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End of train (EOT) remote track-condition monitoring

Abstract

An end of train device (**100**) suitable of use on a railway vehicle includes an enclosure (**110**), one or more accelerometers (**180**) positioned inside the enclosure (**110**) and providing accelerometer data of a railway vehicle (**230**) when travelling on a railway track (**240**), and a tracking device (**185**) positioned inside the enclosure (**110**) and providing location data, wherein the accelerometer data and location data are analyzed to determine a condition of the railway track (**240**). Further, a track monitoring system (**200**) and a method (**300**) for continuous monitoring of railway tracks (**240**) are provided.

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Background/Summary

BACKGROUND
1. Field

(1) Aspects of the present disclosure generally relate to remote track-condition monitoring, specifically remote track-condition monitoring utilizing an end of train device.

2. Description of the Related Art

(2) Railway is one of the most used means of transportation. For the railway system to operate flawlessly constant monitoring and inspection of railway tracks is required to prevent or correct track defects. Currently railway track inspection and monitoring are usually performed by sporadic deployment of specialized track inspection equipment, or by visual inspection, performed manually, which is time consuming and may not be accurate due to human error occurrence. Moreover, practically it is impossible to inspect and monitor railway tracks manually as they run thousands of miles. Another possibility is the use of locomotive-based equipment, such as specially designed camera systems.

(3) Within the railway industry, an end of train device, herein also referred to as EOT, is an electronic device which can perform a number of functions, some of which are required by regulations of the Federal Railroad Administration (FRA). The EOT is typically attached at a rear of a last car on a railway vehicle or train, often to an unused coupling on an end of the last car opposite the head of the train.

(4) EOTs were originally designed to perform some of the functions previously performed by train personnel located in the caboose, thereby allowing trains to operate without a caboose and with a reduced number of train personnel. For example, an EOT can monitor air pressure in the air brake pipe and transmit this information to a head of train device (HOT). Further, EOTs also often include an end-of-train marker light to alert trailing trains on the same track of the presence of the end of the train. Two-way EOTs can accept commands from the HOT, for example to open a valve to release pressure in the air brake pipe so that the train's air brakes activate to stop the train in an emergency. EOTs can comprise many other components and/or functions.

SUMMARY

(5) Briefly described, aspects of the present disclosure relate to remote track-condition monitoring utilizing an end of train device (EOT). The EOT is suitable for railway vehicles such as freight trains and passenger trains.

(6) A first aspect of the present disclosure provides an end of train device suitable of use on a railway vehicle comprising an enclosure, at least one accelerometer positioned inside the enclosure and providing accelerometer data of a railway vehicle when travelling on a railway track, and a tracking device positioned inside the enclosure and providing location data, wherein the accelerometer data and location data are analyzed to determine a condition of the railway track.

(7) A second aspect of the present disclosure provides a track monitoring system comprising an end of train device, a central computer system, a communication network interfacing with the end of train device and the central computer system and adapted to transmit data, wherein the end of train device collects accelerometer data and location data of a railway vehicle when travelling on railway tracks, and wherein collected accelerometer data and location data are transmitted to the central computer system via the communication network.

(8) A third aspect of the present disclosure provides a method for continuous monitoring of railway tracks comprising: collecting accelerometer data and location data by an end of train device, transmitting collected data to a central computer system via a communication network, and analyzing the collected data for markers that indicate railway track defects.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** illustrates a perspective view of an end of train device in accordance with an exemplary embodiment of the present disclosure.

(2) FIG. **2** illustrates schematically a track monitoring system in accordance with an exemplary embodiment of the present disclosure.
(3) FIG. **3** illustrates a flow chart of a method for continuous monitoring of railway track conditions in accordance with an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION

(4) To facilitate an understanding of embodiments, principles, and features of the present invention, they are explained hereinafter with reference to implementation in illustrative embodiments. In particular, they are described in the context of an end of train device (EOT) for a railway vehicle, a track monitoring system and a method for continuous monitoring of railway tracks. Embodiments of the present invention, however, are not limited to use in the described devices or methods.
(5) The components and materials described hereinafter as making up the various embodiments are intended to be illustrative and not restrictive. Many suitable components and materials that would perform the same or a similar function as the materials described herein are intended to be embraced within the scope of embodiments of the present invention.
(6) FIG. **1** illustrates a view of an EOT **100** in accordance with an exemplary embodiment of the present disclosure. The EOT **100** is suitable of use on a railway vehicle located on a last train car of the railway vehicle, for example a freight train. The EOT **100** comprises an enclosure **110**, and a plurality of components, such as electronic components, positioned inside the enclosure **110**. For example, one or more displays **120** are positioned inside the enclosure **110**. The one or more displays **120** display information and/or data provided by the EOT **100**. An important component of the EOT **100** is a high visibility marker light (HVM) **130** which is utilized to illuminate a rearward of the railway vehicle. The EOT **100** further comprises a coupling unit (not visible in FIG. **1**), typically attached to the housing **110**, which couples the EOT **100** to the last train car, for example a train car coupling.
(7) Examples of other components of the EOT **100** include cell phone transceivers, systems for monitoring/controlling brake lines and pressure, communication systems for communicating with other units such as for example head of train devices etc. It should be noted that one of ordinary skill in the art is familiar with structure, components and functions of different types of EOTs, and they will not be described in further detail herein.
(8) In an exemplary embodiment, the enclosure **110** comprises a top portion **150** and a bottom portion **160**. The top portion **150** comprises a transparent dome **155**. The transparent dome **155** is configured such that information displayed by the displays **120** as well as the HVM **130** are visible from an outside of the enclosure **110** through the transparent dome **155** of the top portion **150**. The bottom portion **160** can be opaque or also transparent. The top portion **150** comprising the transparent dome **155** is formed from transparent material, for example molded from transparent material. The transparent material comprises clear plastic material, such as for example polycarbonate. Polycarbonate is available in grades that are clear and that have UV resistance, and it is a strong material that is suitable for use in an industrial enclosure. The top portion **150** can be a monolithic component. In other words, the top portion **150** including the transparent dome **155** can be a one-piece component formed or molded from transparent material thereby providing a single part as the top portion **150**. The bottom portion **160** can be formed, for example molded, from plastic material, but would typically not comprise transparent plastic material, but opaque plastic material.
(9) The EOT **100** further comprises a handle **170** attached to the housing **110** for handling such as installation and removal of the EOT **100** on/off a train car of a railway vehicle, in particular a last train car.
(10) As described before, railway is one of the most used means of transportation. For the railway system to operate flawlessly constant monitoring and inspection of railway tracks is required to prevent or correct track defects. In an exemplary embodiment of the present disclosure, the EOT **100** is configured such that a continuous monitoring of railway tracks may be performed remotely

utilizing the EOT **100**. Specifically, the EOT **100** is adapted or configured to determine and/or measure and record a motion of a railway vehicle across one or more axes (x-, y-, z-axis in the three-dimensional Cartesian coordinate system) as the railway vehicle moves along the railway track, wherein for example vibration, shock, altitude and geographic position information are continuously monitored and captured. Information collected by the EOT **100** is then statistically analyzed for markers that indicate potential track defects. The EOT **100** as a component of a track monitoring system will be described in more detail with reference to FIG. **2**.
(11) FIG. **2** illustrates a schematic of a track monitoring system **200** in accordance with an exemplary embodiment of the present disclosure. The track monitoring system **200** comprises EOT **100**, a central computer system **210** and a communication network **220** interfacing with the EOT **100** and the central computer system **210** and adapted to transmit data.
(12) The EOT **100** is attached at a rear of a last car **235** on a railway vehicle/train **230** travelling on railway track **240**, for example to an unused coupling on an end of the last car opposite the head of the train **230**.
(13) In accordance with an exemplary embodiment, the EOT **100** comprises at least one accelerometer **180**, the accelerometer providing accelerometer data, specifically accelerometer vibration data, of the railway vehicle **230** when travelling on the railway track **240**, and a tracking device **185** providing location data. The at least one accelerometer **180** and tracking device **185** are positioned inside the enclosure **110**, for example in the bottom portion **160**, of the EOT **100** (see FIG. **1**)
(14) Generally, the accelerometer vibration data and the location data are utilized for a continuous monitoring of railway track conditions. The EOT **100**, when coupled to the railway vehicle **230** and travelling on railway track **240**, determines and/or measures a motion of the railway vehicle **230** across one or more axes (x-, y-, z-axis of the Cartesian coordinate system), wherein for example vibration, shock, altitude and geographic position information are continuously monitored and captured utilizing the at least one accelerometer **180** and the tracking device **185**. Information captured and collected by the EOT **100** is then statistically analyzed to determine the conditions of the railway tracks, for example is analyzed for markers that indicate potential track defects. It should be noted that the EOT **100** can comprise one or more accelerometers **180**, depending on for example a capacity of an accelerometer or specific requirements of the EOT **100**. The one or more accelerometers **180** can be configured as accelerometer sensor card(s).
(15) The at least one accelerometer **180** measures and captures a motion of the railway vehicle **230** across three axes, the x-, y-, and z-axis in a three-dimensional space (3-axis-accelerometer). To detect and differentiate between types of vibration and shock, the at least one accelerometer **180** comprises a high-resolution accelerometer, and can detect and process low-frequency vibrations. Using a high-resolution, low-frequency accelerometer **180**, the EOT **100** can detect for example track voids under both switchings and crossings and plain track, dip track on both plain track and switchings and crossings, and rough ride of the railway vehicle. Track voids occur where track support conditions have been deteriorated over time. This could be due to drainage issues, gaps between the ballast and sleeper or poor maintenance. Track voids cause substantial delay minutes, can lead to line closures and can increase the chance of derailment. Dip track occurs where voids underneath the track cause the track to buckle from the lack of support. Rough ride occurs when the train moves over a track defect, causing the train to bounce or sway leading to an uncomfortable ride for passengers. Further, wheel flat spots of the railway vehicle can be detected allowing maintenance teams to repair or replace a wheel before it becomes an issue.
(16) The tracking device **185** comprises a receiver for a satellite navigation system **250**, for example a global positioning system (GPS) receiver. Alternatively, the tracking device **185** may comprise a Galileo satellite navigation system receiver.
(17) The EOT **100** further comprises a memory module **195** for storing monitored and captured accelerometer data and location data. The accelerometer data and/or location data are stored as raw

data or as pre-processed data in the memory module **195**. The data can be pre-processed by the EOT **100**, wherein the pre-processed data can comprise frequency-domain data.

(18) The EOT **100** further comprises a communication module **190** for transmitting captured and collected accelerometer data and location data to the central computer system **210**. Data are transmitted as raw data or pre-processed data. The central computer system **210** is for example a remote central computer system or a remote central server. Such a remote system or server can be located for example at a central train operator station or a rail operations center.

(19) A communication network **220**, adapted to transmit data, is interfacing with the EOT **100** and the central computer system **210**. The communication network **220** comprises a wireless communication network, which can be a network such as for example the Internet or many other network environments that are accessible via an air interface, e.g. Wi-Fi.

(20) The central computer system **210** is adapted to analyze the accelerometer data including defect signals for markers that indicate potential railway track defects. The location data ensure that maintenance is accurately directed and planned, minimizing the time maintenance staff spend on track and therefore improving their safety.

(21) As noted before, vibration, shock, altitude of the railway vehicle when travelling on railway tracks are continuously monitored and captured by the at least one accelerometer **180**. A defect type of the railway track **240**, such as track voids, rough-ride or dip track are defined based on the measured vibration and shock. In an embodiment, the EOT **100** is configured to define the defect type of the railway track. The tracking device **185** and its location functionality is used to provide an accurate defect location. In this case, pre-processed (vibration) data, for example a defect signal corresponding to the defined defect type, and the location data of the defect signal are communicated to the central computer system **210**. In another embodiment, the EOT **100** transmits raw data to the central computer system **210**, wherein the central computer system **210** determines the defect type. The defect type can be determined for example by comparing collected accelerometer vibration data to previously stored data characterizing a specific track defect.

(22) Further, in another embodiment, the track monitoring system **200** can be configured to identify different severity of detected defects. A Red/Amber/Green severity level may be provided wherein Red is more urgent so that track repair resources can be directed towards the more urgent items first. In an example, the central computer system **210** is configured to provide such a severity level.

(23) When EOTs **100** are installed in almost all trains or railway vehicles travelling within the railway network, the disclosed EOT **100**, system **200** and method **300** provide network-wide track condition monitoring. Multiple trains monitoring the same tracks leads to a reduction in false alarms and increased accuracy of defect type and location. Planned and directed maintenance minimizes time maintenance staff spend on tracks, thereby improving maintenance workers' safety. Further, preventive maintenance is provided, where a comparison between runs can highlight sections where track deterioration is detected. This allows the maintenance teams to correct the problems before it becomes a more serious defect.

(24) FIG. **3** illustrates a flow chart of a method **300** for continuous monitoring of railway track conditions in accordance with an exemplary embodiment of the present disclosure. The method **300** refers to the components and elements as described before with reference to FIG. **1** and FIG. **2**.

(25) Summarizing, in a first step **310**, accelerometer vibration data and location data are collected by the EOT **100** when coupled to the railway vehicle **230** travelling on the railway track **240**. Collected accelerometer data and location data are stored by the EOT **100** (step **315**). After data and information has been collected by the EOT **100**, the data and information are periodically transmitted wirelessly to the central computer system **210** by communication network **220** (step **330**). The data and information can be directly or indirectly transmitted to the central computer system **210**. For example, the data/information may be transmitted to an intermediate (in-between) device, for example a control unit installed close to the railway track **240**, such as for example a grade crossing predictor (GCP), wherein collected data from multiple railway vehicles or trains **230**

are collected by the intermediate device and are then transmitted to the central computer system **210** for further processing and analyzing. The collected data are analyzed for markers that indicate defects of the railway track **240**. The collected accelerometer data may be pre-processed by the EOT **100** before transmitting to the central computer system **210** or an intermediate device. It should be appreciated that the described method **300** can comprise more steps, or some steps can be repeated multiple times, or some steps are optional. For example, pre-processing of the accelerometer data by the EOT **100** is optional. Transmitting **320** of data can be repeated multiple times before data analyzing **330**.

(26) While embodiments of the present invention have been disclosed in exemplary forms, it will be apparent to those skilled in the art that many modifications, additions, and deletions can be made therein without departing from the spirit and scope of the invention and its equivalents, as set forth in the following claims.

Claims

1. An end of train device for a railway vehicle comprising: an enclosure, at least one accelerometer positioned inside the enclosure and providing accelerometer vibration data of a railway vehicle when travelling on a railway track, a tracking device positioned inside the enclosure and providing location data, and a communication module integrated into the end of train device and configured to transmit the accelerometer vibration data and location data directly to a central computer system via a wireless communication network interfacing with the end of train device, the central computer system being a remote central computer system located at a central train operator station or a rail operations center, a memory module for storing the accelerometer vibration data and location data, wherein the accelerometer vibration data and location data are stored as pre-processed data in the memory module, wherein the pre-processed data comprise accelerometer frequency-domain data, wherein the accelerometer vibration data and location data are analyzed to determine a condition of the railway track, and wherein the at least one accelerometer is configured to measure and capture a motion of the railway vehicle across three axes in a three-dimensional space to detect types of vibration and shock and conditions including track voids and dip track.
2. The end of train device of claim 1, wherein the at least one accelerometer comprises a high-resolution accelerometer.
3. The end of train device of claim 1, wherein the tracking device comprises a global positioning system (GPS) receiver.
4. The end of train device of claim 1, further comprising: a top portion and a bottom portion, wherein the top portion comprises a transparent dome formed from transparent material.
5. A railway vehicle comprising an end of train device as claimed in claim 1.
6. A method for continuous monitoring of railway tracks comprising: collecting accelerometer vibration data and location data by an end of train device when coupled to a railway vehicle travelling on a railway track, wherein the end of train device comprises at least one accelerometer configured to measure and capture a motion of the railway vehicle across three axes in a three-dimensional space to detect between types of vibration and shock and conditions including track voids and dip track, storing collected accelerometer vibration data and location data by the end of train device, pre-processing the collected accelerometer vibration data by the end of train device before transmitting to the central computer system, pre-processed accelerometer vibration data and location data comprising accelerometer frequency-domain data, transmitting, by a communication module integrated in the end of train device, collected accelerometer vibration data and location data directly to a remote central computer system via a wireless communication network interfacing with the end of train device and the remote central computer system, the remote central computer system being located at a central train operator station or a rail operations center, and analyzing the collected data for markers that indicate defects of the railway track.

7. The method of claim 6, further comprising: defining a defect type of the railway track based on the accelerometer vibration data.