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AIRFLOW MEASUREMENT TEST DEVICE FOR AIRFLOW SENSORS

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Abstract: The paper deals with didactic model of test device for testing of airflow sensors and measurement equipment's. The test device contains from source of wind flow with regulator, flow channel with place for the testing of airflow sensors or anemometers. Students can have training with working with sensors and measurements equipment's and also experience with calibration and verification of sensors.

1 Introduction

Nowadays, there are many applications where it is necessary to measure airflow velocity. This measurement is possible to divide into two main groups as:

- Airflow measurements in opened channels.
- Airflow measurements in closed channels.

Area of meteorology uses airflow measurements for weather-forecast. The anemometers are used for the measurement of flow of wind.

Closed channel is represented with tube or pipe and for measurement of airflow is used pitot and Prandtl pipe.

Figure 1 Cup wind anemometer

There are several principles of measurement of airflow. Venturi device is based on principle of reduction of cross-section of flow which causes a pressure differential before and after the cross-section reduction. Airflow measurements is derived from pressure measurement.

Similar principle based on pressure difference uses orifice plate with exactly defined hole diameter and thickness.

Rotameters (Fig. 2) are also famous principle of measurement of airflow. Principle is based on flow of air through the tube with continually increased cross-section where float is lifted with airflow. Float is stabilized in position where gravity force and force from flow are in equilibrium. This position gives information about the airflow velocity.

Ultrasonic principle is principle, where we cannot change anything inside tube. Ultrasonic transducer is attached to outer side of pipe wall and uses two type of principle as Doppler principle and time to flight principle.

Cup wind anemometer is used for airflow measurement on opened space also frequently called as wind speed anemometer. Change of wind speed causes the change of velocity rotation of vertical shaft with horizontal arms with spherical cups (Fig. 1).

Figure 2 Rotameter

Vane anemometer (Fig. 3) is also suitable for wind speed measurement. It uses the propeller on horizontal axis in wind direction.

Figure 3 Vane anemometer

Hot-wire (Fig. 4) anemometer uses the thin wire, which is electrically heated. Airflow causes the decreasing of wire temperature.

Figure 4 Hot wire anemometer

Controller has to compensate it with higher electric current which gives information about airflow velocity measurement. Advantage is that, there is no moving parts [1-5].

2 Testing device for airflow measurement

Model of system consists of big fan BL6800 as source of airflow with tube for stabilization of airflow and Prandtl tube also called as pitot static tube (Fig. 5) used as reference measurement of airflow.

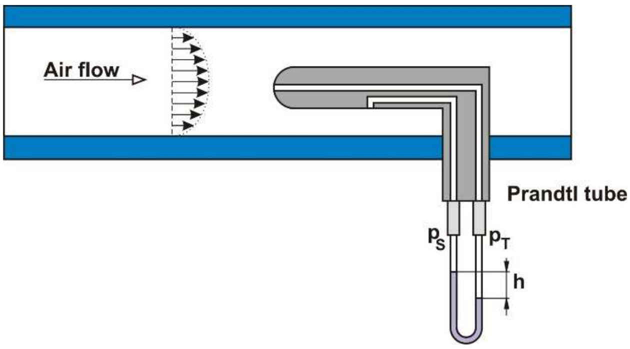

Figure 5 Concept of Prandtl tube measurement

Prandtl tube has one tube hole in flow direction which measures the total pressure composed from static pressure and dynamic pressure. Second input hole – static port is placed on side of Prandtl probe. Both input ports are connected with output terminal on Prandtl tube (Fig. 5). Both terminals are connected to U-tube manometer for measurement of pressure difference. Also, different type of manometer can be used. U-type manometer can be used only in vertical position, because it includes liquid filling.

The velocity of airflow along the cross-section is not constant. The configuration with static pitot tube also allows the measurement of velocity profile of airflow along the cross-section of tube, where we measure airflow velocity. Pitot tube is also used for velocity measurement of aeroplane. In this case pitot tube also includes heater as prevention of frost cover, which can disable the functionality of pitot tube.

Figure 3 Prandtl tube with input and output ports.

Blower MASTER BL 6800 (Fig. 4) has been used as source of airflow. This is an excellent source because it provides air pressure 388Pa and air displacement 3900m^3/h. It has robust and stabile design.

Figure 4 Blower MASTER BL 6800

It has terminal with bayonet lock for connecting of tube. Blower has one constant speed and for our purpose it is connected with speed controller RS 10,0 T (Fig. 5). It is normally used in ventilation and air conditioning systems to control the output of single-phase fans by means of smooth variation of the voltage supplied to the motor. The controller operation is based on changing the output voltage. The controller body is made of non-combustible thermoplastic. The controller is equipped with an ON/OFF button. The power output is modulated from 25 to 100%.

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Figure 5 Speed controller RS 10,0 T

Overall setting up is shown on figure 6. Blower (1) is connected to the conical reduction (2) and stabilization tube (3). Speed controller (4) is connected to the blower (1). Hot wire anemometers (5) and (6) are tested and installed in hole. Also, vane anemometer (7) is installed for testing.

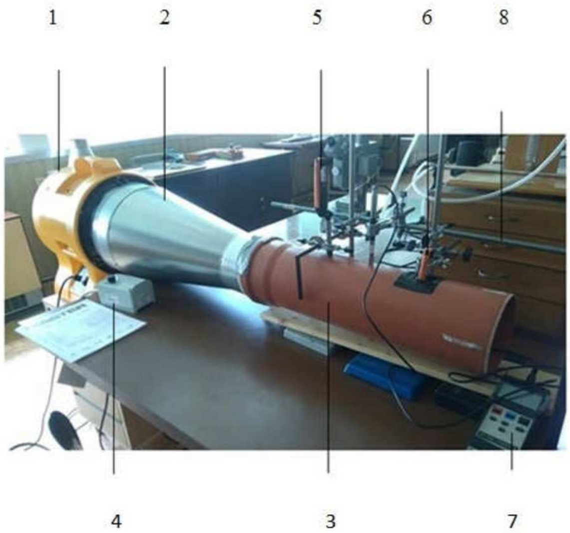

Figure 6 Change of the position of robot chassis

All tested anemometers (Fig. 7) are compared with static pitot tube. Data from all tested anemometers will be compared.

Velocity of airflow measured on pitot tube is defined with equation:

$$w = \sqrt{2 \cdot \frac{p_d}{\rho}} = \sqrt{2 \cdot \frac{q \cdot s}{\rho}} \qquad (1)$$

Where

w – airflow velocity; q – kinetic pressure; ρ – air density; p_d – dynamic pressure p_T – total pressure; s – compress ability (liquids s=1; gasses s≠1).

For kinetic pressure it is possible to derive equation:

$$q = \frac{\rho}{2} \cdot w^2 \qquad (2)$$

Pressure difference can be measured via using the U-tube and for this case it can be derived as:

$$\Delta p = p_T - p_S = h \cdot \rho \cdot g \qquad (3)$$

Where h is height of liquid bar in U-tube and g is gravitational constant.

Figure 6 Vane anemometer and two hot wire anemometers

3 Experimental results

All mentioned anemometers are tested on designed testing device. Ten measurements measured during the constant velocity is shown on figure 7.

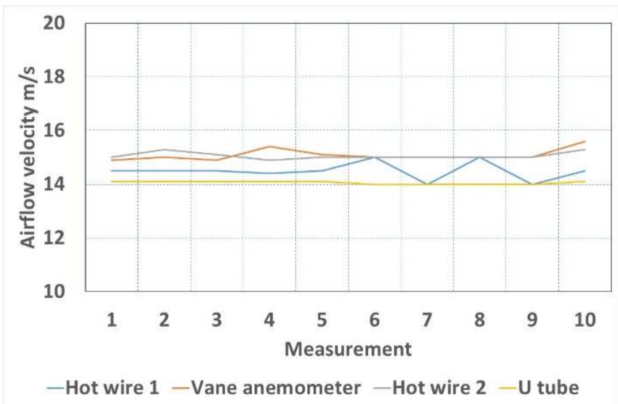

Figure 7 Simulation of locomotion for selection of drive servomechanism for wheels

Measured data are relatively stable and it is close to the reference value. Blower has been adjusted to ten different values and it brought the ten various values of airflow velocity. From this data the averages have been done for comparing the results with reference value. It is shown on figure 8.

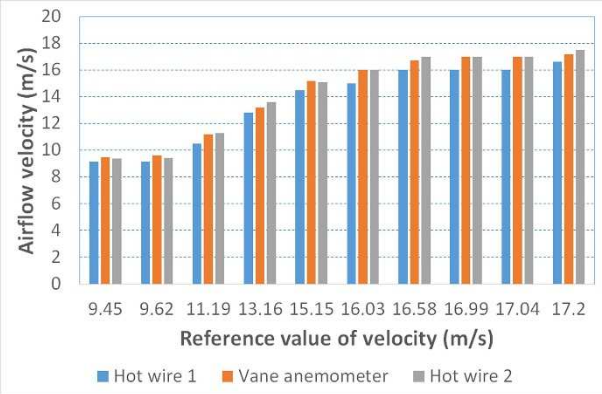

Figure 8 Verification of anemometers value with reference value

After comparing with reference value, measurement error is shown on figure 9. Vane anemometer has the best results from the viewpoint of measurement error.

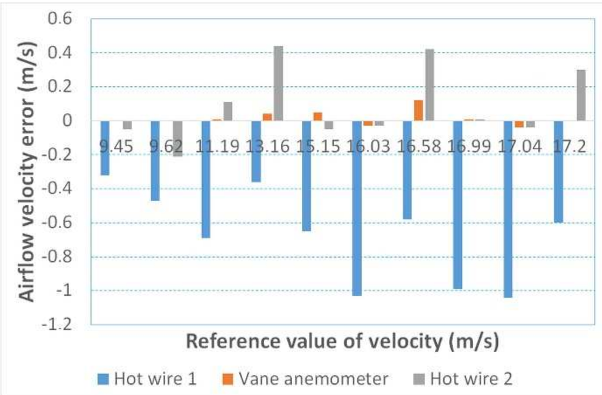

Figure 9 Airflow measurement error

On the base of valid standards [6-9], it is possible to make computation of uncertainty of measurements for comparison of measuring devices (fig. 10).

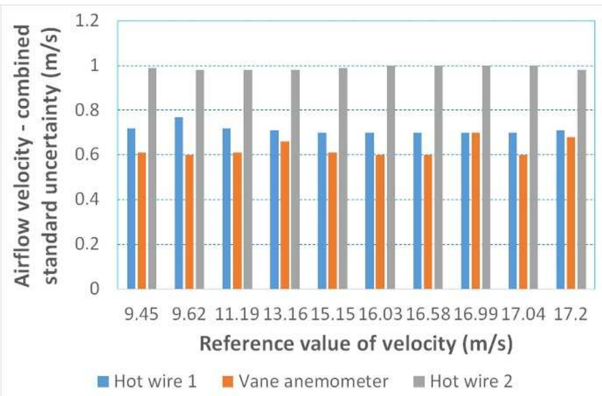

Figure 10 Combined uncertainty of airflow measurements

Vane anemometer also has the best values of combined uncertainty of measurements (fig. 10).

4 Conclusion

The aim of this work was to build the test device and to make a test the available anemometers. The best results have a vane anemometer. On the base of these results, it is possible to declare the uncertainty of measurements and systematic error of measurements.

All measure device should be periodically verified for accessible measurement error and uncertainty fir receive the valid results of measurements [10-26].

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