The invention provides an apparatus for detecting speed and position of a vehicle, having a detecting means that does not depend on the adhesion state of wheels or road surface state. The invention comprises a rotation sensor, a noncontact velocity sensor such as a Doppler sensor for detecting the velocity of the vehicle without referring to the rotation of the wheel, and an acceleration sensor for detecting the acceleration of the vehicle. The acceleration according to the velocity sensor and difference between the Doppler and velocity sensor readings are compared to detect slipping or sliding of the wheel. Road surface state is detected based on the noise from the output of the doppler sensor. Calculation of the vehicle velocity is switched between different modes depending on the detected conditions.
FIG. 4

VEHICLE VELOCITY COMPONENT

DETECTION LEVEL $\Delta S_d$

DOPPLER SIGNAL SPECTRUM $S_d$

FREQUENCY

$\Delta S_{d^2}$

SIGNAL STRENGTH
FIG. 5
VEHICLE SPEED DETECTION APPARATUS

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to detecting the velocity and position of vehicles moving via wheels.

Description of the related art

In order to control rail vehicles, it is necessary to accurately detect the position of vehicles. A known position detecting method is a method for calculating the vehicle position by detecting the velocity of the vehicle via a rotation sensor attached to the wheel, and integrating the detected values. When using this method, detection errors occur to the detected velocity and position due to influences of slipping or sliding of the wheels. In order to correct such errors, transponders are provided at given positions, and when the vehicle passes a transponder, the calculated value of the vehicle position is corrected to match the position of the transponder. A large number of transponders are provided to sufficiently enhance the position detecting accuracy.

Further, in order to convert the output of the rotation sensor accurately to vehicle speed, the wheel diameter must be strictly controlled.

With respect to the above-mentioned prior art method,
Japanese patent application laid-open publication No. 05-249127 (patent document 1) discloses a method for detecting the vehicle speed/position that is not influenced by the slipping and sliding of wheels, by utilizing a noncontact-type velocity detection means that does not depend on the rotation of the wheels.

Patent document 1 discloses a system for detecting the vehicle speed for example via a Doppler sensor using electric waves. According to this system, velocity is detected by irradiating electric waves to a direction having a depression angle with respect to the traveling direction of the vehicle, and receiving the reflected waves. Therefore, under conditions such as flooded road surface or road surface covered with iron sheets, the strength of the reflected waves returning to the sensor is likely to be reduced, causing the accuracy of velocity detection to be deteriorated.

SUMMARY OF THE INVENTION

In order to detect the vehicle position stably, not only is it necessary to eliminate the effect of slipping and sliding of the wheels, but it is also necessary to use a velocity/position detecting means that does not depend on the road surface state.

The present invention provides a vehicle speed/position detecting means that is not influenced by the slipping and sliding of the wheels or by the road surface state by using, in addition to a noncontact velocity sensor such as a Doppler sensor, a velocity sensor that is not influenced by the road surface state.
The present invention enables stable detection of vehicle velocity and position despite the slipping or sliding of the wheels or the change in road surface state.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an explanatory view showing the method for implementing the vehicle speed/position detection apparatus;

FIG. 2 is an explanatory view showing the state transition of vehicle speed/position calculation;

FIG. 3 is an explanatory view showing the method for detecting the adhesion state;

FIG. 4 is an explanatory view showing the method for detecting the road surface state; and

FIG. 5 is an explanatory view showing the operation according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first preferred embodiment of the present invention is illustrated in FIG. 1. FIG. 1 illustrates a speed and position detection system of a rail vehicle to which the present invention is applied, for calculating the vehicle speed and vehicle position based on the output of a rotation sensor, a Doppler sensor and an acceleration sensor.

The rotation sensor 101 outputs approximately 60 to 100 pulse signals per single rotation. In rotation velocity calculation 102, a rotation velocity $V_r$ corresponding to the
wheel circumferential velocity is calculated using the pulse signals and wheel diameter.

The Doppler sensor 103 irradiates microwaves or millimeter waves in a direction having a depression angle with respect to the direction of travel of the vehicle via an antenna. The reflected waves returning to the sensor are received via the same antenna and detected via a mixer, and Doppler signals having a frequency component proportional to the vehicle speed are output.

In FFT calculation 104, the Doppler signals are subjected to FFT analysis to generate spectrum Sd. In Doppler velocity calculation 105, the peak frequency of Sd is searched, which is converted into Doppler velocity Vd.

The acceleration sensor 106 outputs an acceleration signal in the front-rear direction of the vehicle. In acceleration calculation 107, the noise contents in the acceleration signals are removed via a low-pass filter to produce the acceleration Ag of the vehicle.

In vehicle velocity/position calculation 120, the velocity Vt and the position Pt of the vehicle are calculated based on the rotation velocity Vr, the Doppler velocity Vd, the acceleration Ag and the spectrum Sd. The calculation 120 includes six types of calculation modes, and the modes are switched corresponding to adhesion state of the wheels and the road surface state.

The details of the vehicle position/velocity calculation
will now be described with reference to FIG. 2. The velocity calculation mode is divided into six modes by the adhesion state of the wheels and the road surface state. The adhesion state is divided into three states, which are the following: (1) an "adhesion" state in which no sliding occurs; (2) a "slide increase" state in which sliding occurs and the slide quantity is increasing; and (3) a "slide decrease" state in which the slide quantity is decreased until the wheels are re-adhered. Further, the road surface state is divided into two states, which are the following: (1) a "signal strong" state in which the strength of the reflected waves returning to the Doppler sensor is sufficiently high and velocity detection is possible; and (2) a "signal weak" state in which the strength of the reflected waves is weak and velocity detection is impossible. By the combination of the above states, the velocity calculation mode is divided into six modes, and the modes are switched by detecting the changes in adhesion state and road surface state. The initial state is mode 1.

The method for detecting the adhesion state of the wheels will be described with reference to FIG. 3. FIG. 3 shows the vehicle velocity, the velocity calculated from the outputs of the various sensors, the rate of change of the rotation velocity \( V_r \), and the difference between \( V_r \) and Doppler velocity \( V_d \), when sliding occurs during deceleration of the vehicle.

When sliding occurs, the state of the wheels transits from "adhesion" state to "slide increase" state, then to "slide
decrease" state, and by re-adhesion, the state returns to the "adhesion" state.

We will now describe the detection of the "slide increase" state.

When sliding occurs, the rotation velocity is reduced with a greater rate of change than during normal deceleration. Therefore, as the first condition, sliding is detected by comparing the rate of change of Vr with a given detection level β1. Further, during sliding, Vr is significantly reduced with respect to the vehicle velocity. Thus, as the second condition, sliding is detected by comparing the difference between Vr and Vd with a given detection level Vd1. By combining these detection methods, the transition to the "slide increase" state can be detected. The transition to the "slide decrease" state can be detected via dVr/dt>0.

The return of the state to the "adhesion" state by the re-adhesion of the wheels is detected via dVr/dt<0, or by comparing the difference between Vr and Vd with a given detection level Vd2. The change in adhesion state accompanying the slip can be detected similarly by setting in advance a detection level having a different polarity as during sliding.

The method for detecting the road surface state will be described with reference to FIG. 4. The center frequency component of the Doppler signals is proportional to the vehicle velocity, so the spectrum Sd has a peak in signal strength around the frequency corresponding to the vehicle velocity. Normally,
the vehicle velocity is detected using this peak, but in addition to the velocity components, the spectrum $S_d$ includes noise contents. Therefore, when signal strength is deteriorated due to road surface state, the noise content will have greater signal strength than the velocity component, by which the velocity is erroneously detected. Therefore, the spectrum $S_d$ is compared with a predetermined detection level $\Delta S_d$, and when the spectrum is greater than $\Delta S_d$, it is determined that signal is strong, and when the spectrum is smaller than $\Delta S_d$, it is determined that signal is weak. The detection level $\Delta S_d$ is determined for example by the noise level when the vehicle is stopped.

The above-described detections of the adhesion state and the road surface state are combined to perform state transition between calculation modes. The conditions for the state transition are shown in Table 1.

[TABLE 1]
<table>
<thead>
<tr>
<th>Next Mode</th>
<th>Previous Mode</th>
<th>Transition Condition</th>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>$\frac{dV_r}{dt}&lt;0$ or $V_r-V_d&gt;\Delta V_{d2}$</td>
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<td>$\frac{dV_r}{dt}&lt;\beta_1$ or $V_r-V_d&lt;\Delta V_{d1}$</td>
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<tr>
<td></td>
<td>5</td>
<td>$S_d&gt;\Delta S_d$</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>$\frac{dV_r}{dt}&gt;0$</td>
</tr>
<tr>
<td></td>
<td>6</td>
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<tr>
<td></td>
<td>5</td>
<td>$\frac{dV_r}{dt}&gt;0$</td>
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The velocity calculation in each mode will be described with reference to FIG. 5. FIG. 5 shows the velocity during deceleration using brakes, the rate of change of rotation velocity $V_r$, the difference between $V_r$ and Doppler velocity $V_d$, and the difference between $V_r$ and the acceleration sensor.
velocity $V_g$.

The initial state of the calculation mode is mode 1. In mode 1, the calculation shown in the following expression is performed.

[Expression 1]

$$\begin{align*}
V_{d1}[n] &\leftarrow V_d[n-T_1/T_s] \\
V_{r1}[n] &\leftarrow V_r[n-T_1/T_s] \\
A_{g1}[n] &\leftarrow A_g[n-T_1/T_s] \\
V_g[n] &\leftarrow V_{r1}[n]+A_{g1}[n] \times T_1 \\
V_t[n] &\leftarrow V_r[n]
\end{align*}$$

In the expression, $[n]$ is a suffix showing that the value is of the $n$-th control cycle, and $T_s$ represents the control cycle.

As for the Doppler velocity $V_d$, the rotation velocity $V_r$ and the acceleration $A_g$, the values prior to $T_1[s]$ are stored as state variables $V_{d1}$, $V_{r1}$ and $A_{g1}$. The acceleration sensor velocity $V_g$ is calculated by extrapolation of $A_{g1}$ and $T_1$ using $V_{r1}$ as the initial value. The value of $V_r$ is assigned to the vehicle velocity $V_t$.

At time $t_1$, the sliding is detected, and the mode is transitioned from mode 1 to mode 2. In mode 2, the calculation shown in the following expression is performed.

[Expression 2]

$$\begin{align*}
V_{d1}[n] &\leftarrow V_{d1}[n-1] \\
V_{r1}[n] &\leftarrow V_{r1}[n-1] \\
A_{g1}[n] &\leftarrow A_{g1}[n-1] \\
V_g[n] &\leftarrow V_{r1}[n]+A_{g1}[n] \times (T_1+t)
\end{align*}$$
\[ Vt[n] \leftarrow Vd[n] - Vd1[n] + Vr1[n] \]

The state variables Vd1, Vr1 and Ag1 are stopped from being updated per every control cycle, and the previous value is retained. Vt is calculated by compensating the Doppler velocity Vd via Vd2 and Vr1.

At time t2, slide decrease is detected, and the mode is transited from mode 2 to mode 3. The calculation of mode 3 is the same as mode 2.

At time t3, “signal weak” is detected, and the mode is transited from mode 3 to mode 6. In mode 6, the following calculation is performed.

[Expression 3]

\[ Vd1[n] \leftarrow Vd1[n-1] \]
\[ Vr1[n] \leftarrow Vr1[n-1] \]
\[ Ag1[n] \leftarrow Ag1[n-1] \]
\[ Vg[n] \leftarrow Vr1[n] + Ag1[n] \times (T1 + t) \]
\[ Vt[n] \leftarrow Vg[n] \]

The state variables Vd1, Vr1 and Ag1 retain the previous values, and Vt is set as the acceleration sensor velocity Vg.

At time t4, re-adhesion is detected, and the mode is transited from mode 6 to mode 1.

The velocity arithmetic expressions of all modes are shown in Table 2. The vehicle position Pt is calculated by integrating the vehicle velocity Vt.

(TABLE 2)
What is claimed is:

1. A vehicle speed and position detection apparatus comprising a rotation sensor for detecting a rotation velocity of a wheel for moving or supporting a vehicle, a noncontact velocity sensor for detecting the velocity of the vehicle without referring to the rotation of the wheel, an acceleration sensor for detecting the acceleration of the vehicle, a means for detecting slipping or sliding of the wheel based on the output of the rotation sensor, the noncontact velocity sensor and the acceleration sensor, a means for detecting a road surface state based on the output of the noncontact velocity sensor, and a means for detecting the adhesion state, wherein a calculation mode for calculating the vehicle velocity and vehicle speed is switched based on the means for detecting the road surface state.

2. The vehicle speed and position detection apparatus according to claim 1, characterized in comprising

   a means for comparing a rate of change of velocity calculated from the output of the rotation sensor with a given detection level, and a means for comparing a difference between the velocity calculated from the output of the rotation sensor and the velocity calculated from the output of the noncontact velocity sensor with a given detection level, as said means for detecting the slipping or sliding of the wheel; and

   a means for comparing the output of the noncontact velocity
sensor with a given detection level as said means for detecting the road surface state.

3. The vehicle speed and position detection apparatus according to claim 1, characterized in comprising

a means for comparing a rate of change of velocity calculated from the output of the rotation sensor with a given detection level, and a means for comparing a difference between the velocity calculated from the output of the rotation sensor and the velocity calculated from the output of the noncontact velocity sensor with a given detection level, as said means for detecting the slipping or sliding of the wheel; and

a means for referring to a track data entered in advance as said means for detecting the road surface state.
Application No: GB0820544.5

Examiner: Mr Peter Davies

Claims searched: 1 - 3

Date of search: 30 January 2009

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:<sup>+</sup>:

Worldwide search of patent documents classified in the following areas of the IPC:

B61L: G01C; G01P

The following online and other databases have been used in the preparation of this search report:

EPDOC, WPI

International Classification:

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