embodiment, the railroad switch actuation system further comprises a transmitter configured to wirelessly send the recorded data to a server via radiocommunication. Particularly, the server is not comprised by the component or the railroad switch.

**[0027]** According to another embodiment, the sensor unit is configured to compare each of the data to reference data, such that the state of wear of the component and/or the railroad switch can be further determined based on deviations between the sensor data and the reference data. The sensor unit may comprise a processing unit configured to compare the data to the reference data, wherein the reference data may be stored on the sensor unit. The processing unit may comprise a microchip or a computer.

**[0028]** Alternatively, the data sent to the server are compared by an external processing unit that it is - like the server - not comprised by the railroad switch actuation system. Particularly, the server and/or the external processing unit may not be physically associated to the railroad switch system. To compare the data to the reference data, the processing unit may access reference data stored on a server on a non-transitory storage medium. The external processing unit may be comprised by the server.

**[0029]** Particularly, the sensor unit may be configured to store the recorded data and/or state of wear data indicative for the state of wear for a predetermined time, after which the recorded data and/or the state of wear data may be deleted. More particularly, the sensor unit may be configured to send at least parts of the recorded data and/or the state of wear data within the predetermined time upon a request from the server.

**[0030]** The reference data may comprise datasets with motion data recorded for railroad vehicles passing the railroad switch, corresponding to a known state of wear of the component and/or the railroad switch. For example, the reference data may comprise datasets with motion data recorded upon assembly or upon maintenance of the component and/or the railroad switch, such that the reference data recorded under these conditions correspond to a minimum state of wear or no indication of a state of wear. Due to mechanical stress caused by railroad vehicles passing the railroad switch, the recorded data tend to deviate more and more from the reference data as the number of railroad vehicles passing the railroad switch increases. The deviation of the recorded data from the reference data is thus an indication for the state of wear of the component and/or the railroad switch. Particularly, the deviation of the recorded data from the raw data

may be in case of motion data characterized by deviations in amplitudes and/or directions of deflection, and/or by deviations in the temporal characteristics of the motion data, such as the frequency spectrum of the motion data. As such, a comparison by means of deviations between recorded and reference data may for example be realized essentially by performing subtraction operations between respective datasets.

**[0031]** However, the state of wear does not need to be based on a comparison with reference data. Alternatively, the sensor unit may be configured to determine the indication of the state of wear by means of a trend of the recorded motion data. For example, the sensor unit may measure motion data for every passage of a train, wherein respective motion data with respective deflection amplitudes, deflection directions and deflection frequencies are determined. From a trend analysis, i.e. from an analysis of a temporal evolution of the respective deflection amplitudes, deflection directions and deflection frequencies, particularly from increasing deflection amplitudes and/or frequencies, the indication of the state of wear may be determined.

**[0032]** Particularly, a pattern recognition algorithm, more particularly a pattern recognition algorithm based on machine learning, may be used to analyze the trend of the recorded motion data in order to identify systematic characteristics in the recorded data, particularly with respect to the temporal evolution of the respective deflection amplitudes, deflection directions and deflection frequencies, that may represent indications of the state of wear.

**[0033]** The recorded data may be filtered, in order to separate security-relevant data from irrelevant data, for example by means of a machine learning algorithm. For example, the machine learning algorithm may be configured to separate security-relevant data from irrelevant data based on security requirements defined by railroad authorities, particularly with respect to thresholds of vibration deflection amplitudes and/or frequencies. As such, the machine learning algorithm may cause the transmitter to only transmit security-relevant data, reducing costs and power consumption of the railroad switch actuation system.

**[0034]** Generally, the determined indication of the state of wear, for example based on comparison to reference data or trend analysis, particularly based on motion data of multiple sensor units from multiple locations may be used to detect deformations of for example the point machine- and/or the end position detection assembly as well as constituents of the railroad switch such as switch- and/or stock rails and/or frogs.

**[0035]** Next to the motion data, the recorded temperature, humidity of air, and/or sound, velocities and/or weight of passing railroad vehicles may be taken into account for the determination of the indication of the state of wear. For example, the reference data may be associated to a known temperature, humidity of air, and/or sound, velocities and/or weight of passing railroad vehicles, particularly to a respective temperature and/or humidity of air prevailing at a railroad switch when the reference data was recorded and/or to a respective sound, velocity and/or weight of a railroad vehicle passing the railroad switch when the reference data was recorded. As such, the conditions temperature, humidity of air, and/or sound, velocities and/or weight of passing railroad vehicles can be taken into account for the determination of the indication of the state of wear by considering the recorded conditions for the motion data and selectively comparing the motion data to reference data recorded under similar conditions. Similar conditions may be understood as deviations of the respective recorded condition to the condition of the reference data by less than 50%, particularly less than 25%, more particularly less than 10%. The comparability of the recorded data to the reference data is thus advantageously improved, which allows for an improved determination of the indication of the state of wear.

**[0036]** In another embodiment, the transmitter is configured to send state of wear data indicative of the indication of the state of wear to a server. The state of wear data may comprise the recorded data and/or a comparison between the recorded data and the reference data. In particular, the state of wear data may comprise deviations between the recorded data and the reference data.

**[0037]** Particularly, the transmitter may be configured to send the state of wear data while or after, particularly immediately after, more particularly less than 10 seconds after a railroad vehicle passes or has passed the railroad switch. For example, the transmitter may determine and send the state of wear data in real-time, that is while the data are recorded, particularly during passage of a railroad vehicle, to the server. Alternatively, the transmitter may first record the data, particularly during or upon passage of a railroad vehicle, and send the data after the railroad vehicle has passed the railroad switch. The state of wear data may be determined and sent for every railroad vehicle passing the railroad switch within a predetermined monitoring timeframe. The monitoring timeframe may be for example several days, weeks, months or years. As such, the indication of the state of wear may be tracked over large periods of time, allowing to monitor a temporal evolution of the state of wear or an evolution of the state of wear depending on the number of passing railroad vehicles, particularly taking into account the recorded conditions such as temperature, humidity of air, and/or sound, velocities and/or weight of passing railroad vehicles. At the same time, by recording, determining and sending the state of wear data during or after the passage of a railroad vehicle, a data volume of the state of wear data is advantageously reduced compared to systems that send unprocessed or unevaluated raw data. In other words, the determination of the state of wear using a processor unit comprised by the sensor unit represents an advantageous reduction of the data volume sent to the external server compared to systems that determine the state of wear externally, i.e. on the external server after sending unprocessed raw data to said server, which leads to correspondingly large volumes of data that are typically sent at nighttime, when less or no trains are passing the railroad switch. Moreover,

the data volume can be further reduced by said pattern recognition algorithm and/or a data compression algorithm, particularly wherein the pattern recognition algorithm and/or the data compression algorithm is executed by means of edge computing on a processing unit integrated in the sensor unit. These measures permit to downscale the data volume by a factor 1.000 or more compared to systems that provide external evaluation on an external server based on unprocessed raw data.

**[0038]** Particularly, the transmitter is configured to send the state of wear data in case, more particularly only in case, the determined deviation exceeds a predetermined limit. As such, the railroad switch actuation system may provide a warning in case a critical state of wear beyond the predetermined limit has been determined. The predetermined limits may be given by railway regulation authorities, such as for example the German Eisenbahnbundesamt (federal railroad authority).

**[0039]** According to an embodiment, the component comprises one of the following:

- a fastening structure of the point machine assembly for fastening a point machine of the point machine assembly to the railroad switch;
- a fastening structure of the end position detection assembly for fastening an end position detector of the end position detection assembly to the railroad switch.

**[0040]** According to this embodiment, the sensor unit is mounted in or on the fastening structure of the point machine assembly or of the end position detection assembly, which allows for a mechanically rigid connection between the sensor unit and the component as well as the railroad switch.

**[0041]** In another embodiment, the railroad switch actuation system comprises at least one point machine and at least one end position detection assembly, wherein both the switch motor assembly and the end position detection assembly each comprise a respective sensor unit. Particularly, both the point machine assembly and the end position detection assembly each comprise at least one respective sensor unit. As such, the motion data can be recorded from both the switch motor assembly as well as the end position detection assembly, which improves the reliability of the determined indications of the state of wear.

**[0042]** In another embodiment, a further sensor unit is mounted in or on a railroad element, such as a rail, a frog, or a sleeper. As such, the indication of the state of wear of the component may be determined as a consequence of the indirect connection between the further sensor unit and the component via the railroad element arranged between the further sensor unit and the component. The arrangement of the further sensor unit on the railroad element is, however, less sensitive and less accurate with regard to determining the state of wear of the component, as compared to the arrangement of the sensor unit in or on the component. This is due to the fact that the further sensor arranged at the railroad element is prone to mechanical damping of vibrations at the location of the component, such that potentially critical vibrations of the component may remain hidden for the further sensor unit. The damping of the vibrations by the railroad element is comparably strong, since tracks are commonly arranged on a track bed which precisely serves to absorb and thus damp vibrations. However, advantageously, data generated by the further sensor unit may be combined with the data recorded by the sensor unit that is mounted in or on the component, allowing for a more precise estimation of the state of wear of the component.

**[0043]** A second aspect of the invention relates to a railroad switch comprising a railroad switch actuation system according to one of the preceding claims. A railroad switch according to the present invention comprises at least three track portions, wherein a first track portion splits into at least two track portions as well as the railroad switch actuation system.

**[0044]** According to an embodiment, the sensor unit of the component of the railroad switch actuation system is mounted on a fastening structure for joining the railroad switch actuation system and the railroad switch. As such, the sensor unit is mounted in a mechanically rigid connection between the component and the railroad switch. The sensor unit may be mounted onto the existing fastening infrastructure, particularly using existing fastening means such as screws or bolts, which considerably simplifies, speeds up and reduces the cost of assembly. Particularly, the sensor unit may be mounted by railroad maintenance personnel with conventional tools and -equipment within less than a minute.

**[0045]** A third aspect of the invention relates to a method for recording data for determining a state of wear of the railroad switch actuation system according to the second aspect of the invention and/or the railroad switch according to the third aspect of the invention, wherein the method comprises the steps of:
with the sensor unit,

i) recording a motion of the component of the railroad switch actuation system caused by a railroad vehicle passing the railroad switch,
ii) generating motion data comprising information on the recorded motion,
iii) based on the generated motion data, generating state of wear data comprising information of a deviation of the motion data from the reference motion data of the component, wherein said deviation is indicative to a state of wear

of the component and/or the railroad switch.

**[0046]** The method of the third aspect of the invention may be executed with the railroad switch actuation system according to the first aspect of the invention and/or with the railroad switch according to the second aspect of the invention. The embodiments, definitions and terms disclosed for the first and/or the second aspect of the inventions may also be applied to the third aspect of the invention and vice versa.

**[0047]** In an embodiment, the method comprises at least one of the following steps:

- recording the motion of the component and generating motion data comprising information on a corresponding motion direction along three spatial dimensions of the recorded motion, as well as a motion amplitude associated to the motion direction
- recording a temperature of the component and generating temperature data comprising information on the temperature of the component
- recording a humidity of air surrounding the railroad switch actuation system and generating humidity data comprising information on the humidity of air surrounding the railroad switch actuation system
- recording a sound from a passing railroad vehicle and/or from the railroad switch and generating sound data comprising information on the sound recorded from a passing railroad vehicle and/or the railroad switch
- recording a velocity of a passing railroad vehicle and generating velocity data comprising information on the velocity of the passing railroad vehicle.

**[0048]** In an embodiment of the method, the recorded data are sent to a server.

**[0049]** According to another embodiment of the method the sensor unit compares each of the data to reference data, particularly reference motion data of the component, such that the state of wear of the component and/or the railroad switch can be further determined based on deviations between the sensor data and the reference data.

**[0050]** In yet another embodiment of the method the sensor unit processes at least some of the generated data, particularly the generated motion data, so as to determine a velocity and/or a weight of a passing railroad vehicle.

**[0051]** In another embodiment of the method the sensor unit comprises a transmitter that sends state of wear data to a server. Particularly, the transmitter sends the state of wear data in case, more particularly only in case the determined deviation exceeds a predetermined limit.

**[0052]** According to an embodiment of the method, the transmitter sends the state of wear data via radiocommunication.

**[0053]** In another embodiment of the method, recommendation data comprising an information on maintaining the railroad switch system and/or the railroad switch is generated based on the determined deviation, particularly wherein the recommendation data is sent to the server. The information on maintaining the railroad switch may be generated by the sensor unit or alternatively by an external processing unit away from the railroad switch actuation system.

**[0054]** According to an embodiment of the method the sensor unit switches from an off-state to an on-state once it detects an approaching railroad vehicle, whereafter the state of wear is determined and wherein the sensor unit switches back to the off-state once the motion and particularly one of the other recorded quantities has been recorded and the state of wear has been determined. The off-state corresponds to a state of the sensor unit in which it is not operational such that the sensor unit does not record motion- or conditions such as ambient temperature and to generate data from the recorded motion or condition. In the off-state, the power consumption is significantly reduced compared to the on-state of the sensor unit, in which the sensor unit is configured to record motion and particularly conditions such as ambient temperature and to generate data as stated above.

**[0055]** The other recorded quantities particularly comprise the motion of the component, the temperature of the component, the humidity of air surrounding the railroad switch actuation system, the sound from a railroad vehicle passing the railroad switch and/or a velocity and/or a weight of a railroad vehicle passing the railroad switch.

**[0056]** Exemplary embodiments are described below in conjunction with the Figures. The Figures are appended to the claims and are accompanied by text explaining individual features of the shown embodiments and aspects of the present invention. Each individual feature shown in the Figures and/or mentioned in the text of the Figures may be incorporated (also in an isolated fashion) into a claim relating to the aspects according to the present invention.

Fig. 1 shows a schematical view of a railroad switch according to an embodiment of the invention and

Fig. 2 shows a perspective view of a railroad switch with a railroad switch actuation system according to another embodiment of the invention.

**[0057]** Fig. 1 shows a schematical view of a railroad switch 2 according to an embodiment of the invention that splits a first track 41 into a second and a third track 42,43, wherein each track 41,42,43 comprises a pair of stock rails 5.

**[0058]** To this end, two stock rails 51,53 forming the first track 41 split and turn into a respective stock rail 51,53 of

the second and a third track 42,43. To guide a railroad vehicle passing the railroad switch 2 to one of the second or the third track 42,43, the railroad switch 2 comprises a railroad actuation switch system 1 with components 10 by means of two-point machine assemblies 20 and two end position detection assemblies 30. The point machine assemblies 20 each comprise a respective point machine 22. The point machine 22 is arranged and configured to exert a force on a corresponding shifting element 4 in order to move switch rails 6 of the railroad switch 2. A first shifting element 4 associated to the left of the two-point machine assemblies 20 viewed in the drawing plane of Fig. 1 is connected to two switch rails 61,62 arranged between the stock rails 5, such that the switch rails 61,62 may be moved between a respective first and a second position by the corresponding point machine 22. A second shifting element 4 associated to the right of the two point machine assemblies 20 viewed in the drawing plane of Fig. 1 is connected to movable frog 50, such that the tip of the movable frog 50 may additionally be moved by the corresponding point machine 22 between a respective first and second position. As such, the frog 50 forming a crossing between two wing rails 52,54 of the second and third track 42,43 may be moved by moving the tip of the frog 50 relative to the wing rails 52,54.

**[0059]** The first position of the switch rails 61,62 and the movable frog 50 is depicted in Fig. 1, wherein the switch rail 61 is contacting the stock rail 51, while switch rail 62 is spaced from stock rail 53. Moreover, in the first position, the frog 50 is in contact with wing rail 52. Consequently, for this position of the switch rails 61,62, the railroad switch 2 is in a setting that causes a passing railroad vehicle to be guided onto the third track 43. The left point machine 22 may cause the switch rails 61,62 to move downward in the drawing plane such that switch rail 62 contacts stock rails 53, while now switch rail 61 is spaced from stock rail 51, and wherein the frog 50 is contacting wing rail 54, and not wing rail 52. Accordingly, in this second position, the railroad switch 2 is in a setting that causes a passing railroad vehicle to be guided onto the second track 42.

**[0060]** The position of the switch rails 61,62 with respect to each other and with respect to the stock 51,53 rails is monitored by the end position detection assemblies 30, particularly by their respective end position detectors 32.

**[0061]** In operation, the switch rails 61,62 may be secured with respect to each other and the associated adjacent stock rail 51,53 with a lock that closes once the respective switch rail 61,62 has been moved to a predetermined position, particularly said first or second position, such that the switch rail 61,62 is securely kept in the predetermined position. The end position detector 32 may be configured to monitor the lock and whether the lock is closed, particularly using a switch mechanism based on an electrical or mechanical switch that switches between two states once the lock is locked or unlocked. As such, the left end position detector 32 shown in Fig. 1 is configured to detect the position of the two switch rails 61,62 with respect to their associated neighboring stock rails 53,51 according to the state of the switch mechanism.

**[0062]** In the same fashion, the right end position detector 32 shown in Fig. 1 is configured to detect the position of the frog 50 with respect to the wing rails 52,54.

**[0063]** Both the point machine assemblies 20 as well as the end position detection assemblies 30 comprise a respective sensor unit 3 configured to record a motion of the component 10 caused by a railroad vehicle passing the railroad switch 2 for evaluating the recorded motion to determine an indication of a state of wear of the component 10 and/or the railroad switch 2. Due to the arrangement of the sensor unit 3 in or on the point machine assemblies 20 as well as the end position detection assemblies 30, motion sensors comprised by the sensor unit 3 are configured to sense vibrations from the most critical areas of the railroad switch 2. Consequently, wear occurring on the point machine assemblies 20 and/or the end position assemblies 30 can be immediately identified in the recorded motion data due to the direct mechanical connection between the assemblies 20,30 and their respective sensor units 3. As such, wear can be identified in an early stage, that is, before wear shows by means of mechanical damage on the component 10 and/or the railroad switch 2. In contrast, systems according to the prior art do not allow for reliable identification of wear in an early stage as sensor units are typically only indirectly connected to the point machine assemblies 20 and/or the end position assemblies 30, which causes distortions of the recorded data, such that security relevant wear may be remain hidden.

**[0064]** Fastening structures 21,31 for mounting the point machine assemblies 20 and the end position detection assemblies 30 to the railroad switch 2 are depicted in Fig. 2.

**[0065]** Fig. 2 depicts another embodiment of a railroad switch actuation system 1 according to the invention. In this embodiment, the railroad switch actuation system 1 comprises a point machine assembly 20 and an end position detection assembly 30. This perspective view shows the onset of a railroad switch 2 with two stock rails 5 as well as two switch rails 6 arranged between the stock rails 5.

**[0066]** The point machine assembly 20 comprises a point machine 22 and a fastening structure 21, wherein the fastening structure 21 fastens the point machine 22 to the railroad switch 2. Two sensor units 3 are mounted on the fastening structure 21 of the point machine assembly 20 by way of a mechanically rigid connection. The mechanically rigid connection in this embodiment is realized by existing fastening structures provided by the railroad switch actuation system 1 that allows for screw- or bolt connections of additional elements. As such, the sensor unit 3 is mechanically coupled to the point machine assembly 20 and thus to the railroad switch 2, which is in mechanical connection with the point machine assembly 20 via its fastening structure 21. The sensor unit 3 is configured to record a motion or vibrations. As an advantageous consequence of the sensor unit 3 being mounted on the fastening structure 21 of the point machine

assembly 20, vibrations of the railroad switch 2 as well as the point machine assembly 20 are directly transmitted onto the sensor unit 3, which allows thus to record a motion or vibration of the point machine assembly 20 and/or the railroad switch 2 caused by railroad vehicles passing the railroad switch 2. Moreover, the sensor unit 3 may be configured to record and/or to determine an ambient temperature, an ambient humidity, and/or a sound, a velocity and/or a weight of a passing railroad vehicle. The sensor unit 3 may further be configured to generate data indicative of the recorded motion, temperature, humidity, sound, velocity and/or weight. These conditions may be taken into account to determine the indication of the state of wear. Based on the data, the railroad switch actuation system 1 is configured to determine an indication of a state of wear of the component 1 and/or the railroad switch 2. To this end, the recorded motion data may for example be evaluated by means of a comparison of the recorded motion data to reference data or alternatively by a trend analysis of the recorded motion data. The reference data may comprise for example motion data recorded for a known state of wear of the component 10 and/or the railroad switch 2, for instance upon assembly or maintenance of the component 10 and/or the railroad switch 2, wherein the state of wear is considered to be minimal. Based on deviations of the recorded motion data to the reference data indicating the minimal state of wear, indications of the state of wear of the component 10 and/or the railroad switch 2 may be determined. In particular, larger deviations may indicate a more advanced state of wear, which thus acts an indicator for maintaining the component 10 and/or the railroad switch 2 once the deviations exceed a predetermined limit that may be set for example by national railroad authorities. The deviations may relate to deviations in motion amplitudes and/or motion directions between the recorded motion and the reference data.

**[0067]** As can further be seen in Fig. 2, the railroad switch actuation system 1 according to this embodiment further comprises an end position detection assembly 30 with an end position detector 32 mounted to the railroad switch 2 via a fastening structure 31 of the end position detection assembly 30. Two sensor units 3 are mounted to the fastening structure 31 of the end position assembly 30, such that these sensor units 3 are configured to record the motion of the end position detection assembly 30 and/or the railroad switch 2.

**[0068]** As such, the railroad switch actuation system 1 according to the present embodiment is configured to generate motion data from sensor units 3 located at different locations on both the point machine assembly 20 as well as the end position detection assembly 30. This allows to determine a state of wear of the point machine assembly 20 as well as the end position assembly 30, which are crucial constituents of railroad systems and guarantee safety and correct functioning of railroad switches 2. Due to the mechanical connection of the point machine assembly 20 and the end position assembly 30 with the railroad switch 2 via their respective fastening structures 21,31, the railroad switch actuation system 1 is at the same time configured to determine a state of wear of the railroad switch 2. The present invention thus provides a railroad switch actuation system 1 and a corresponding method to determine indications of the state of wear of a component 10 of the railroad switch actuation system 1 as well as the railroad switch 2, which increases safety and simplifies maintenance of railroad systems.

**List of reference signs**

| | |
|---|---|
| Railroad switch actuation system | 1 |
| Railroad switch | 2 |
| Sensor unit | 3 |
| Shifting element | 4 |
| Stock rail | 5 |
| Switch rail | 6 |
| Sleeper | 7 |
| Component | 10 |
| Point machine assembly | 20 |
| Fastening structure of point machine assembly | 21 |
| Point machine | 22 |
| End position detection assembly | 30 |
| Fastening structure of end position detection assembly | 31 |
| End position detector | 32 |
| First track | 41 |
| Second track | 42 |
| Third track | 43 |
| Frog | 50 |
| First stock rail | 51 |
| Wing rail of second track | 52 |

(continued)

| | |
|---|---|
| Third stock rail | 53 |
| Wing rail of third track | 54 |
| First switch rail | 61 |
| Second switch rail | 62 |

## Claims

1. A railroad switch actuation system (1) comprising a component (10) selected from the group consisting of: one or more point machine assemblies (20), one or more end position detection assemblies (30);
wherein the component (10) is configured to be attached to a railroad switch (2), **characterized in that** a sensor unit (3) is mounted in or on said component (10), wherein the sensor unit (3) is configured to record a motion of the component (10) caused by a railroad vehicle passing the railroad switch (2) for evaluating the recorded motion to determine an indication of a state of wear of the component (10) and/or the railroad switch (2).

2. The railroad switch actuation system (1) according to claim 1, wherein the sensor unit (3) is mounted in or on the component (10) by way of a mechanically rigid connection, such that the motion of the component (10) is transmitted essentially undamped to the sensor unit (3).

3. The railroad switch actuation system (1) according to claim 1 or 2, wherein the sensor unit (3) comprises one or more sensors selected from the group consisting of:

- a motion sensor, configured to record the motion of the component (10) and to generate motion data comprising information on a corresponding motion direction along three spatial dimensions of the recorded motion, as well as a motion amplitude associated to the motion direction,
- a temperature sensor, configured to record a temperature of the component (10) and to generate temperature data comprising information on the temperature of the component (10),
- a humidity sensor, configured to record a humidity of air surrounding the system (1) and to generate humidity data comprising information on the humidity of air surrounding the railroad switch actuation system (1),
- a sound sensor, particularly a microphone, configured to record a sound from a passing railroad vehicle and/or from the railroad switch (2) and to generate sound data comprising information on the sound recorded from a passing railroad vehicle and/or the railroad switch (2),
- an optical sensor, configured to record a velocity of a passing railroad vehicle and to generate velocity data comprising information on the velocity of the passing railroad vehicle.

4. The railroad switch actuation system (1) according to claim 3, wherein the sensor unit (3) is configured to compare each of the data to reference data, such that the state of wear of the component (10) and/or the railroad switch (2) can be further determined based on deviations between the sensor data and the reference data.

5. The railroad switch actuation system (1) according to one of the preceding claims, wherein the component (10) comprises one of the following:

- a fastening structure (21) of the point machine assembly (20) for fastening a point machine (22) of the point machine assembly (20) to the railroad switch (2);
- a fastening structure (31) of the end position detection assembly (30) for fastening an end position detector (32) of the end position detection assembly (30) to the railroad switch (2).

6. The railroad switch actuation system (1) according to one of the preceding claims, comprising a plurality of sensor units (3), wherein each sensor unit (3) is mounted at a different location in or on the component (10) and also in case there are more point machines or end position detectors at each point machine or end position detector along the railway switch and/or the movable frogs, wherein the data recorded by the plurality of sensor units (3) comprises datasets associated to the individual sensor units (3), such that the indication of the state of wear can be determined from the data recorded by the plurality of sensor units (3).

7. The railroad switch actuation system (1) according to one of the preceding claims, wherein the railroad switch actuation system (1) comprises the point machine assembly (20) and the end position assembly (30), and wherein

both the point machine assembly (20) and the end position assembly (30) each comprise a respective sensor unit (3).

**8.** A railroad switch (2) comprising a railroad switch actuation system (1) according to one of the preceding claims.

**9.** The railroad switch (2) according to claim 8, wherein the sensor unit (3) of the component (10) of the railroad switch actuation system (1) is mounted on a fastening structure for joining the railroad switch actuation system (1) and the railroad switch (2).

**10.** A method for recording for determining a state of wear of the railroad switch actuation system (1) according to one of the claims 1 to 7 and/or the railroad switch (2) according to claim 8 or 9, wherein the method comprises the steps of: With the sensor unit (3),

i) recording a motion of the component (10) of the railroad switch actuation system (1) caused by a railroad vehicle passing the railroad switch (2),
ii) generating motion data comprising information on the recorded motion,
iii) based on the generated motion data, generating state of wear data comprising information of a deviation of the motion data from the reference motion data of the component (10), wherein said deviation is indicative for a state of wear of the component (10) and/or the railroad switch (2).

**11.** The method according to claim 10, comprising at least one of the following steps:

- recording the motion of the component (10) and generating motion data comprising information on a corresponding motion direction along three spatial dimensions of the recorded motion, as well as a motion amplitude associated to the motion direction,
- recording a temperature of the component (10) and generating temperature data comprising information on the temperature of the component (10)
- recording a humidity of air surrounding the railroad switch actuation system (1) and generating humidity data comprising information on the humidity of air surrounding the railroad switch actuation system (1),
- recording a sound from a passing railroad vehicle and/or from the railroad switch (2) and generating sound data comprising information on the sound recorded from a passing railroad vehicle and/or the railroad switch (2) and
- recording a velocity of a passing railroad vehicle and generating velocity data comprising information on the velocity of the passing railroad vehicle.

**12.** The method according to claim 11, wherein the sensor unit (3) compares each of the data to reference data, particularly reference motion data of the component (10), such that the state of wear of the component (10) and/or the railroad switch (2) can be further determined based on deviations between the sensor data and the reference data.

**13.** The method according to one of the claims 10 to 12, wherein the sensor unit (3) processes at least some of the generated data, particularly the generated motion data, so as to determine a velocity and/or a weight of a passing railroad vehicle.

**14.** The method according to one of the claims 12 or 13, wherein recommendation data comprising an information on maintaining the railroad switch actuation system (1) and/or the railroad switch (2) is generated based on the determined deviation, particularly wherein the recommendation data is sent to the server.

**15.** The method according to one of the claims 10 to 14, wherein the sensor unit (3) switches from an off-state to an on-state once it detects an approaching railroad vehicle, whereafter the state of wear is determined and wherein the sensor unit (3) switches back to the off-state once the motion and particularly one of the other recorded quantities has been recorded and the state of wear has been determined.

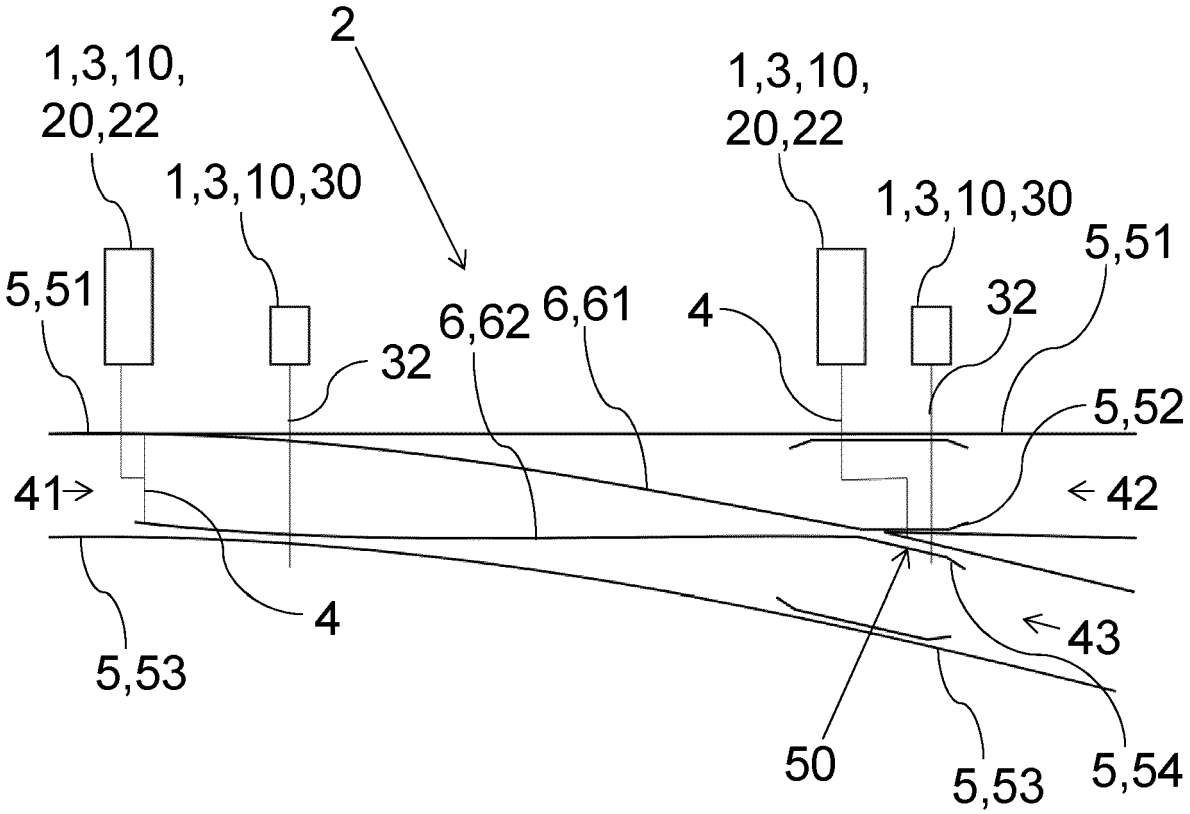
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Fig. 1

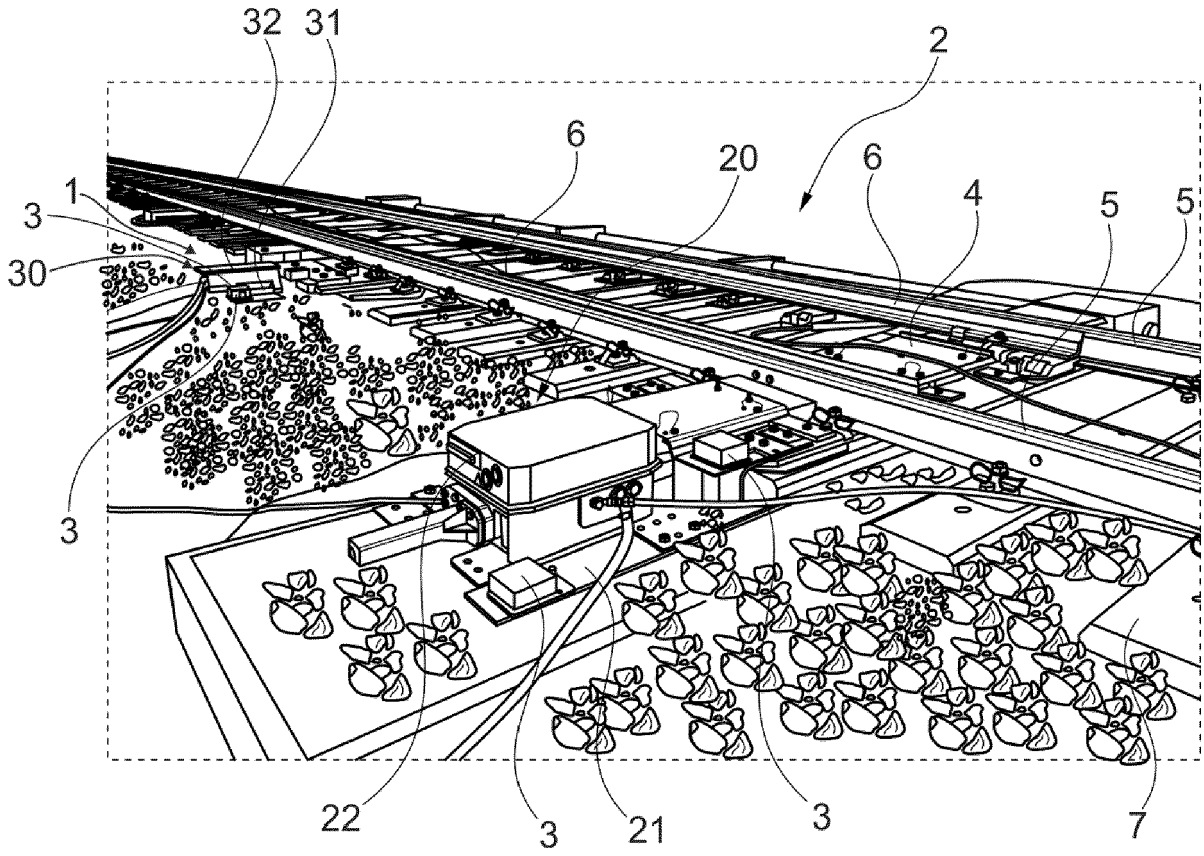


Fig. 2

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# EUROPEAN SEARCH REPORT

Application Number
EP 23 15 2771

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X | WO 2019/185873 A1 (KONUX GMBH [DE])<br>3 October 2019 (2019-10-03)<br>* abstract *<br>* figure 1 *<br>* page 5, paragraph 5 - page 6, last paragraph *<br>* page 7, last paragraph - page 8, paragraph 3 *<br>* page 15, paragraph 6 - page 16, column 1 *<br>* page 17, paragraph 2 - page 18, paragraph 1 *<br>----- | 1-14 | INV.<br>B61L23/04<br>B61L27/53 |
| | | | TECHNICAL FIELDS SEARCHED (IPC) |
| | | | B61L |

~~The present search report has been drawn up for all claims~~

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 26 June 2023 | Janssen, Axel |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
.....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 23 15 2771

## CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

## LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

**see sheet B**

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

**1-12, 14(completely); 13(partially)**

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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## LACK OF UNITY OF INVENTION
## SHEET B

Application Number
EP 23 15 2771

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-12, 14(completely); 13(partially)

   Measuring motion of parts of railway points
   ---

2. claim: 13(partially)

   Measuring the weight of the railway vehicle
   ---

3. claim: 15

   Standby mode
   ---

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 15 2771

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-06-2023

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| WO 2019185873 A1 | 03-10-2019 | NONE | |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82