AGH Journal of Mining and Geoengineering • vol. 36 • No. 3 • 2012

*Yong Mei Li**, *LiaoYuan Chen**

MEASURING FAN SPEED USING THE IMPELLER TIP PRESSURE METHOD

1. Introduction

Fan performance test is to obtain flow, pressure, power and efficiency under the certain fan speeds, as well as studying between their relations. Therefore, the accurate measurement of rotational speed is an important condition for getting fan performance. With the development of information society, fan performance experiments largely use automated testing replace manual testing, but the fan speed use manual measurement. The paper presents a new method that impeller tip measured fan speed that the counterrotating fan speed measurement as an example, when the fan is running, the impeller beat the air, and the air pressure at this time there is a phenomenonof cyclical changes.

2. The theory of the tip pressure measurement speed

When the ventilator is running, rotation of the impeller will air around the cyclical changes [1], thereby causing the internal gas pressure cyclical pulsation. And they exist the relationship of $f = nz/60$ in the pulsation frequency and the number of impeller blades and impeller rotation frequency, in which f means the air pressure pulsation frequency, *Hz*, *n* means the rotation speed of the impeller, r/min, and z means the number of impeller blades. Then for two impeller fan, each level of the impeller speed can be calculated by measuring the number of blades of the impeller and the impeller tip at the gas pressure pulsation frequency. That is, $n_i = 60f_i/z_i$, in which $i = 1, 2$, means first stage impeller and the second stage impeller respectively. Therefore, to be solved is how to measure the pulse frequency of the impeller tip-pressure.

* Anhui University of Science and Technology

3. The signal acquisition and processing of impeller tip-pressure

The experiment is based on the counter-rotating fan, drilling one hole of 2 mm diameter in the fan shell of the first and second stage impeller tip respectively. Collecting air pressure at the impeller tip through pressure sensor, and collected data entered into the computer through data acquisition card, then computing the collected data into air-pressure pulsation frequency according to the formula through self-written program. Finally, it will complete the data processing according to the theory of the tip pressure measurement speed.

The system uses CYB21-type pressure sensor. The sensor uses a high-precision, high stability micro-pressure sensitive chip. Very small differential pressure signal is converted into a reliable industry standard 4–20 mA or 0–10 mA signal output by the strict precision temperature compensation and linear compensation, signal amplification, *V*/*I* conversion, reverse polarity protection, pressure overload-limiting and other signal processing [2], in the system line connection, the red line of the sensor connects the positive power supply, and the black line of the sensor connects the negative terminal of the power. At the same time, sensor cathode connects to the hole of 2 mm diameter in the fan shell, while the negative terminal of the sensor is directly connected to the atmosphere. The system line connection as the Figure 1 follows.

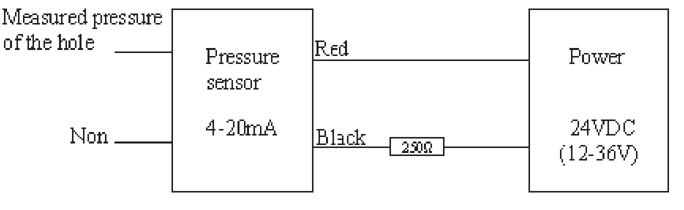

Fig. 1. Pressure sensor signal connection diagram

The system uses the C++ Builder object-oriented visual programming platform [3], It achieved developmentof application program through properties of component, methods, and time as well as event handlers. The acquisition card is used PCI2361 data acquisition card for data sampling. The card’s driver using object-oriented programming, so you want to use some of the features of the equipment, you can use the card itself comes with some function of the device management. First “CreatDevice” function creates a device object handle “hDevice”, so that you have absolute control over the device. Then this handles as a parameter deliver to other functions.

Simple procedures are as follows during the data collection using the system on two impellers blade tip air-pressure of the counter-rotating fan:

```
void __fastcall TForm1::FormCreate(TObject *Sender)
```

```
{
DEVAPI BOOL FAR PASCAL PCI2361_InitDeviceProAD(HANDLE hDevice,
PPCI2000_PARA_AD pPara); collectdatathread = new TCollectDataThread(true);
…}
```

4. Experimental Calibrations and Data Validation Compensation

In the design of this system, the calibration experiments is one of the very important works, must separately calibrate for each channel signal, and then compare the test data in instructions given in order to reduce the error. First of all, we need to do calibration experiments to the data acquisition card, that is, the data collected to validation compensation.

Specifically, different frequency sine wave signal is inputted to the data acquisition card through the signal generator. And then compare the collected data and the signal generator input signal, and found that there are some differences between the measured frequency f_1 and input frequency f_2, this difference is called the compensation coefficient, can be defined as $\xi = f_2/f_1$.Calibrations the measured actual air-frequency signals using the compensation factor in experiment. The formula of Fan speed is amended to $n_i = \xi \times 60f_i/z_i$ ($i = 1, 2$).

In addition, the pressure sensor in need of calibration experiments, this system uses a linear regression method calculated the linear relationship of input and output. A linear regression method produced only a simple linear function $f(x) = ax + b$, but the constant variables a and b are n data points in the constructor (x_i, y_i) ($i = 0, 1, ..., n - 1$) by a linear regression computation method to get. Given n data points (x_i, y_i) ($i = 0,1, ..., n - 1$), looking for a straight line $f(x) = ax + b$ makes this a straight line to the points of difference between the square of the smallest, namely least squares method. Data measured is calculated using a linear regression method by gambit software in practice.

In addition, we know that the fluid in the wind tube is unstable by the fan operating characteristics. Therefore, the program also need to adopt some anti-jamming measures, such as excluding abnormal data, the average processing and compensation coefficient.

5. The Validation of Experimental Results and Error Analysis

The first stage blade number of the counter-rotating fan $Z1 = 11$, the second stage blade number $Z2 = 10$ in our laboratory, through Inverter technology to change the fan speed of two impellers, then the above measurement of the two impeller of the fan speed. In the experiment, first of all, fan of the console will adjust the fan frequency to 20 Hz. At this point, we measure the Department air-pressure value by the impeller tip of the pressure sensor, and then the data collected transmission to the data acquisition card. And the values displayed in the form of waveform through own-written procedures. Finally, real-time data that calculated from the fan impeller speed displayed in the software window. Software windows are as shown in the following figure.

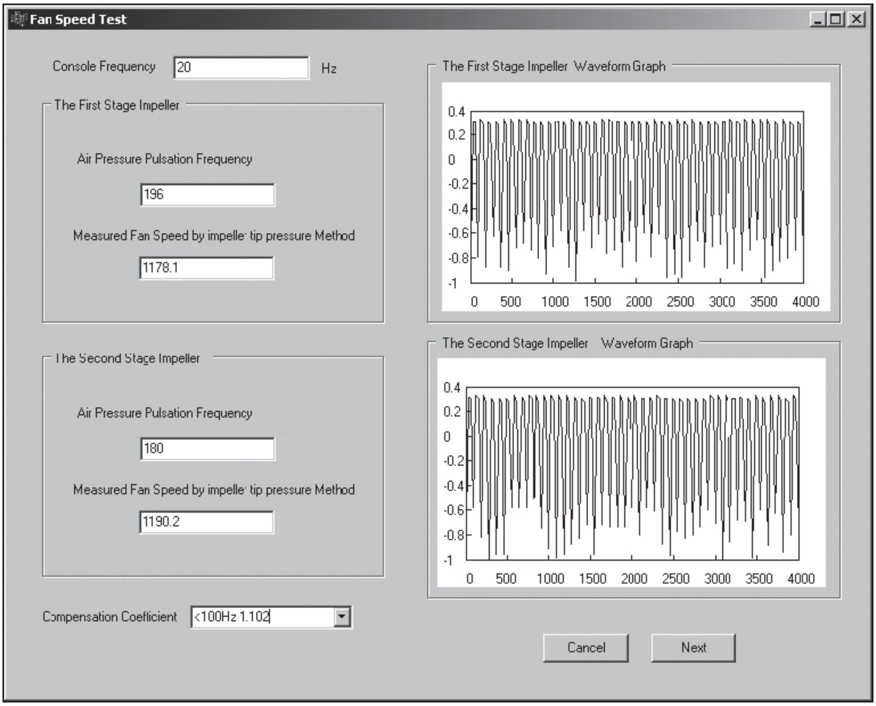

Fig. 2. The dialogue diagram of fan speed test

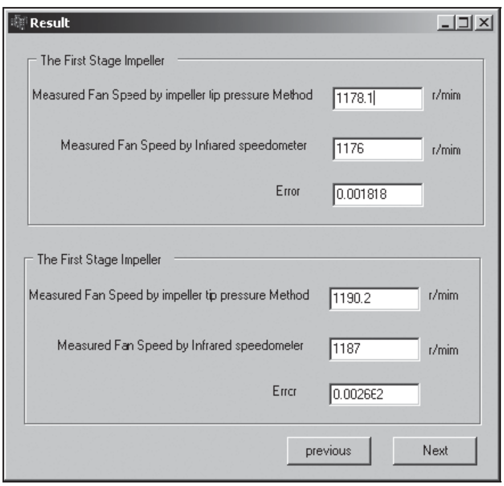

Fig. 3. The dialogue diagram of result

TABLE 1

Experimental result

	Inputting frequency of console, Hz	Air pressure pulsation frequency, Hz	Compensation coefficient	Measured fan speed by impeller tip pressure method, $r \cdot min^{-1}$	Measured fan speed by infrared speedometer, $r \cdot min^{-1}$	Standard error
The first stage impeller	20	196	1.102	1178.1	1176	0.001818
	30	294	1.102	1767.2	1766	0.000684
	40	392	1.102	2356.3	2355	0.000542
	50	492	1.102	2957.4	2950	0.002497

TABLE 2

Experimental result

	Inputting frequency of console, Hz	Air pressure pulsation frequency, Hz	Compensation coefficient	Measured fan speed by impeller tip pressure method, $r \cdot min^{-1}$	Measured fan speed by infrared speedometer, $r \cdot min^{-1}$	Standard error
The first stage impeller	20	180	1.102	1190.2	1187	0.002662
	30	270	1.102	1785.2	1781	0.002381
	40	359	1.102	2373.7	2375	–0.000540
	50	450	1.102	2975.4	2970	0.001818

The experiment measure data of the fan speed to verify by infrared digital tachometer In order to verify the correctness of the method. We obtain fan speed through tip pressure method while each input frequency is changed. At the same time fan speed is measured and recorded by manually infrared digital tachometer. The data obtained as shown in the following figure, and relative error is obtained by the results of both methods.

Curve is drawn through the experimental data as the figure follows. Two speed curves coincide well that Tip-pressure method and infrared digital tachometer measured. And this method has higher accuracy.

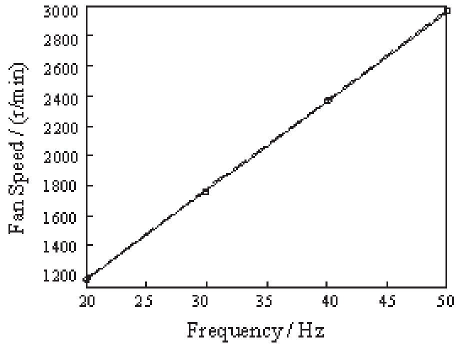

Fig. 4. Comparison of the first impeller acquired by two measuring methods

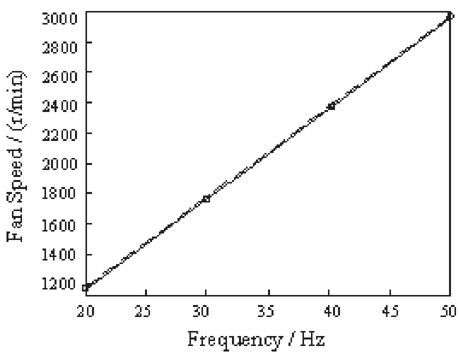

Fig. 5. Comparison of the second impeller acquired by two measuring methods: – – Measured curve by infrared speedometer; —— Measured curve by tip pressure; ▫ Measured value by tip pressure

6. Analysis of experimental results

The experimental data error is 0.26–0.05% that Compared with the data of infrared digital tachometer through the above analysis. There are many factors that can produce the error. First of all, the experiment console < 100 Hz frequency compensation coefficient *took*1.102, but different speed compensation coefficient is not the same. Secondly, the output waveform of the signal may not be an integer in a sampling interval of the sign because signal transduction of the measuring device in the electrical components has nonlinear hysteretic phenomenon. But wave peak is rounded to calculate when the measured frequency is calculated. In addition, because rated speed of the laboratory counter-rotating fan is 2900 r/min, the experiment also has some limitations. Overall, the experiment from the experimental values are the values of the model wind turbine in normal operation can be measured. The experimental values are measured during the fan normal operation, therefore, experimental results are true and reliable.

7. Conclusion

Impeller tip pressure achieves fan speed automatic test by the pressure sensor, data acquisition card, and C++ Builder programming platform, and achieves real-time monitoring of data and waveforms. Verified by experiment we can see, the method of measuring speed is very accurate. Therefore, the experiment method can be generalized to other types of automatic fan speed measurement.

REFERENCES

[1] *Chen Liaoyuan, Ai Zijian, Li Yongmei*: Study on measuring impeller rev of counter-rotating fans by blade tip pressure method. Mining & Processing Equipment, 2011, 39 (3): 12–15 (in Chinese).

[2] *Li Yongmei*: the Study of Testing Platform about Counter-rotating Fan and Fan Performance Analysis. Ms D Thesis. Anhui Province: AnHui University of Science and Technology, 2007 (in Chinese).

[3] *Li Yongmei, Chen Liaoyuan*: Automatic Testing System for Fan Performance. Coal Mine Machinery. 2009, 30 (2): 135–136 (in Chinese).