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Infrared Anemometer Transducer for the Velocity Measurement in a Wind Tunnel

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ABSTRACT
An electronic instrument, developed for the velocity measurement in a wind tunnel is presented in this article. The device is mainly formed for a lead/infrared phototransistor, a propeller and an interface connected to a PC, in order to record the lectures in a file. The velocity measurement is performed inserting the signal in one of the PC parallel port input pins. The software for data acquisition was also developed in order to get graphical output.
This device provides a frequency signal which is introduced into the parallel port of the PC, and with a simple software adjustment, it is possible to get the velocity of the wind. The instrument calibration was performed using a calibrated pitot tube and a barometer, expressing the velocity like a function of the dynamic pressure. The calibrated device has been already employed in some measurements in a wind tunnel, always providing acceptable results. This instrument could be an economic solution of several flow velocity measurement problems.
Keywords: *Anemometer Transducer, Velocity Measurement, Wind Tunnel*

1. INTRODUCTION

In the most recent years, the electronic instrumentation made the data acquisition easier, in all the research fields and industry, generally the instrumentation interacts strongly with a PC which displays graphical results. In our case, we are interested in the air velocity measurement in a wind tunnel, and we pretend to develop a reliable and economic instrument for this purpose.

A wind tunnel is a very important hardware which allows studying and evaluating qualitatively and quantitatively some fluid-dynamic problems, regarding the turbomachinery and drag aerodynamic problems of the bodies in general. For instance, in blade cascades, as shown in Figures 1 and 2, it is possible to get useful information regarding the flow behavior in order to improve the machine performance, to perform the machine design and even to detect some flow instabilities. All above mentioned ideas show the importance of having an instrument which provides a direct velocity measurement in the test region. The instrument is more useful when the lecture is in real time, which is fast and reliable.

In order to perform a good design for the instrument, first of all, a study of the different transducers generally used in this kind of measurements, was undertaken. According to the kind of transducer selected, the software and hardware to process the signal and display the results was developed.

Several transducers were analyzed, but the first of them was a transducer for stress measurement. This transducer can be mounted i.e. on a Wheatstone bridge and its deformation provides a pressure signal proportional to an equivalent voltage due to the tension applied to the transducer.

Other transducer which could be used, in this kind of application, is the hot wire which must be also mounted on a Wheatstone bridge. When the air is circulating, the resistance value of the hot wire transducer changes and the output voltage given by the bridge also does.

The third type of transducer that could be employed is the propeller type which is very common in metrology. In the aim of starting a study of the different possibilities for the air velocity measurement in a wind tunnel, we propose to start with the propeller type transducer combined with a coupled pair led-infrared phototransistor, because it is very simple and economic. The display selected was a PC and all the circuitry was developed in order to provide adequate data for the PC port.

Figure 1. Wind Tunnel

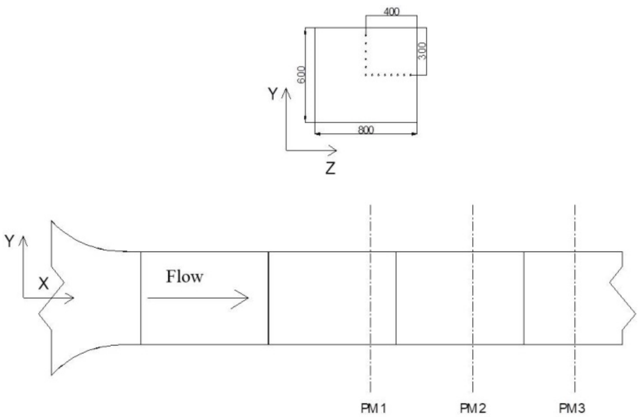

Figure 2. Wind Tunnel with measure section profiles

2. INSTRUMENT DIAGRAM

The instrument blocks diagram is showed in figure 3. The transmitter has an infrared photo-transmitter, whose beam is interrupted by the propeller blades, all these interruptions are detected by the receiver, which sends pulse signals to the computer for its counting in a period of one second, this provides the spinning propeller frequency. In order to make useful this information, a relationship between the required velocity and the frequency measured by the system, must be established.

The sensor

The velocity sensor more commonly reported by the literature, for this kind of measurements, is the hot wire. In our case, the alternative we intend to analyze is a modified propeller type anemometer due to its low cost and simplicity. Unfortunately this device is still an intrusive instrument inducing some measurements errors, which must be taken into account. The full scheme of the sensor is showed in figure 4.

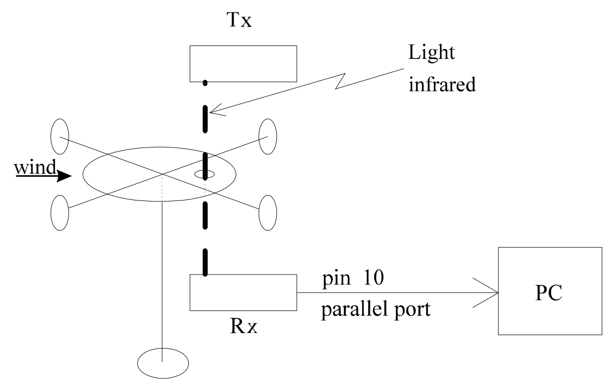

Figure 3. Instrument diagram for the air velocity in a wind tunnel.

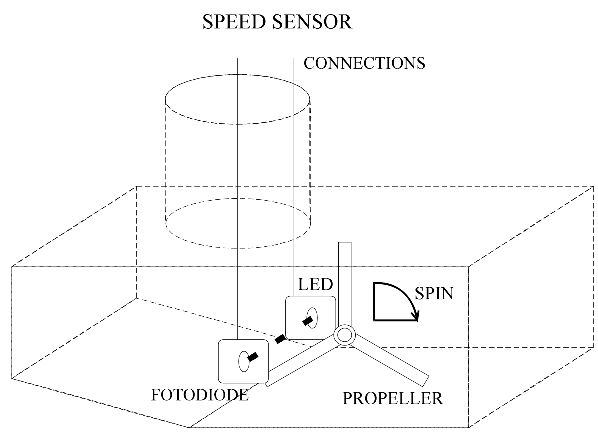

Figure 4. Velocity sensor propeller type.

The small propeller used has four semi spherical blades which turned with a proportional velocity respect to the air. Each time the infrared beam is interrupted by a blade, a pause is obtained between the receiver and the transmitter. The velocity measurement is completed by sensing the frequency of the propeller.

The expression relating the longitudinal advance of the helix in function of the cotangent of the helix angle respect to the axis is given by:

$$l_x = \cot\ (\alpha * \pi) \quad (1)$$

The velocity range which can be measured in the wind tunnel is from 7 m/sec to 70 m/sec (25 km/h to 252 km/h), after some technical reports, with this kind of sensor it is possible to measure velocities from 1 km/h to 150 km/h [1].

The transmitter

An infrared transmitter is used, this kind of element was selected because of its simplicity efficiency and its low cost, when compared with other type of transducers. It presents a good immunity to the characteristic noise produced by the motor of the tunnel so, it is not necessary to use special filters. Additionally, it permits almost a direct coupling with the PC. The transmitter and the receiver are both of small size and weight. The only requirement is that both elements are aligned, so the receiver and the emitter must be disposed one in front of the other. In order to avoid additional loose of information, during the transmission, obstacles must be avoided because they could alter the phenomenon to be measured. The full circuit of the transmitter is shown in figure 5.

The transmitter is formed by an infrared device feed by a 15 V DC source, through a series resistance, which is employed to control the luminosity.

The receiver

The receiver shown in figure 3 is formed by an optotransistor coupled with the infrared led of the transmitter. The transistor detects presence or absence of the light emitted by the led. In order to obtain a squared signal which is in phase, two inverters were employed, the first one provides a squared signal and the second locates the signal in phase. In order the PC port could handle properly the adequate current, two voltage followers were located.

Display of velocity

The required display is obtained with a PC, any input parallel port of the PC is employed. To display the results it was necessary to develop a program in C^{++} language by employing the multi-file compilation technique.
The compilated files were:

- ANEMOMET.CPP
- PUERTO.CPP
- GRPP.CPP
- MOUSE.CPP
- TECLAS.CPP

The ANEMOMET.CPP file is the graphic interface with the user and it is also the main program which controls the other two files.

The PUERTO.CPP file controls the parallel port. This file was designed to count the number of interruptions in a second, so we can plot the frequency.

GRPP.CPP allows the plotting of the frequency according to the expression:

$$V = \frac{2\pi r f}{n} \quad (2)$$

On the other hand, the file MOUSE.CPP activates the mouse in order to handle the software.
TECLAS.CPP interprets the direction of the parallel port of the PC as a hexadecimal number (provided by the user).

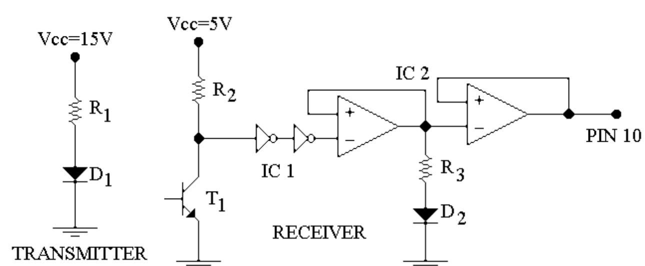

Figure 5. Rx and Tx for the anemometer.

EXPERIMENTAL SET UP DESCRIPTION

Figure 6, shows the experimental set up which consists of a 40 cm bar which is located at the end of the experimental section of the tunnel. On the bar a four blades propeller is mounted, there is an infrared transmission-reception system.
The computer has a program which count the squared pulses (Figure 7) provided by the interface. This counting is undertaken during one second, by considering only the situation when the signal goes

up. The program also has a routine for the arithmetic average of the pulses in order to do an adjustment.

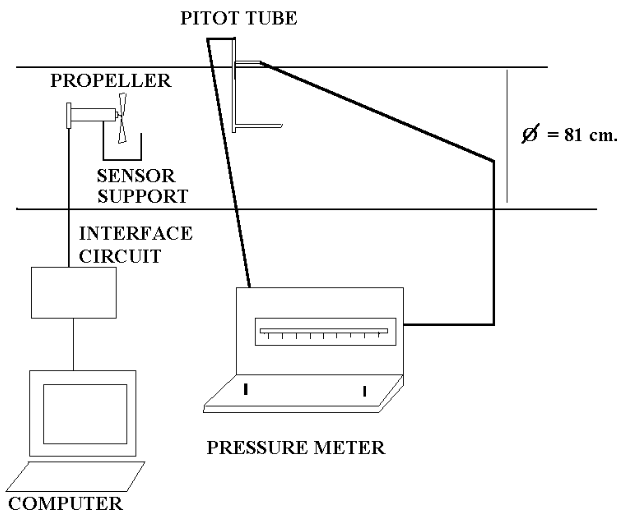

Figure 6. Experimental Set up description

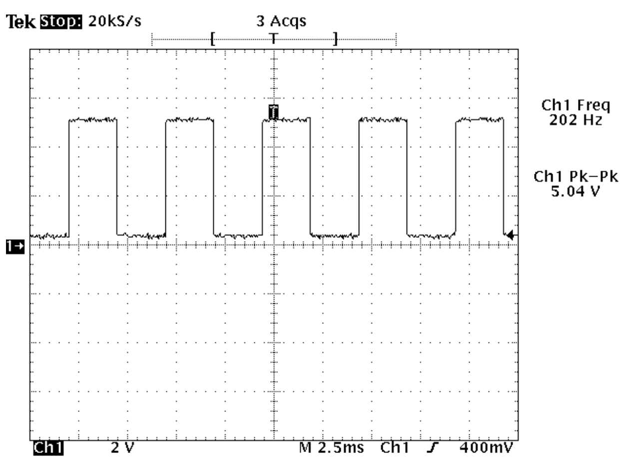

Figure 7. Squared pulses received in the input port of the computer (pin 10 parallel port

RESULTS

In order to evaluate correctly the performance of the system it was necessary to compare it with a measurement pattern, this comparison was conducted in the following way:

A pitot tube was inserted into the wind tunnel in order to determine the dynamic pressure with the help of a barometer.

The velocity is easily obtained from the dynamic pressure by employing the equation:

$$V = \left(\frac{2P_d}{\rho} \right)^{1/2} \tag{3}$$

If the air is considered an ideal gas, it is easy to get its density. On the other hand, the air velocity could be written in function of the dynamic pressure by employing the following expression:

$$V = 1.46\sqrt{P_d} \tag{4}$$

The next step was to operate the wind tunnel, at different velocities, in order to obtain different air velocities in function of the dynamic pressure. Table 1 shows the experimental results. The lectures obtained with the proposed system, were not coincident with the ones we were waiting for, so, we undertook the calibration of the instrument following this procedure: Each measurement of dynamic pressure presented in table 1, is related to a frequency of the propeller, and was registered at the receiver output by means of an oscilloscope, so that the frequency data has a corresponding velocity.

Using the information of table 1, it is possible to obtain a correlation between the mean air velocity and the propeller frequency registered by the receiver. Figure 8 shows a graph of these data, in the vertical axis is plotted the pressure in Pa and in the horizontal the frequency from the output of the receiver.

It is convenient to plot the air velocity versus frequency as shown in figure 9, the response is lineal and we can get a calibration expression for the velocity sensor.

$$V = 0.54\frac{r\pi f}{n} \tag{5}$$

where V is the air velocity in m/sec and f is the frequency of the propeller in Hertz

Table 1. Experimental results from the wind tunnel

Dynamic pressure (N/m^2)	Velocity (m/sec)	Frequency (Hz)
11	4.33	138
15.5	5.48	178
21.5	6.26	208
25.5	6.83	227
33	8.09	277
39	8.77	294
44.5	9.92	312

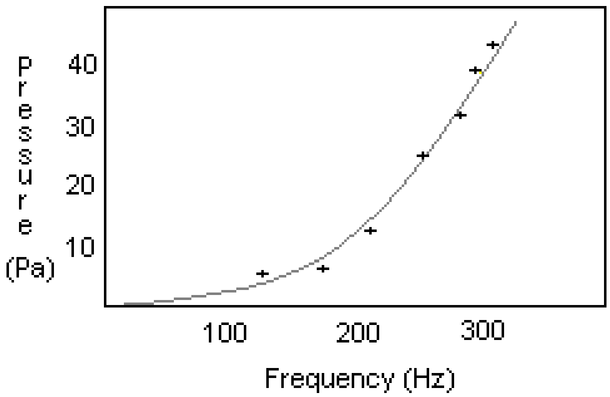

Figure 8. Experimental results from the wind tunnel.

The results provide information for the GRPP.CPP correction. Once the correction was fulfilled it was possible to obtain in a direct form the velocity in the PC screen, and the results were satisfactory.

CONCLUSIONS

In this article a propeller type anemometer has been described. This device provides a lineal response which is good for air velocity measurements in a wind tunnel. The circuitry proposed and the transmitter-infrared receiver was tested giving approximately a 5% of error.

Regarding the data acquisition, some software was developed in order to display the measurements in a direct graphical form. The air velocity is displayed in the PC screen in real time.

The instrument was calibrated in order to obtain an expression which was inserted into the program for the data acquisition.

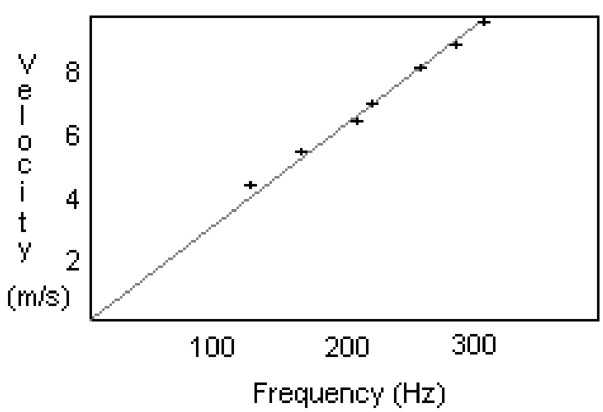

Figure 9. Calibration curve for the transducer.

Finally we conclude that this kind of device is very useful due to its simplicity and low price.

APPENDIX: NOMENCLATURE

P_d = Dynamic Pressure.
ρ = Air density.
V = Velocity (m/s).
I_x = Longitudinal advance of the Helix.
α = Helix angle respect to the axis.
r = Helix radius.
n = Number of helix in the sensor.
f = Frequency.

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