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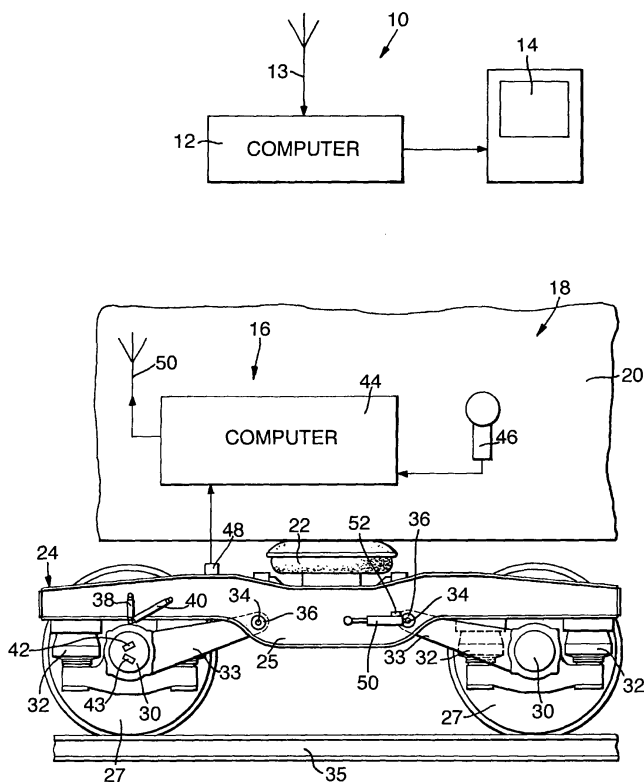
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(54) **Device for monitoring the longitudinal forces applied by a railway vehicle wheel on the rail**

(57) Equipment for monitoring longitudinal forces between the wheels (27) of a vehicle and the track (35) consists of at least one displacement transducer (38, 40) arranged to monitor any longitudinal movement of the wheel relative to the bogie; and an accelerometer (42, 43) arranged to measure longitudinal acceleration.

The low frequency forces can be determined from the displacement measurements, and the high frequency forces can be determined from the accelerometer measurements. These forces are a contributing factor to the development of rolling contact fatigue, and the equipment enables features of the track or the vehicle which exacerbate such forces to be identified.

Fig.1.



Description

[0001] This invention relates to equipment for monitoring interactions between a vehicle and a railway track, in particular for determining longitudinal forces due to wheels of a vehicle.

[0002] Track recording vehicles are known, which include instruments for measuring many different attributes of a railway track, such as longitudinal profile, gauge and cant. It has also been suggested that track monitoring equipment might be installed in service vehicles, so that the track can be monitored more often. For example, WO 00/70148 describes equipment for measuring the profile of a railway track, using an accelerometer measuring the vertical acceleration of a bogie and a linear displacement transducer measuring the vertical displacement of an axle relative to the bogie.

[0003] In recent years a significant problem has been the development of rolling contact fatigue, with the development of cracks which can potentially lead to a rail break. It has been found that such cracking, which may be referred to as head checking or gauge corner cracking, may sometimes develop within a year of laying a new rail yet in other situations no such cracks develop over several decades. It is believed that rolling contact fatigue is most likely to occur in situations where a high load is combined with high longitudinal forces between the wheel and rail. Such longitudinal forces arise, for example, where the two wheels of a wheelset would tend to rotate at different speeds, for example when a rail vehicle goes around a curve, or on a straight track if the wheelset is not accurately aligned with the track (because of the conical rolling surfaces). Where the suspension of a train is such as to suppress yaw motion, this will tend to exacerbate this problem. Such longitudinal forces might possibly be measured using a wheel provided with appropriately-arranged strain gauges, but this is expensive, and cannot detect forces in the high frequency range, because of inertia.

[0004] According to the present invention there is provided equipment for identifying locations along a track at which a wheel of a railway vehicle subjects a rail along which the vehicle is travelling to longitudinal forces, the equipment comprising at least one displacement transducer arranged to monitor any longitudinal movement of the wheel relative to a bogie of the vehicle, and an accelerometer arranged to measure longitudinal acceleration of the wheel, and means for deducing from signals representing the longitudinal movement of the wheel and representing longitudinal acceleration of the wheel the longitudinal forces acting on the wheel from the rail.

[0005] The present invention also provides equipment for identifying locations along a track at which a wheel of a railway vehicle may be expected to cause fatigue in a rail along which the vehicle is travelling, the equipment incorporating means for determining the longitudinal forces as specified above, and hence deducing

those locations at which fatigue may be caused.

[0006] The displacement transducer enables the lower frequency components of the forces to be monitored, while the accelerometer enables the higher frequency components to be monitored. For low frequencies the resilience of the primary suspension is effectively being used as a spring balance, while for high frequencies the resilience becomes irrelevant, and the force can be equated to the mass of the wheel times its acceleration. If the axle box's orientation relative to the track can vary, for example if it is supported by a swing link, there may instead be two such accelerometers on the axle box arranged at different orientations relative to the longitudinal axis (in the vertical plane). From these two accelerometers the actual acceleration can be resolved into components in the longitudinal and perpendicular directions relative to the track (the longitudinal accelerations must be in a direction within a restricted range of angles relative to the orientation of the accelerometers, this being determined by the design of the swing link mounting).

[0007] The directions referred to as longitudinal and perpendicular are relative to the plane of the track. If the track is horizontal, then the longitudinal direction is horizontal and the perpendicular direction is vertical.

[0008] In one preferred arrangement there are two displacement transducers, one of which is arranged to monitor perpendicular displacements and the other of which is inclined at an angle so as to be sensitive to both perpendicular and longitudinal displacements. A comparison of the measurements obtained by these two transducers enables the longitudinal displacement to be determined. In another preferred arrangement, where the axle box is connected to the bogie frame by a swing link secured to the bogie frame by a pin that locates in a resilient bush, the displacement transducer is attached between the bogie frame and the pin to measure any longitudinal displacements of the axle box. In this case the displacement transducer can be aligned in the longitudinal direction. Preferably the accelerometer is arranged to measure longitudinal accelerations of the pin, and may be mounted on the displacement transducer to ensure that it is aligned in the longitudinal direction.

[0009] Preferably the equipment also includes a computer to analyse signals from the sensors, and a position locating instrument arranged to provide position information to the computer, and automatic means for transferring data from the computer to a base station remotely and at intervals.

[0010] The position locating instrument might use GPS. More precise information on position may be obtained using differential GPS, or by detecting the location of objects at known positions along or adjacent to the track such as points or crossings. Dead reckoning methods may also be used, including inertial guidance systems, and measuring distance from known positions.

[0011] Such equipment can be sufficiently small to be installed on a service vehicle, for example a passenger

coach, without causing inconvenience to passengers or staff. Operations can be totally automatic, so no staff are required to monitor it. Consequently the equipment enables the performance of the rolling stock to be monitored automatically, and any occurrences of high longitudinal forces can be correlated with the location along the track at which they occur. Such equipment might be installed in new rolling stock prior to its acceptance into service, so that any faults in the suspension or design features that exacerbate longitudinal forces can be identified.

[0012] The invention will now be further and more particularly described, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 shows a side view, partly diagrammatic, of a vehicle incorporating a monitoring system of the invention.

[0013] Referring to figure 1, a system 10 for monitoring the longitudinal forces acting between wheels and a track includes a base station computer 12 connected to an aerial 13 and to a display screen 14. The system 10 also incorporates instrumentation packages 16 (only one is shown) which are installed in service vehicles, or measurement vehicles, or vehicles undergoing testing. The figure shows a side view, partly diagrammatic, of parts of a vehicle 18 comprising a body 20 supported on air springs 22 on bogies 24 (only one of which is shown). The bogie 24 includes an H-frame 25 and two wheelsets 27, each comprising two wheels integral with an axle. At each end the axle locates in a bearing in an axle box 30, the axle box 30 being connected to the frame 25 by rubber springs 32 and trailing links 33 so that the axle 29 and the axle box 30 can undergo limited movement relative to the frame 25, the trailing links 33 being rigidly connected to the axle box 30 and pivotally connected to the frame 25 by a pin passing through a hard rubber bush 36. The wheelsets 27 roll along a railway track 35.

[0014] The instrumentation package 16 includes two linear displacement transducers 38 and 40 connected between the top of the axle box 30 and the H-frame 25, one transducer 38 being oriented perpendicular to the track 35 (ie vertically, if the track 35 is horizontal), and the other transducer 40 being oriented at an inclination of say 30° to that direction. The package 16 also includes a pair of accelerometers 42, 43 mounted on the axle box 30, and oriented at 45° above and below the horizontal respectively (if the track 35 is horizontal).

[0015] Signals from the accelerometers 42 and 43 and the transducers 38 and 40 are provided to a computer 44 within the body 20. A GPS receiver 46 also provides signals to the computer 44. A tachometer 48 on the bogie 24 measures the rate of rotation of a wheelset 27 and supplies electrical signals to the computer 44. The computer 44 might for example locate beneath a passenger seat in the vehicle. And the computer 44 can

transmit data via an aerial 50 to the base station 12.

[0016] The transducers 38 and 40 and the accelerometers 42 and 43 enable the longitudinal forces between the wheelset 27 and the track 35 to be measured on one side of the vehicle 18, as described below. In order to measure the corresponding longitudinal forces on the other side of a vehicle 18, another such pair of transducers 38 and 40 and accelerometers 42 and 43 would be connected in the same way to an axle box 30 on the other side of the vehicle 18.

[0017] The analogue signals from the transducers 38 and 40 and the accelerometers 42 and 43 may first be digitized (at say 1 kHz, for example within the computer 40), or the analogue signals may themselves be processed in order to deduce the forces. The forces in the low-frequency range (below the resonant frequency for longitudinal oscillations of the wheelset 27 relative to the bogie 24) are determined from the displacement signals from the displacement transducers 38 and 40. It will be appreciated that the inclination of the transducer 40 to the perpendicular, say θ , although nominally 30°, will vary with vertical movements of the wheelset 27 relative to the frame 25. If the longitudinal displacement of the wheelset 27 is x , the perpendicular displacement measured by the transducer 38 is y , and the displacement in the direction of the transducer 40 is s , then:

$$s \cos \theta = y$$

and

$$s \sin \theta = x$$

so, for example, $x = v(s^2 - y^2)$.

Hence by combining the measurements from the transducers 38 and 40, the longitudinal displacement x can be determined. This can be related to the longitudinal force F from a measurement of the spring constant k of the suspension, i.e. of the rubber springs 32 in this example. The spring constant k must therefore be measured during a separate calibration step which can be carried out with the vehicle 18 stationary, applying a known longitudinal (horizontal) force F_c to the wheelset 27 and measuring its longitudinal displacement x_c ; then:

$$k = F_c/x_c.$$

[0018] The high frequency components of the forces between the wheelset 27 and the track 35 are determined from the measurements from the accelerometers 42 and 43. As the vehicle 18 moves along the track 35, the orientation of the top surface of the axle box 30 and so of the accelerometers 42 and 43 will vary through a small angular range, but the signals from the two accelerometers 42 and 43 may be used to deduce the accel-

eration in the longitudinal direction. Various different analysis approaches may be used. The signals from each accelerometer 42 and 43 may be resolved into two orthogonal components (corresponding to the longitudinal and perpendicular directions relative to the track) by assuming an orientation for the longitudinal direction; this can be repeated for a range of different assumed orientations. The true orientation can be determined for example by identifying the orientation at which the components deduced from one accelerometer 42 are equal to those deduced from the other accelerometer 43.

[0019] The preferred approach in this case is to deduce the orientation of the top surface of the axle box 30 from its vertical displacement as measured by the transducer 38; and hence deduce the longitudinal acceleration from the signals from one or other of the accelerometers 42 and 43. (Instead of the two accelerometers at different orientations, alternatively in this case a single accelerometer may be provided, and may be oriented horizontally.)

[0020] From the longitudinal acceleration component determined in this way, the longitudinal force is calculated, being equated to the effective mass of the wheel multiplied by the longitudinal acceleration component.

[0021] Thus the present invention enables the longitudinal forces acting between the wheels and the rails to be measured both in the low frequency and high frequency ranges. The high and low frequency signals may be processed separately, or combined using complementary filters to ensure accurate representation of the cut-off frequencies. The measured forces may be merely recorded by the computer 44, and this data is preferably tagged with positional information from the GPS receiver 46 or from other positional information such as lineside beacons or from the tachometer 48; the speed of the vehicle as determined by the tachometer 48 is preferably also recorded. This recorded data may be downloaded at intervals to the base station 12. This may be in response to a signal from the base station 12, and may for example be done once a day. Furthermore the data may be averaged prior to storage and transmission, for example over a preset length of track such as 10 m; this reduces the amount of data to be stored and transmitted. Thus the equipment enables features of the track or of the vehicle which exacerbate the longitudinal forces to be identified.

[0022] It will be appreciated that the system 10 might differ from that described above. It is applicable to railway vehicles with different suspensions, for example the primary suspension might include helical springs in place of the rubber springs 32. Furthermore the computer 40 might be mounted on the underside of the body 20, rather than within it.

[0023] An alternative monitoring system 10 omits the accelerometers 42 and 43 and the displacement transducers 38 and 40. Instead, as shown on the right-hand side of the figure, a displacement transducer 50 is mounted longitudinally (horizontally as shown) between

the pivot pin 34 of one of the trailing links 33, and the frame 25 of the bogie 24. An accelerometer 52 is mounted on the end of the displacement transducer 50 next to the pivot pin 34. This arrangement avoids the problems arising from the variation in the orientation of the axle box 30, as the displacement transducer 50 is always longitudinal, and the accelerometer 52 is therefore always longitudinal (provided that the displacement transducer 50 is sufficiently long that any changes of orientation due to vertical movements of the pin 34 in the bush 36 can be neglected). As in the monitoring system described earlier, the displacement transducer 50 enables the low-frequency longitudinal forces on the wheel 27 to be determined, while the accelerometer 52 enables the high frequency longitudinal forces to be determined.

Claims

1. Equipment for identifying locations along a track at which a wheel of a railway vehicle subjects a rail along which the vehicle is travelling to longitudinal forces, the equipment comprising at least one displacement transducer arranged to monitor any longitudinal movement of the wheel relative to a bogie of the vehicle, and an accelerometer arranged to measure longitudinal acceleration of the wheel, and means for deducing from signals representing the longitudinal movement of the wheel and representing longitudinal acceleration of the wheel the longitudinal forces acting on the wheel from the rail.
2. Equipment for identifying locations along a track at which a wheel of a railway vehicle may be expected to cause fatigue in a rail along which the vehicle is travelling, the equipment comprising at least one displacement transducer arranged to monitor any longitudinal movement of the wheel relative to a bogie of the vehicle, and an accelerometer arranged to measure longitudinal acceleration of the wheel, and means for deducing from signals representing the longitudinal movement of the wheel and representing longitudinal acceleration of the wheel the longitudinal forces acting on the wheel from the rail, and hence deducing those locations at which fatigue may be caused.
3. Equipment as claimed in claim 1 or claim 2 comprising two such accelerometers on an axle box oriented at different angles to the horizontal.
4. Equipment as claimed in any one of the preceding claims also comprising a computer within the railway vehicle to analyse signals from the sensors, and a position locating instrument arranged to provide position information to the computer.

5. Equipment as claimed in claim 4 also comprising automatic means for transferring data from the computer to a base station remotely and at intervals.
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6. Equipment as claimed in any one of the preceding claims wherein a wheel box is connected to the bogie by a trailing link, the trailing link being connected to the bogie by a pin held in a resilient bush, wherein longitudinal movement of the wheel is monitored by monitoring longitudinal movement of the pin relative to the bogie.
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7. Equipment as claimed in claim 6 wherein longitudinal acceleration of the wheel is monitored by monitoring longitudinal acceleration of the pin.
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8. A system for monitoring longitudinal forces acting between wheels and a railway track comprising a base station and equipment as claimed in any one of the preceding claims installed on a vehicle on the track.
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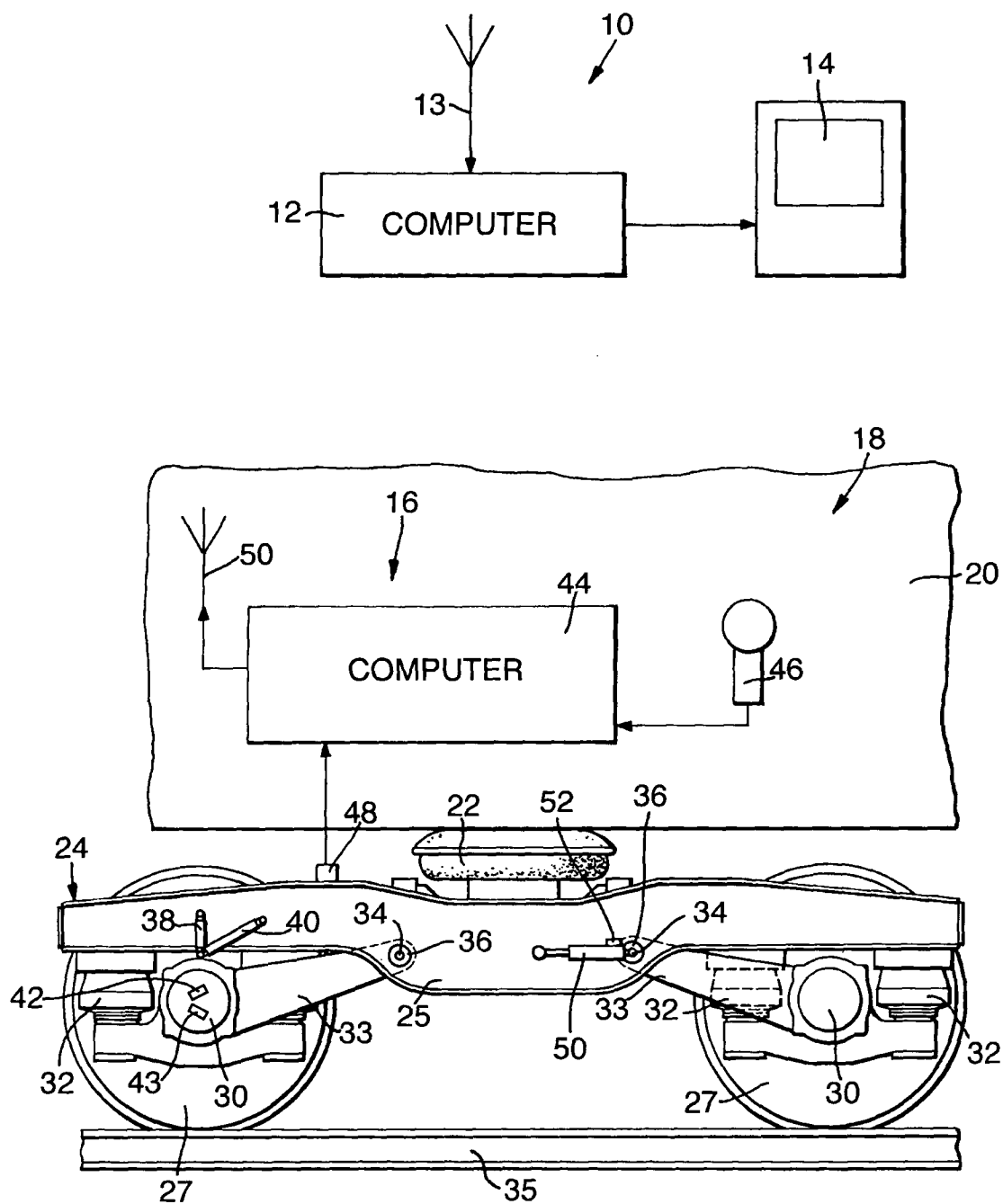
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Fig.1.





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 05 25 2838

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,A	WO 00/70148 A (AEA TECHNOLOGY PLC; GILBERT, DAVID; WESLEY, PETER, DAVID) 23 November 2000 (2000-11-23) * the whole document *	1	B61K9/08
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			B61K B61L
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 30 August 2005	Examiner Fuchs, A
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			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 05 25 2838

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
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