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(54) TRACK TWIST MONITORING

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(57) **ABSTRACT**

The twist of a railway track (**36**) can be measured with a vehicle which includes a frame (**25**). This frame (**25**) carries a roll sensor (**40**) to measure the rate of roll (w) about a longitudinal axis, and sensors (**38**) to monitor the variations in the relative tilt between the frame (**25**) and the rails (**35**). The signals from these sensors (**38**) and (**40**) enable the changes in cant (Δc) between one instant and the next to be determined, and so the twist of the track can be calculated by summing successive changes in cant. This method of determining twist can operate at substantially any vehicle speed, and gives consistent measurements in real-time.

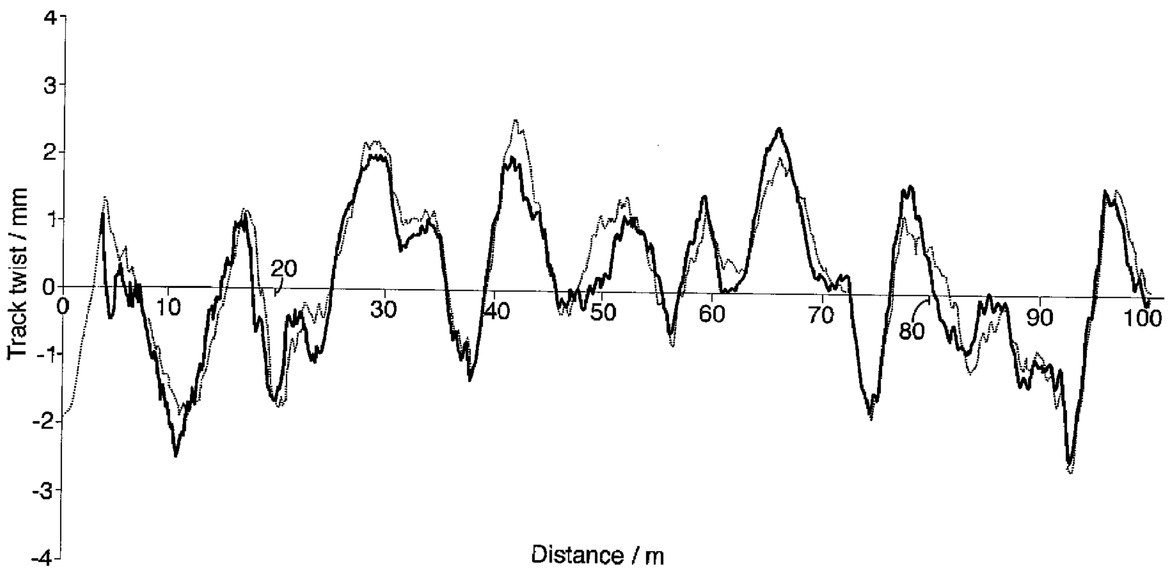


Fig.1.

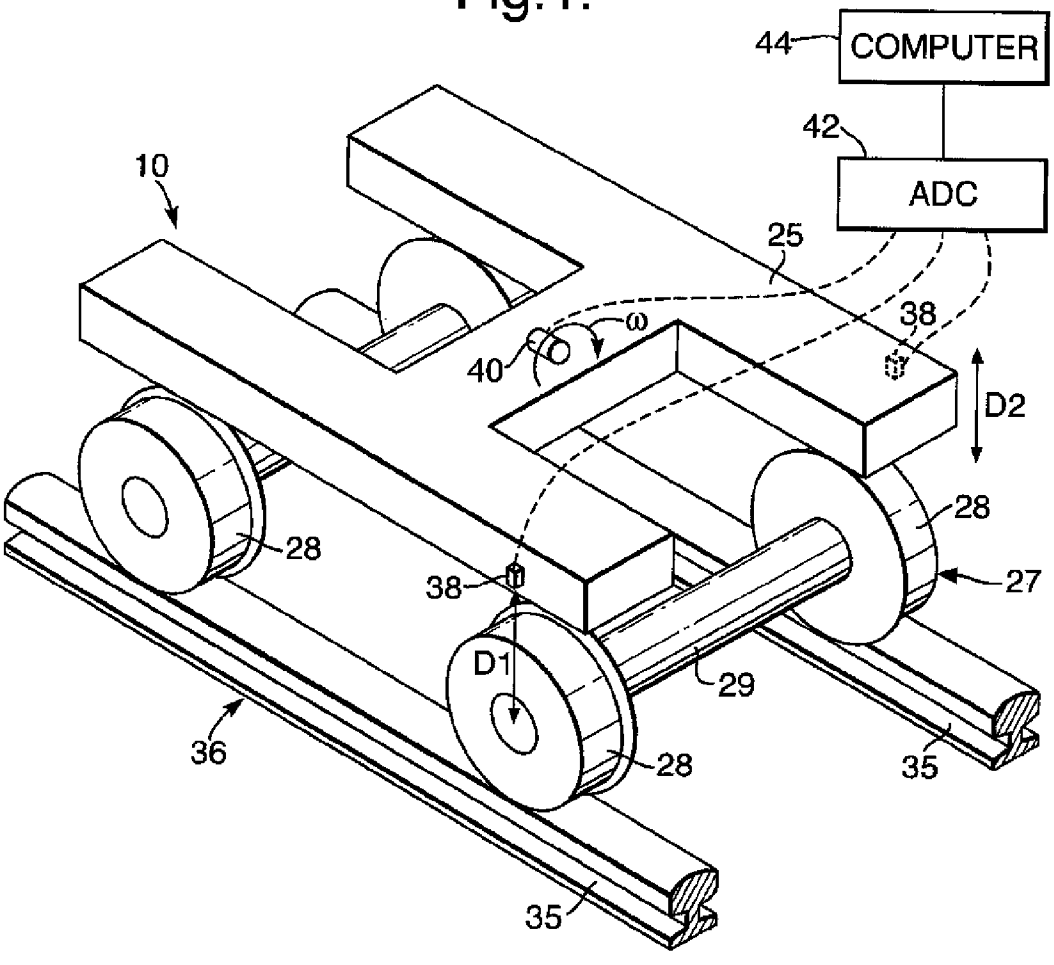
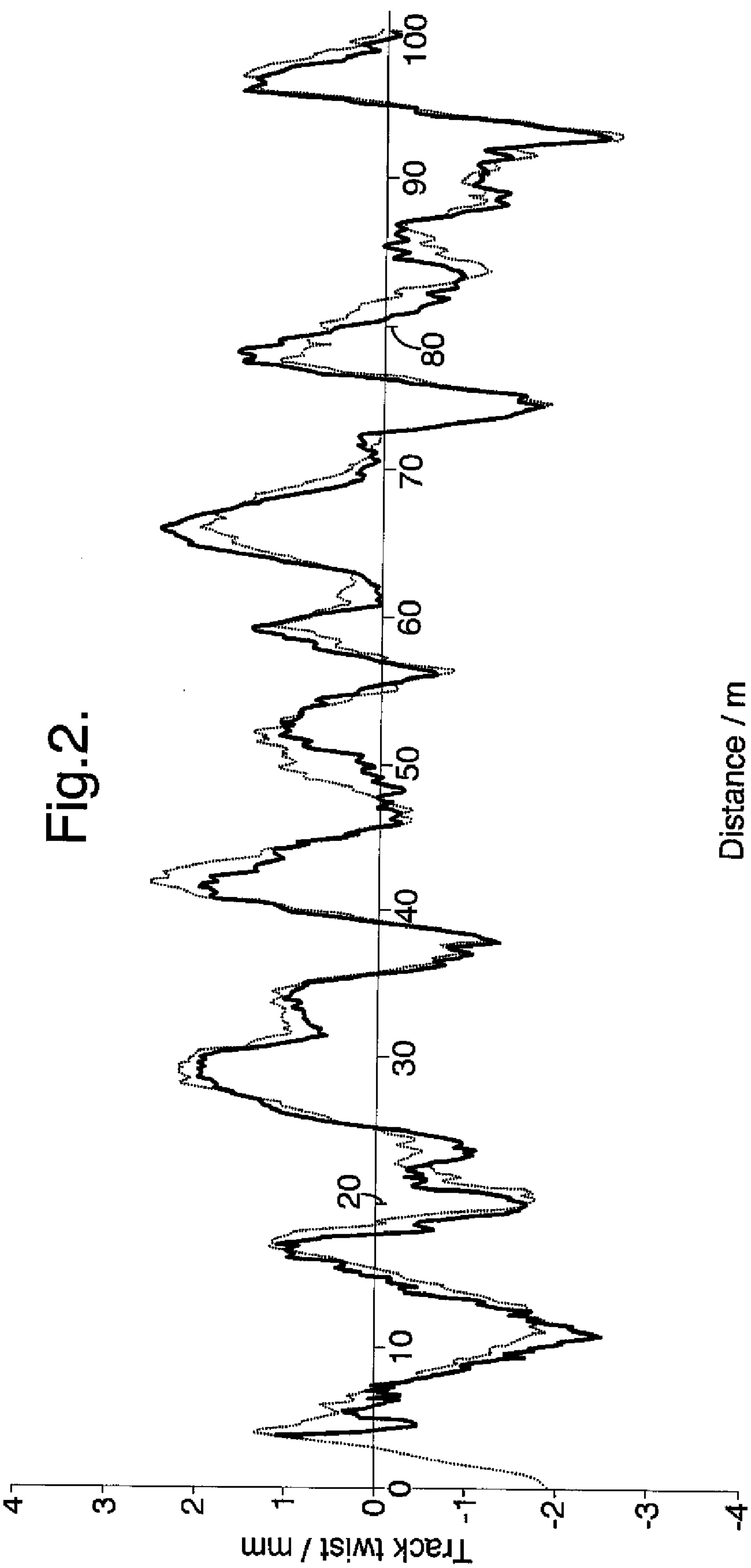


Fig.2.


Track twist / mm
4
3
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90
100
Distance / m

TRACK TWIST MONITORING

[0001] This invention relates to a method and to equipment for monitoring railway tracks, in particular for determining their twist over the full range of wavelengths.

[0002] Track recording vehicles are known, which include instruments for measuring many different attributes of a railway track. One of the frequently measured properties is track cant, which is the tilt of the track at a particular point when compared to the horizontal plane. Track twist is the difference of the track cant between one point of measurement and another point along the track. The distance between the two points is fixed during the measurement and is called the base of the twist. If the base is 3 m then the measured twist is called 3 m twist.

[0003] Track twist can be measured directly using a rigid frame (usually the body of a vehicle) and transducers measuring the distance of the frame above the rails. Track maintainers often use measurements of more than one kind of twist to determine the quality of the track. Instrumentation to provide direct measurements for all these different twists is expensive.

[0004] Inertial track measurement systems can cost-effectively measure track twist of any base from measurement of track cant at successive positions along a track. For example track cant may be measured with sensors most of which are on the body of a track recording vehicle. Typically the instrumentation involves sensing as follows: the lateral acceleration A of the body; the angular speed Gr of roll of the body (i.e. turning about its longitudinal axis); the angular speed Gy of yaw of the body (i.e. turning about a vertical axis). These transducers can measure the tilt of the body. In addition there are sensors for the heights, on each side, to measure the relative tilt between the body and the rails. These heights can be measured directly, using optical transducers; or using electronic transducers in multiple stages, using sensors for the distances on each side between the bogie and the body, and sensors for the distances on each side between the bogie and the axle, assuming that the tilt of the rigid axle is the same as the tilt of the rails. There is also a sensor of the displacement along the track (tachometer) and a system clock. These two instruments are used to regulate the sampling and calculate the vehicle speed. Such instrumentation enables a full bandwidth cant signal to be obtained, made up of short and long wavelengths components, ie high and low frequency components.

[0005] However, this way of determining cant (and hence twist) uses a number of components, whose measurement errors add up during the processing, thus increasing the uncertainty of the measured geometry data. The cant data is assembled from long and short wavelength components. The filtration procedure producing these two components has inherent start-up transients, rendering the beginning of the recorded data unreliable, and this unreliable section can be several hundred metres long, depending on filter design. The processing also involves integration of the high frequency signal from the roll gyroscope. Integration is a sensitive operation as the limited accuracy of any system may render it unstable, especially at low speeds. This is why a method of determining twist would be desirable that:

[0006] 1) used less transducers

[0007] 2) needed no filtration

[0008] 3) avoided the need for integration.

[0009] According to the present invention there is provided equipment for monitoring twist of railway tracks, the equipment comprising a vehicle including a frame, and sensors on the frame comprising a roll sensor to measure the rate of roll about a longitudinal axis, and sensors to monitor the variations in the relative tilt between the frame and the rails, a sensor to monitor distance traveled, means to sample data from the sensors, and means to determine from the sampled data the twist of a railway track.

[0010] The frame may comprise at least part of a vehicle body, or at least part of a bogie of a vehicle. As in the prior art system described above, height sensors may be arranged to measure the variations in height between the frame and axle boxes at each end of a wheelset. Alternatively height sensors may be arranged to measure the variations in height between the frame and the rails, for example by a non-contact optical technique. The difference of the height measurements on the opposite sides can be used to calculate the relative tilt between the frame and the rails.

[0011] The twist determining means requires values of time, and this may be provided by a clock means. Such a clock means may be used to control sampling, or alternatively the sampling may be controlled in response to signals from the sensor monitoring vehicle travel. This may monitor the distance traveled along a track (tachometer), or may monitor vehicle speed from which the distance traveled can be deduced. The clock means may form part of a computer for performing the calculations, or may be a separate component.

[0012] The present invention also provides a method for monitoring twist of railway tracks, the method using a vehicle with a frame, the method comprising measuring the distance traveled by the vehicle, the changes in lateral tilt of the frame between successive positions along the track, subtracting therefrom measured changes in the tilt of the frame relative to the rails, and so deducing the change in cant, and from successive deduced changes in cant determining the twist of the railway track.

[0013] The data may be sampled either at time intervals, or at positions spaced along the track, that is to say the data may be sampled in either the temporal or spatial domain. The intervals between successive samples do not have to be equal, but there are preferably several samples per metre of vehicle travel along the track. More preferably there are at least eight samples per metre. The data may be digitized before being subsequently processed. The measurements from the roll rate sensor, combined with the time interval between one measurement and the next, enable changes in lateral tilt of the frame to be detected; this may be combined with measurements of changes of tilt as determined from the values of height, to determine the change of cant along a length of track, and hence to determine the twist.

[0014] Such measurements avoid the need to filter or integrate signals, and the results are consequently stable, and measurements can be made at substantially any desired speed. It will be appreciated that, unlike the prior art, the present invention provides a way of determining track twist directly using a system of the inertial track recording type, rather than first determining cant; the present invention determines values of changes in cant, rather than determining absolute values of cant.

[0015] Preferably the equipment also includes a position locating instrument arranged to provide position information, and may also include automatic means for transferring data to a base station remotely and at intervals.

[0016] Such equipment can be installed on a bogie of a service vehicle, for example a passenger coach, without causing inconvenience to passengers or staff. Operations may be totally automatic, so no staff are required to monitor it, and are not affected by changes in vehicle speed or by the vehicle stopping. Consequently the equipment enables the track along which that service vehicle travels to be monitored for twist on every journey, so the track twist may be monitored several times a day. Because it is installed in a service vehicle, no additional vehicle operating costs are incurred in performing the monitoring. Alternatively the equipment may be installed in a dedicated track monitoring vehicle, and the data obtained may be stored on board the vehicle.

[0017] 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.

[0018] The invention will now be further and more particularly described, by way of example only, and with reference to the accompanying drawings, in which:

[0019] FIG. **1** shows a diagrammatic perspective view of the bogie of a vehicle incorporating a track twist monitoring system; and

[0020] FIG. **2** shows graphically the results of experimental measurements of track twist using the system of FIG. **1**.

[0021] Referring to FIG. **1**, a track monitoring vehicle **10** includes bogies **24** (only one of which is shown). The bogie **24** includes an H-frame **25** and two wheelsets **27** each comprising two wheels **28** integral with an axle **29**. At each end the axle **29** locates in a bearing in an axle box (not shown), the axle box being connected by springs (not shown) to the frame **25** so that the axle **29** and the axle box can undergo limited movement relative to the frame **25**; these features are conventional. The wheels **28** roll along the rails **35** of a railway track **36**.

[0022] The vehicle **10** also incorporates linear displacement transducers **38** at each side of the bogie **24**, above the ends of one of the wheelsets **27**. Each linear displacement transducer **38** is connected between the frame **25** and the axle box associated with that wheelset **27**, so as to measure any vertical displacement, D**1** or D**2**, of the wheel **28** relative to the frame **25**. Mounted at the middle of the frame **25** is an angular velocity roll sensor **40**, such as a gyro sensor, providing signals representing the angular velocity w. The signals from the two transducers **38** and from the roll sensor **40** are provided via an ADC (analogue-to-digital converter) **42** to a computer **44** on the vehicle **10**, represented diagrammatically.

[0023] The signals from the transducers **38** and from the roll sensor **40** are sampled at frequent intervals. They may, for example, be sampled at regular intervals of say 2.5 msec (if the vehicle is travelling fast), or at regular intervals of say 10 msec if the vehicle **10** is travelling slowly (say no more than 36 km/hr); or alternatively, the signals may be sampled at regular distances along the track, say every 0.1 m. In the following explanation it will be taken that the interval between successive samples is Δt, but it should be appreciated that these successive intervals are not necessarily equal to each other.

[0024] Between one and sample and the next, the angular change of the tilt (θ) of the frame **25** (referred to above as the lateral tilt, and referring to the tilt in an absolute frame of reference), can be calculated from:

$$\Delta\theta = w\Delta t$$

where w is the angular velocity of roll, as deduced from the signals from the sensor **40**. (The value of w used in this equation may be either the value at the start of the interval, or that at the end of the interval, or alternatively might be the average of the values sampled at the beginning and the end of this interval.)

[0025] To determine the changes in cant it is necessary to take into account the fact that the frame **25** may be tilted relative to the track **36**. From the sampled measurements from the sensors **38** at an instant of time the corresponding angle of tilt of the frame **25** relative to the track **36** can be calculated from:

$$\alpha = (D2 - D1)/L$$

where L is the separation between the two rails **35**. Between one data sample and the next this angle of tilt α changes by $\Delta\alpha$, which can be deduced from the successive calculated values of α.

[0026] Hence the change in cant, Δc, of the track **36** between one sample and the next is given by:

$$\Delta c = w\Delta t - \Delta\alpha$$

The twist, Tw, of the track **36** can hence be deduced by adding the successive calculated values of Δc over an appropriate length of track, for example 3m.

$$Tw = \Sigma\Delta c \text{ or } Tw' = L(\Sigma\Delta c)$$

[0027] The number of the samples used for the summation is fixed in case of spatial sampling and variable if temporal sampling is used. The actual result does not depend on the method chosen, provided that the temporal sampling is frequent enough to yield a sample close enough to the end of the base, in our example 3m.

[0028] It will be appreciated that the equations given above assume consistent units for all the parameters, for example SI units, and that the values of change of cant (Δc), and those of twist (Tw), are consequently given in radians. If the value of twist is to be given in mm, it is merely necessary to multiply the twist (Tw) in radians by the track width (L) in mm, as indicated in the equation for Tw' above. Preferably these summations are carried out on a rolling set of data, so that the twist is determined at every sample point (for the previous 3 m of track).

[0029] It has been found that it is sufficient to obtain eight data samples per m of travel along the track **36**. It will be appreciated that the above calculation

[0030] 1) does not involve any data filtration, so the results are available right after the traveled distance of the twist base (3 m in the example), substantially in real-time

[0031] 2) does not involve any data integration, so the result calculated is stable, and the measurements can be taken at substantially any speed of the vehicle **10**,

[0032] 3) is subject only to the resolution of the transducers **38** and **40**, and any limits imposed by the ADC **42**.

[0033] Since the results are available in real time, the invention can be used to control a marking system, such as a paint-spraying device, to mark locations of excessive twist values. The on-site marks help the track maintainers find the locations where twist faults have to be eliminated.

[0034] Referring out to FIG. **2**, experimental measurements of 3 m twist along a 100 m section of track are shown as obtained using the instrumentation described above. One set of measurements are shown in a solid line, and a repeat set of measurements are shown with a broken line. The solid line was measured starting the vehicle and operation of the instrumentation at the start of the section, while the broken line was measured starting the vehicle (and the instrumentation) from an earlier point. No meaningful measurements of twist can be calculated over the first 3 m of operation; however, beyond this distance the solid line immediately matches the broken trace. It will be seen that the values of the twist are substantially consistent, and that along this section of track the twist does not exceed 2.5 mm in magnitude at any point. This is an excellent result from an inertial system optimized to operate at 125 mph. Further optimization for measuring at low speeds can eliminate any significant differences between recordings.

What is claimed:

1. Equipment for monitoring twist of railway tracks, the equipment comprising a vehicle including a frame, and sensors on the frame comprising a roll sensor to measure the rate of roll about a longitudinal axis, and sensors to monitor the variations in relative tilt between the frame and the rails, a sensor to monitor distance traveled, means to sample data from the sensors, and means to determine from the sampled data the twist of a railway track.

2. Equipment as claimed in claim **1** wherein the frame forms at least part of a bogie of the vehicle.

3. Equipment as claimed in claim **1** wherein the frame forms at least part of a body of the vehicle.

4. A method for monitoring twist of railway tracks, the method using a vehicle with a frame, the method comprising measuring the distance traveled by the vehicle, measuring the changes in lateral tilt of the frame between successive positions along the track, subtracting therefrom measured changes in the tilt of the frame relative to the rails, and so deducing the change in cant, and from successive deduced changes in cant determining the twist of the railway track.

5. A method as claimed in claim **4** wherein the measurement data are sampled at sufficiently short intervals that there are several samples per metre of vehicle travel along the track.

6. A method as claimed in claim **5** wherein there are at least eight samples per metre.

7. A method as claimed in claim **4** also comprising marking locations of excessive twist values using a marking device, in real time.

8. A dedicated track monitoring vehicle incorporating equipment for monitoring twist of railway tracks by a method as claimed in claims **4**.

9. (canceled)

10. A method as claimed in claim **5** also comprising marking locations of excessive twist values using a marking device, in real time.

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