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BLOCKAGE EFFECT OF MECHANICAL ANEMOMETERS

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Abstract:

Investigation of the blockage effects of the mechanical anemometers that are located at the end of the wind tunnel during the calibration process is one of the important research projects in the flow metrology.

The presence of anemometer and its support structure that are placed at the end of the wind tunnel causes a reduction in the cross sectional area of the flow and hence a variation in the velocity distribution. It is evident that the flow rate and so the flow velocities are changed by a factor "k", strongly depending on the frontal area of the anemometer with its support structure and the changing velocities.

In this study, two different sizes of vane anemometers with propeller diameters 20 and 70 mm were used as test anemometers which were located in the center of the tunnel end. The reference static-pitot tube anemometer was placed in the center, 60 cm away from the measuring end of the tunnel. Five different velocities, between 2 m/s and 19 m/s, were used for measurement.

For two different propeller diameter sizes of vane anemometers and their support structures, blockage areas were measured carefully. Then using continuity equation, correlations between reference anemometer velocities and test anemometer velocities were found for two different sizes of anemometers and actual error equations were drawn. Thus, a calibration procedure was prepared.

The measured velocities, using the 70 mm propeller size vane anemometer, were 3 to 9 percent higher than the reference velocities.

In addition, before the test (without blockage) and during the test, variation in the reference anemometer velocities were found constant as 2 percent, except low velocities, for the 70 mm propeller size vane anemometer.

Key words: Anemometer, Calibration, blockage

1. INTRODUCTION

It is always a problem to calibrate mechanical anemometers accurately that are located at the end of wind tunnel. Because of different size of anemometers and their supports and different size of wind tunnel cause different blockage effects[1] and due to that they give different percentage of error. In fact, the ratio of the frontal area of the vane anemometer and its support to the total cross sectional area of the tunnel is the most important geometrical parameter. The velocity distribution in the tunnel is disturbed by the vane anemometer and its support and this leads to error in the flow rate measurements.

One of the easiest method to over come this problem and to get calibration procedure is, to classify anemometers according to their propeller diameter sizes and chose accurate one from each class approve them by the test pitot tube anemometer which can be placed near by them and get velocity relation graph with the reference anemometers, obtain correction coefficients for each type of anemometers and use these coefficients, during the calibration process.

Other method is, to measure blockage area accurately and knowing velocities for reference and test section; both sections flow rate can be obtained by using continuity equation. It is important to know that both sections' flow rate may not be equal each other, because air is a compressible fluid.

2. BRIEF DESCRIPTION OF THE EXPERIMENTAL WORK

As seen from the figure, the wind tunnel system used for this purpose consists of a frequency controlled fan, static pitot tube anemometer and 300 x 300 mm rectangular duct. A perforated orifice type flow straightener is used to have a regular flow profile.

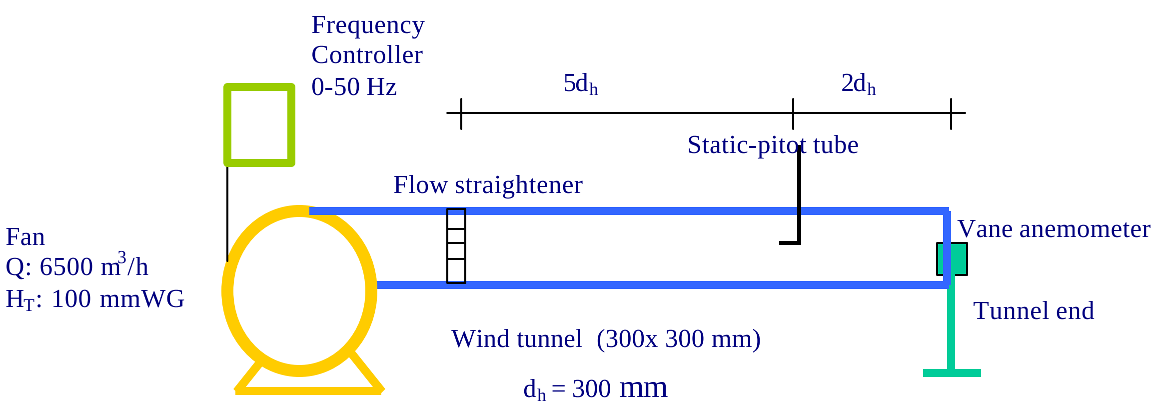


Figure 1. Anemometer calibration system

The reference, static pitot tube anemometer which is traceable to UME national standard of bell prover with a 0.7 percent expanded uncertainty was placed in the center of the duct and 5d away from the upstream and 2d from the tunnel end ("d" is the hydraulic diameter of the duct). And other static pitot tube anemometer and vane anemometer were used together as the test anemometers which were located end of the duct center. The roll of using this second anemometer was to verify the wane anemometers accuracy.

Before the experimental work, velocity map from the end of the duct was obtained by the static pitot tube with a moving attachment on x-y axes[2]. The velocity distribution shows there is no significant velocity change around the duct center at the measuring area of big size anemometer (70-mm diameter). Thus, measuring and comparing maximum velocity location from the reference and the test anemometers were found satisfactorily.

Also from velocity distribution map, C factor which is the ratio of "$(V_R)_{mean} / (V_R)_{max}$" was obtained and variation of this factor by the velocity can be seen on **Table 2.**

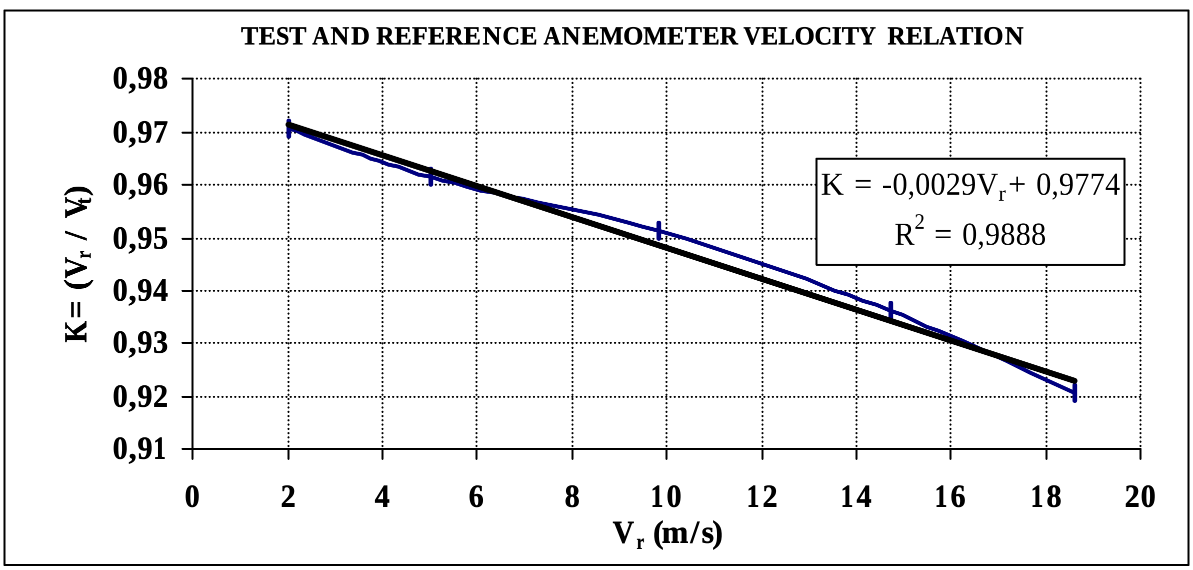
3. MEASUREMENT RESULT

Without and with placing the test anemometers just on front of the tunnel end, reference manometer velocities and test anemometers velocities were recorded by changing the fan frequencies. The Result is in **Table** 1.

Experimental data for propeller diameter 70 mm vane anemometer			**Experimental data for propeller diameter 20 mm vane anemometer**		
V_R **(m/s)** without Blockage	V_r **(m/s)** with Blockage	V_t **(m/s)**	V_R **(m/s)** without Blockage	V_r **(m/s)** with Blockage	V_t **(m/s)**
2,00	2,00	2,10	2,00	1,95	2,00
5,00	5,00	5,20	5,00	5,00	5,00
10,00	9,80	10,30	10,00	9,95	10,00
15,00	14,70	15,70	15,00	14,95	15,10
19,00	18,60	20,20	19,00	18,90	19,10

Table 1. Experimental data for different Anemometers

For the propeller diameter size 70 mm vane anemometer Plotting the ratio of reference velocities (V_r) to test velocities (V_t), the velocity relation can be obtained, as seen on **Graph 1**.



Graph 1. Reference and Test Anemometer velocity relationship for the propeller diameter 70 mm vane anemometer

Taking "K" coefficient from the **Graph 1**, measuring (V_t), corrected velocity can be calculated as;

$$(V_t)_{corrected} = K \times (V_t) \quad \text{.......} (1)$$

Thus the vane anemometers calibration error can be found by the following equation;

$$\text{Actual Error} = ((V_t)_{corrected} - V_r) / V_r \quad \text{.......} (2)$$

where;

V_R : Reference anemometer velocity without Blockage
V_r : Reference anemometer velocity with Blockage
V_t : Test anemometer velocity
$(V_t)_{corrected}$: Corrected Test anemometer velocity
$K = V_r / V_t$

Other method of checking anemometer velocity error is using the continuity equation. In theory, the restriction in the cross sectional area by the blockage of the vane anemometer leads to an increase in the velocity at the tunnel end as the continuity equation states.

The continuity equation for steady state flow through a controlled volume can be expressed as;

$$_{Ar}\int \rho_1 V_1 dA - _{At}\int \rho_2 V_2 dA = 0 \quad \text{.......} (3)$$

Assuming that density of ρ is constant;

$$(V_r)_{mean} \times A_r = (V_t)_{mean} \times A_t \quad \text{.......} (4)$$

or

$$Q_r = (V_r)_{mean} \times A_r \quad \text{and} \quad Q_t = (V_t)_{mean} \times A_t \quad \text{.......} (5)$$

$$C = (V_R)_{mean} / (V_R)_{max} \quad \text{.......} (6)$$

$$(V_r)_{mean} = C \times V_r \quad \text{.......} (7)$$

$$(V_t)_{mean} = C \times V_t \quad \text{.......} (8)$$

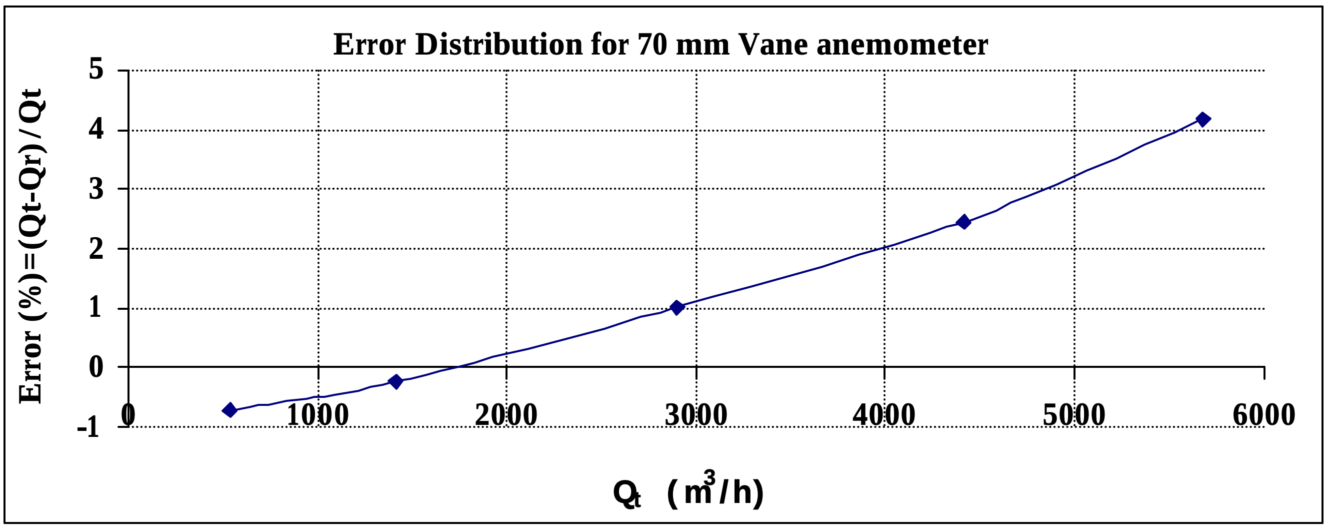
A_r : Wind tunnel cross sectional area
A_t : A_r - Blockage area
Q_t : Test anemometer volumetric flow rate
$K_1 = Q_t / Q_r$

For 70 mm Vane anemometer,
A_r : 0.0885 m^2
A_t : 0.0849 m^2
Blockage area : 0.0036 m^2

Using Equation (5) and taking velocity data from **Table 1, Table 2** is prepared. And the flowrate error distribution for the propeller diameter 70 mm vane anemometer graph (**Graph 2)** is drawn.

Experimental and calculated data for propeller diameter 70 mm Vane anemometer								
C	A_t (m^2)	A_r (m^2)	(V_t) (m/s)	(V_r) (m/s)	(Q_r) m^3/h	(Q_t) m^3/h	$K_1=Q_t/Q_r$ *100	Error=(Q_t-Q_r)/Q_r *100
0,85	0,0849	0,0885	2,1	2,0	542	538	99,3	-0,7
0,89	0,0849	0,0885	5,2	5,0	1418	1415	99,8	-0,2
0,92	0,0849	0,0885	10,3	9,8	2873	2902	101,0	1,0
0,92	0,0849	0,0885	15,7	14,7	4309	4415	102,5	2,5
0,92	0,0849	0,0885	20,2	18,6	5452	5680	104,2	4,2

Table 2. Experimental and calculated data for propeller diameter 70 mm Vane anemometer



Graph 2. Reference and Test Anemometer Volumetric Flow rate Error distribution for the propeller diameter 70 mm vane anemometers.

4. DISCUSSION OF THE RESULTS AND CONCLUSIONS

- It can be seen from the **Table1** that there is no significant velocity change for the propeller diameter 20 mm vane anemometer and the reference meter.

- The blockage effect of "K" factor which is the ratio of reference velocities (V_r) to test velocities (V_t) that was obtained from **Graph 1** depends on the wind tunnel sizes, reference anemometer place and vane anemometer sizes. In our case for the propeller diameter 70 mm vane anemometer K found as;

  $K = - 0.0029\ V_r + 0.9774$ ....(9)

  During the calibration process of the propeller diameter 70-mm vane anemometers, actual error can be found by using equations (9), (1) and (2).

- For the 70 mm propeller size vane anemometer, the measured velocities were found 3 to 9 percent higher than the reference velocities due to increasing velocity.

- For the 70 mm propeller size vane anemometer, before the test (without blockage) and during the test, variation in the reference anemometer velocities were found constant as 2 percent, except for the low velocities,

- Since air is a compressible fluid, the continuity equation could not be verified experimentally as seen from the **Graph.2** error in volumetric flow rate increases up to 5 percent due to increasing velocity.

REFERENCES

[1] E.Ower & R.C.Pankhurst, The Measurement of Air Flow, Pergamon Press, Oxford,1977
[2] BS 1042 Measurements of fluid flow in closed conduits, Part 2: Velocity area methods, 1994

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