Mobile Wind Speed and Wind Direction Measurement System of Train Vehicle

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ABSTRACT

In order to solve the ground fixed wind station can not fully measure the wind field along the railway, mobile wind speed and direction measurement system of train vehicle is required. Which need to be addressed is with the vehicle moves, the result of the measurement system is integrated wind speed, there is a need for measured wind and direction for transformation to get the real result. And the measurement system is installed on the roof of the train, the appropriate measurement method to avoid high-voltage interference is very important. The paper designed a mobile wind speed and direction measurement system by using pore air pressure measure wind speed and direction, realized speed and position measurement through the GPS module, and completed measurement of wind speed and direction data calibration and transmission by microprocessor.

Key words: mobile, wind speed, wind direction, measurement system

1. INTRODUCTION

Wind speed and direction is an important element of weather, navigation and energy fields. Especially in China’s high-speed railway, Xinjiang Railway, Qinghai-Tibet Railway and other large wind-induced railway lines, wind speed and direction is one of the important indicators of traffic command system. For
now, the method to measure wind speed of the coastal railway or Xinjiang Railway is to install wind measuring equipment at fixed point along the railway\cite{1-4}. This method cannot fully measure the wind field along the railway, mobile vehicle measurement equipment has a wide range of needs. The most widely used wind speed and direction sensor is divided into three categories: mechanical, ultrasonic and thermal, and for interference or security considerations, the existing sensors cannot be directly installed on the train for wind speed measuring\cite{5-8}. In this paper, a kind of two-dimensional mobile wind speed and direction measurement system of train vehicle is designed. The wind speed is calculated by the measured air pressure around the equipment. By measuring the speed and position of the train, we can correct the data and get the real wind speed and direction. The system has the characteristics of low power consumption, high precision, high reliability and strong adaptability to the environment.

2. PRINCIPLE AND STRUCTURE DESIGN

2.1 Principle

According to the principle of the flow around the cylinder, the flow pattern of the two-dimensional cylinder at low velocity is only related to the Re number. After $Re > 300$, the "vortex street" gradually lost regularity and periodicity, but before the separation point, the flow near the cylindrical wall is still a laminar boundary layer, the flow after the separation point is laminar flow; the separation point is about 82 degrees. In this paper, the pressure of each point is measured by arranging a plurality of air pressure sensors before the separation point, the pressure of each point is related to the wind speed. Considering the train speed and direction, through the vector operation, the wind speed and direction are finally obtained.

There are two different situations due to different train running direction, that is, one situation is the train runs in the same direction as the environment wind, and the other one is the direction of the train runs in the opposite direction to the environment wind. As shown in Figure 1 and Figure 2.
Figure 1. Train running direction and wind direction is opposite.

Figure 2. Train running direction and wind direction is same.

The relationship between the variables in the figure can be described as:

\[ V_l^* = V_l - V \]  

\[ V^2 = V_c^2 + V_l^2 \]  

\[ V_{e}^2 = V_c^2 + V_l^{*2} \]  

\[ \theta = 180^\circ - \tan^{-1}(V_c/V_l^*) \]  

\[ \theta = \tan^{-1}(V_{e}/V_l^*) \]  

where \( V \) is the sensor measured wind speed, \( V_l \) is the train speed, \( V_c \) is cross wind speed, \( V_l \) is the component of \( V \) in the train running direction, \( V_e \) is the environment wind speed, \( V_e^* \) is the component of \( V_e \) in the train running direction, \( \theta \) is the environment wind direction. When the wind direction is the same as train
running direction, $\theta$ is calculated by Formula 4, otherwise $\theta$ is calculated by Formula 5.

According to Formula 1-5, we can calculate environment wind speed and direction. Also we can calculate cross wind speed, which is important to the research of influence of cross wind on aerodynamic performance of the train. In the same time, the system can record the running speed and position, and it is meaningful to analyze the relationship between the extreme wind point and the windbreak facilities along the railway.

2.2 Structure Design

The system includes an air pressure sensor measurement unit, a GPS measurement unit, and a microcontroller unit. The system uses ATmega 128 as a microcontroller, with small size, powerful and fast and so on. Air pressure sensor using M191D differential pressure digital pressure sensor, the sensor has a high precision, good stability characteristics, and with a temperature compensation function, the range is ± 3Kpa. GPS measurement unit using the existing U-BLOX NEO-6 module, the module also supports GPS navigation and Beidou satellite navigation, and the use of NMEA 0183 standard protocol, including latitude and longitude, ground rate, ground heading and other information. System block diagram shown in Figure 3.

![System block diagram](image)

Figure 3. System block diagram.

As the core unit, ATmega 128 microcontroller is responsible for data acquisition, data processing and data transmission. The system’s workflow is: the microcontroller obtains the train speed and position through the GPS measurement unit, calculates the wind speed and direction according to the data of the air pressure sensors. And then microcontroller corrects the wind speed data and transmits the data to the host computer through the network interface.
3. SYSTEM SOFTWARE DESIGN

Mobile wind speed and direction measurement system must meet the functions of the real-time measurement, processing and display, so based on LabWindows development platform design and development of a measurement system. To make the system simple, software development using structured programming, the system meets the functional requirements of real-time and accuracy. The system includes delay subroutine, communication subroutine, data acquisition subroutine, wind speed calculation subroutine. The system consists of main control module, data acquisition module and data transmission module. The main control module is responsible for coordinating the operation of the whole system. The data acquisition module is responsible for reading the sensor's pressure signal and receiving the GPS signal. The data transmission module realizes the real-time communication between the acquisition system and the host computer. System program flow chart is shown in Figure 4.

![System flow chart](image_url)

Figure 4. System flow chart.
4. EXPERIMENTAL DATA

Figure 5 shows the data in a wind test of Xinjiang Railway, from the curve, it can be clearly seen the wind speed at the train’s location and the maximum wind speed, we can also get the speed and mileage of the train where the maximum wind speed occurs. It provides important information to study the wind speed information along the railway line and improve the windbreak capacity of the windbreak wall along the railway.

5. CONCLUSION

In this paper, the development of the wind speed wind direction measurement system of the vehicle is mainly completed. The measurement system is based on the principle of cylindrical flow. By measuring the air pressure and using the GPS data to realize mobile wind speed and direction measurement, it has the advantages of small error and high stability. The system can also be applied to fixed wind speed monitoring systems. In practice, the accuracy of the measurement system is affected for GPS data cannot be obtained when the train passes through tunnels. In the latter part of the study we can combine GPS and other speed measuring equipment to make up for this defect. At the same time, the system has high stability in high temperature, severe cold and strong wind and
sand environment. Therefore, the system can be widely used in the field of wind speed measurement.

REFERENCES