Environment, Resource and Ecology Journal (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2024.080213
ISSN 2616-3756 Vol. 8 Num. 2

Fault Diagnosis and Analysis of 70 m/s Straight Open Wind Tunnel for Meteorology

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Keywords: Metrological Verification; Straight open wind tunnel for meteorology; Fault diagnosis and analysis; Wind speed sensor

Abstract: The verification quality of the sensor is the primary task of the metrological verification laboratory, and the wind tunnel is a tubular experimental equipment used to measure the difference in the influence of air flow on the wind speed sensor. Taking Jilin Province as an example, this paper studies and analyzes the causes of the faults in the actual operation of the 70m/s straight open wind tunnel for meteorology, and gives the corresponding solutions. Through the practical work experience in the straight open wind tunnel, according to the principle of dealing with related problems, the causes of the faults are analyzed in terms of hardware and software, and the problems existing in the verification process are summarized and compared. The suggestions for the use of 70 m/s straight open wind tunnel in the future are listed in detail, which provides experience for the use of meteorological wind tunnel laboratories in the country.

1. Introduction

At present, the instruments and equipment used to measure wind speed and wind direction include mechanical wind direction and wind speed sensor, impeller anemometer, thermal anemometer, ultrasonic wind speed sensor and laser wind radar. It is necessary to ensure the accuracy and reliability of wind speed measurement instrument data through wind tunnel test.

Straight open wind tunnel is a kind of tubular experimental equipment used to verify and calibrate the accurate operation of wind speed sensor [1-2], which is widely used in aviation, automotive aerodynamics [3], wind engineering and other fields. In the meteorological industry, wind speed sensors are widely used in meteorology, environment, transportation, construction, wind power and other industries. Their detection standards and results are closely related to disaster prevention and mitigation, environmental monitoring, energy utilization, etc. Accurate wind speed control and stability are critical to the reliability of test results. Therefore, in-depth analysis of the operation failure of the straight-path open wind tunnel can not only improve the accuracy of the experiment, but also provide guidance for future technical improvement. Most of the straight open

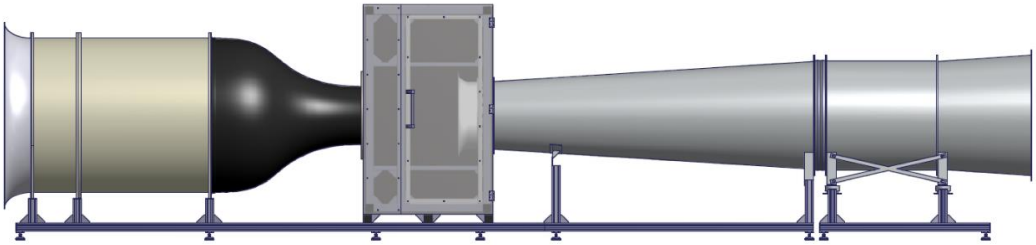
wind tunnels for meteorology adopt modular design, which are mainly composed of lip, stable section, diffusion section, fan, contraction section, standing room, fan diffusion section and so on. They are the most commonly used and most effective large-scale professional equipment for testing wind speed sensors [4-5].

Through the use of meteorological straight open wind tunnel, this paper aims to analyze the common faults and their effects of 70 m/s straight wind tunnel, deeply discuss the causes of the faults and their solutions, and put forward effective solutions. Through systematic analysis, it is expected to provide a scientific basis for the maintenance and operation of the wind tunnel, and improve the stability and experimental efficiency of the wind tunnel. At the same time, the research will discuss the preventive measures of wind tunnel faults and the direction of future improvement.

2. Summary of straight open wind tunnel structure

At present, the mainstream meteorological wind tunnels are mainly divided into two types: loop wind tunnel and straight wind tunnel. The loop wind tunnel covers a large area, and the advantage is that the wind speed flow field is relatively stable, the energy consumption is small, and the noise is small. The straight wind tunnel covers a small area, but it has large energy consumption and noise. The meteorological 70 m/s straight open wind tunnel used in Jilin Province is a low-speed DC open wind tunnel. The model is WZ860070-E, which was completed in 2020 and put into operation in 2021. Its size is :10900×2000×2500 mm, and the maximum wind speed can be measured in the test section is 70m / s. The structure of the wind tunnel meets the design requirements of the low-speed wind tunnel, and can generate stable airflow in the test section to simulate the daily low-altitude wind speed distribution characteristics [6]. The introduction of digitization and automation technology makes the operation and management of straight open wind tunnel more convenient. The combination of computer control system and intelligent algorithm improves the automation level of wind tunnel experiment, reduces the human operation error and improves the experimental efficiency. It belongs to the more advanced meteorological wind tunnel laboratory in China.

The Pitot static pressure tube used in the straight open wind tunnel is a standard Pitot static pressure tube of NPL type. The measurement range is 0.05 m/s~70 m/s, and the accuracy level is second class. Thermometers, hygrometers and barometers. The temperature, humidity and pressure parameters of the outdoor environment are collected, recorded and displayed by the temperature, humidity and pressure recorder. It only needs to start the temperature and humidity pressure recorder, and the serial port is connected to the serial port server. After the software configuration, the temperature and humidity pressure data can be collected. The precise differential pressure meter DPM2500 and pitot hydrostatic tube are used as standard devices to cooperate with each other. By collecting the differential pressure values at different wind speeds, the differential pressure values are shared with the wind speed controller Windbox to control the wind speed of the straight wind tunnel system. As shown in Figure 1, it is a schematic diagram and a real shot of a 70m/s straight open wind tunnel.



(a) Schematic diagram

(b) Real shots

Figure 1: 70 m/s straight open wind tunnel

As shown in Table 1, it is the hardware condition of 70m/s straight open wind tunnel.

Table 1: Hardware conditions of 70m/s straight open wind tunnel

Hardware	Introduction
Device name	70m/s straight open wind tunnel
Model	WZ860070-E
Size	10900×2000×2500 mm
Weight	2600 kg
Power	90 kw
Power supply	380 V/3 phase

The straight-line open-ended wind tunnel draws air into the tubular equipment through the fan to generate a stable airflow. The flow of air is accelerated by the shape design of the stable section and the contraction section, so that the airflow velocity is accelerated and contracted to the chamber. The meteorological equipment to be detected and fixed is placed in the chamber to test their performance in the airflow. The data is collected by the Pitot static pressure tube in the chamber and uploaded to the computer for data analysis. The airflow after the test is discharged through the diffusion section, and the diffusion section is mostly designed as an expansion shape, so as to reduce the air velocity and turbulence, and avoid the interference of the airflow on the test results. As shown in Table 2, it is an overview of each part of the wind tunnel main body.

Table 2: Overview of each part of the wind tunnel main body

Name	Description
Stable section	Equal diameter pipe to keep the air flow uniform and stable
Shrinkage segment	Shrinkage pipe that makes the air flow uniformly accelerate
Experimental section (standing room)	A transparent isolation operating room is set up for the experimental cabin.
Diffusion section	Convert gas kinetic energy into pressure energy
Fan	Produce stable airflow

3. Fault problem analysis

3.1 Fault type classification

The overall temperature of the wind tunnel laboratory is controlled between 15-30 ℃, the relative humidity is controlled below 80%, and the closed environment is maintained during use. The differential pressure is stable within 0.25 Pa, and all test instruments and equipment meet the test requirements.

Structural faults and operational faults are the main problems in the daily use of wind tunnels. As shown in Table 3, the fault phenomena and fault points of each fault type are summarized.

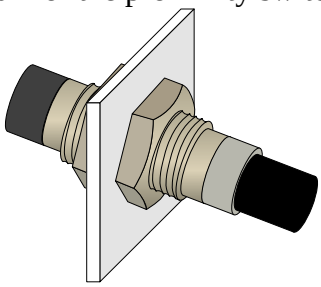
Table 3: Fault type classification

Fault type	Fault phenomenon	Fault point
Structural failure	The deviation of wind speed sensor is obvious	Fan failure Control system failure Measuring instrument failure
	Unstable operation of wind tunnel	Preheating time, stable time is not enough Control system failure Air flow disturbance
	Tmperature anomaly	Changes in ambient temperature Temperature sensor failure
	Conveyor belt cardboard	Proximity switch failure
Operational failure	Indoor air flow is not uniform	There are interfering substances in the room
	Nise anomaly	Fan failure Manipulator door is not closed The sealing of the door is weak.
	The manipulator does not grab the sensor	The software has not been restarted Manipulator power distribution cabinet is not started Manipulator power loss

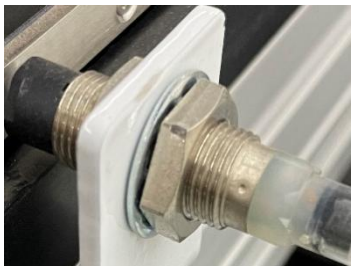
3.2 Fault diagnosis and analysis

The problems of structural faults in wind tunnel system are more complicated. For example, when there is a significant deviation between the sensor value and the standard value, most of the faults occur when the sensor detection accuracy does not reach the standard. If it is determined that there is no problem with the sensor, it is necessary to check the fan or compressor failure, fan impeller wear, deformation, damage caused by airflow instability, at this time the need for detailed inspection of the fan, including impeller, bearing, motor and other parts of the state. The instability of wind tunnel operation is mostly manifested in the insufficient time of preheating the whole wind tunnel system, and a few disturbances occur in the external environment. For example, the placement of high-power fans in the laboratory leads to airflow disturbance, and the failure of control system is also one of the reasons for the instability of wind tunnel operation. The problem of abnormal temperature is usually caused by the failure of the temperature sensor, and the change of temperature environment is not ruled out in the tropical area. Most of the conveyor belt jamming problems are manifested in the deviation of the proximity switch, which is adjusted to an appropriate height, and the conveyor belt tooling moving track can operate normally. The deviation

of the conveyor belt track caused by the long-term placement of the left and right lifts is also one of the important causes of the conveyor belt jam. As shown in Figure 2, it is a schematic diagram and a real shot diagram of the proximity switch.



(a) Schematic diagram



(b) Real shot picture

Figure 2: Proximity switch

Operational failures are mostly caused by lack of human experience. For example, the uneven air flow in the room is mostly disturbed by the external environment, and there are interfering substances in the room; the reasons for the abnormal noise in the wind tunnel are as follows : after the verification of the standard model sensor, the lifting door of the manipulator is not closed, which leads to the instability of the indoor air pressure, and the software internal misjudgment that the standard wind speed of the wind tunnel is not up to the standard, and a few are due to the weak sealing of the door. After the manipulator receives the instruction, the sensor is not grabbed. Most of the faults are that the starting button of the manipulator power distribution cabinet is not opened and the manipulator loses power. In addition, due to the different versions of the software in each province, taking Jilin Province as an example, when the manipulator is needed for automatic verification, the software should be restarted after the instrument is selected for subsequent operation.

3.3 Fault prevention and regular maintenance

After the long-term operation of the straight open wind tunnel, the wear of the fan will lead to the decrease of the output wind speed and affect the accuracy of the metrological verification. According to the experimental data, the actual standard wind speed value decreases by 7% on average after 1000 hours of operation. The uncertainty of the actual standard wind speed value directly affects the measurement of aerodynamic performance. Therefore, in the operation of the wind tunnel, the timely treatment and regular maintenance of the fault are very important.

In addition, it should be noted that during the use of the manipulator, the built-in No.2 battery of the manipulator should be replaced in time, and the positive and negative poles should be paid attention to during the replacement. It is recommended to replace every 2-3 months. The built-in manipulator of WZ860070-E wind tunnel should be charged for the built-in battery, that is, the manipulator power distribution cabinet, the manipulator starting key and the standard should be opened at the same time to prevent the loss of the zero point of the manipulator. When the conveyor belt starts to circulate indefinitely, most of the reasons are: the wind speed sensor is not placed on the tray.

In order to improve the stability and reliability of the straight open wind tunnel, technicians can establish a real-time monitoring system to monitor the key parameters of the wind tunnel operation, such as wind speed stability, pressure change, and equipment operation status. At the same time, acoustic sensors can also be used to detect the acoustic characteristics of wind tunnel operation. Acoustic analysis can effectively identify airflow disorders and equipment failures, such as fan blade damage, airflow leakage, etc. Develop a regular maintenance plan, including the overall

maintenance of the wind tunnel, regular inspection of the standard device, etc., regular inspection of the working status of the fan, valve, sensor, clean air duct and filter, to prevent fouling and foreign matter on the air flow interference.

4. Summary

In this paper, aiming at the failure of 70 m/s straight open wind tunnel in Jilin Province in actual operation, the causes of the failure are introduced in detail, and the maintenance suggestions are given. This will provide guidance for the construction of wind tunnel and the improvement of subsequent related models, ensure that its design can meet a variety of experimental needs, and reduce the probability of failure. At the same time, it also provides work experience for the staff of the new meteorological straight open wind tunnel in the country. Through different fault cases, it accelerates the research process nationwide and improves the efficiency and accuracy of fault handling.

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