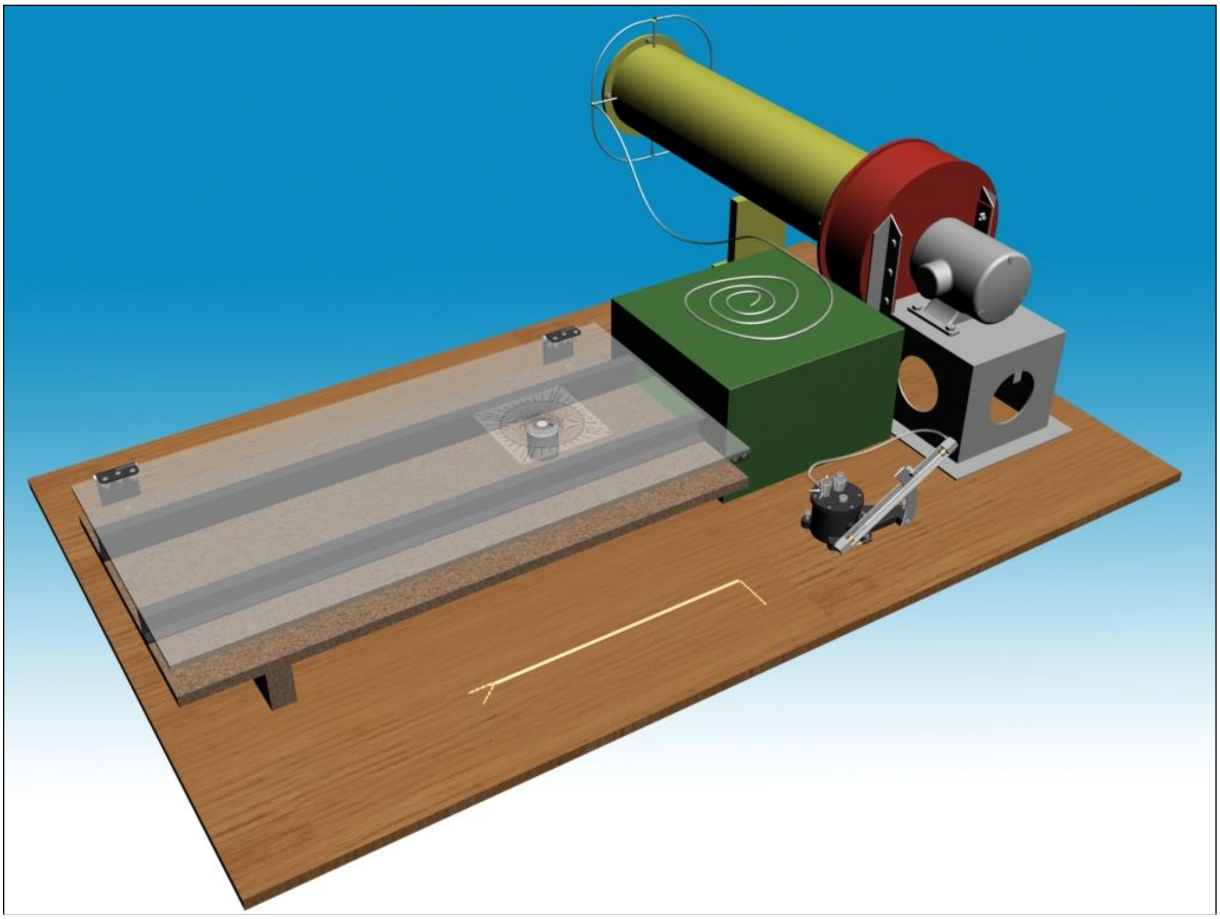


M11
Investigation of Flow Around Bodies

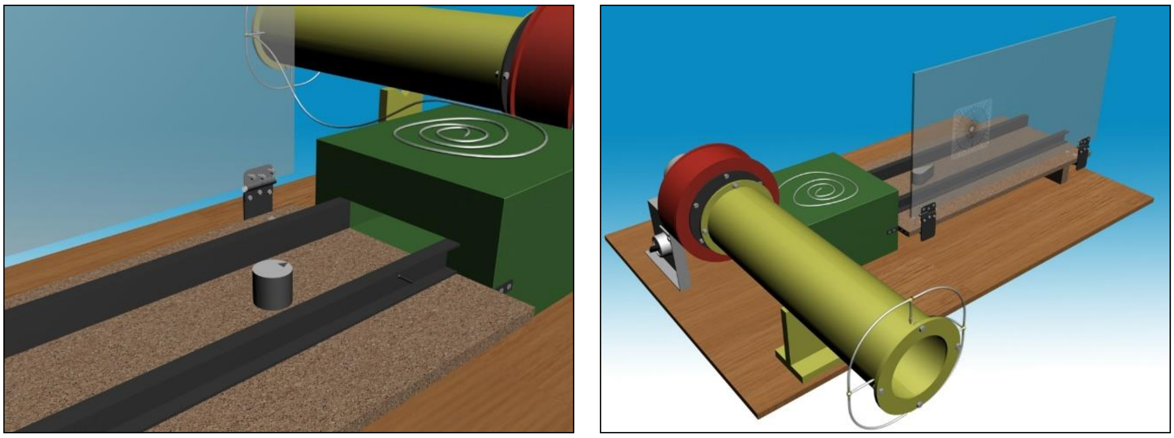
1. PURPOSE OF THE MEASUREMENT, PRACTICAL SIGNIFICANCE

Purpose of the Measurement:

- Investigation of the flow pattern around column-shaped bodies with different cross-sections (square, circular, and airfoil) using flow visualization methods.
- Determination of the pressure distribution around the bodies through measurements.
- Establishing the relationship between the developed flow pattern and the pressure distribution around the bodies.
- Calculation of drag and lift force coefficients based on the measured pressure distribution.
- Comparison of the characteristics of the flow patterns around different shaped bodies.

In practice, there is often a need to understand the flow characteristics around objects placed in a flow. Among these, the most important are the velocity and pressure distributions that develop around the object during the flow, as well as the flow-induced forces acting on the object. Knowledge of these characteristics is crucial, for example, in determining the dynamic performance of vehicles such as road vehicles and aircraft, or in assessing the loads caused by wind forces on the structural design of buildings. A detailed understanding of the flow pattern

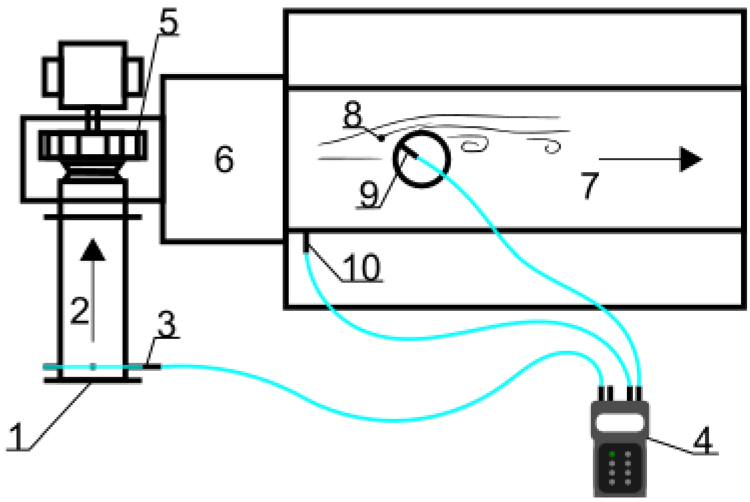
around vehicles is important because its nature is closely related to the amount and distribution of dirt deposited on the vehicle's surface. We can protect against the contamination of a vehicle's exterior by influencing the characteristics of the flow around it. Another interesting phenomenon is that under certain flow conditions, a periodically fluctuating flow pattern can develop around certain objects. A fluctuating pressure field is associated with a time-periodically varying velocity field. If the pressure distribution along the object's surface changes periodically over time, the resultant flow-induced force acting on the object will also change periodically. In such cases, if the unfortunate situation arises where the periodicity of the excitation matches the natural frequency of the mechanical vibrations of the object placed in the flow, resonance will occur. At this point, the amplitude of motion will continue to increase until the power of the forces aiding the motion equals the power consumed in the dissipative processes occurring during the motion. However, this balance can often result in motions with such large amplitudes that it can lead to mechanical damage to the structure. Therefore, for elongated, rounded objects placed in a flow, the investigation of the static characteristics of the flow pattern must always be complemented by the examination of dynamic characteristics.
This measurement task provides an opportunity for fundamental practical understanding of this topic under laboratory conditions.



1. ábra 3D model of the Measuring Equipment

2. DESCRIPTION OF THE MEASURING EQUIPMENT

The measuring equipment suitable for investigating planar flow-type channel flows consists of two main components: a small wind tunnel designed to create a uniform jet velocity profile and the measuring section. The entire measurement setup is composed of the following parts, as shown in Figure 2, in the direction of airflow through it:



2. ábra 2D model of the Measuring Equipment

1. Inlet measuring flange suitable for measuring **volumetric flow rate**.
2. **Suction pipe** for introducing air.
3. **Pressure measurement location**, which consists of small cross-sectional taps located at the front of the suction pipe, directly after the inlet measuring edge. Each tap is connected with a thin rubber tube for pressure measurement, which then connects to a pressure gauge via a pipe connection and additional thin rubber tubing. The pressure measured here allows for the determination of the **volumetric flow rate**.
4. Dual-channel digital **pressure meter**
5. An electric motor-driven **radial fan** is responsible for moving the air.
6. The purpose of the **wind box** is to create a **uniform velocity distribution** in the exiting air jet. In the wind box, air first passes through a filter cloth and then exits through a diffuser. Both the filter cloth and the diffuser serve to smooth the uneven velocity profile coming from the radial fan's pressure connection.
7. The **measuring section**, where the flow around various bodies can be investigated. The nearly uniform velocity distribution air stream exiting the wind box is directed straight into the measuring section. The measuring section is bounded below by a base plate covered with cork (into which flags for flow visualization can be inserted (8)). Above, there is a transparent cover made of plexiglass, through which the flow pattern can be observed using flags that align with the airflow.
8. **Flags** for **flow visualization**.
9. **Pressure measurement locations** that will allow for the determination of the **pressure distribution along the surface of the examined body**.
10. **Pressure taps** for measuring the **static pressure** developed in the channel.

In addition to the basic measuring equipment described above, other supplementary devices such as a barometer, thermometer, and measuring tape will also be necessary for conducting the measurements.

(Note: The base and cover plates of the measuring section are parallel flat surfaces, with the sidewalls positioned perpendicular to these at every cross-section. Thus, in the first approximation, neglecting the effect of the boundary layer, we can consider that the fluid particles do not deviate in the direction perpendicular to the base and cover plates. It can generally be stated that the flow characteristics vary much less in this direction compared to the other two directions lying in the plane of the measuring section. This property makes the measuring section suitable for examining relatively simpler two-dimensional planar flows.)

3. DETAILED DESCRIPTION OF THE MEASUREMENT TASK, BASIC INVESTIGATION AND EVALUATION CRITERIA

The first step in the extensive investigation of the problem outlined in Section 1 is to examine the static characteristics of the flow around bodies with different cross-sections. During the measurement, we will use three different cross-sectional test specimens:

A. square,
B. circle,
C. airfoil

The following investigations should be carried out:

IMPORTANT: THE FLOW MUST NOT BE RESTRICTED AT EITHER THE INLET OR OUTLET CROSS-SECTION DURING THE MEASUREMENTS. THE COVER OF THE MEASURING SECTION MUST BE KEPT CLOSED DURING MEASUREMENTS (except for flow visualization if environmental conditions do not allow for photography).

Before starting the measurement, it is necessary to perform the calibration of the digital pressure gauge, which can be done using a Betz manometer. The calibration can be carried out based on the preparatory information and the provided instructions.

3.1 Investigation of the Flow Pattern Around the Object Placed in the Flow Using a Flow Visualization Method

As a first step, the measuring section must be set up by placing the object under investigation. After this, the observation of the flow pattern can be carried out by inserting pins into the cork-covered base plate, distributed throughout the free-flow area. At the ends of these pins, thin threads made of soft, fluffy material, about 10-15 mm in length, should be attached. Considering the nature of the task, a spacing of 10-15 mm between the pins is considered dense, while a spacing of 100-150 mm is considered sparse. Naturally, in areas where the flow pattern changes significantly over short distances (close to the object under investigation), the flags indicating the direction of the flow should be placed more densely, while in more uniform regions (further from the object), they can be placed more sparsely. The thread should be positioned on the pin so that it is located approximately in the mid-plane of the channel. Once the flow begins, the threads will align with the direction of the flow. If the flags are placed correctly, the positioning of the threads will reveal the flow pattern of the channel flow. For documenting the investigation, it is possible to make a freehand sketch of the observed flow pattern or take a photograph. When preparing the evaluation, special attention should be given to direction changes, separations, and areas where the threads indicate reverse flow or fluctuating velocity. The outlines of any separation bubbles that form should be indicated in the diagram.

3.2 Measurement of the Velocity Profile at the Inlet Cross-Section of the Channel

At the inlet cross-section of the channel, we perform velocity measurements using a specially designed Pitot tube. The Pitot tube used is a copper tube with a measurement hole placed on its surface. The copper tube can be inserted into the measuring section through an opening on the sidewall without raising the cover of the measuring chamber. By positioning the measurement hole facing the flow, it is possible to measure the compression formed in the stagnation point. The static pressure in the channel can be measured through a static pressure tap located on the side of the measuring section. The difference between the two pressures yields the dynamic pressure, from which velocity can be calculated. With the correct connection of the digital manometer, the dynamic pressure can be read directly. The obtained velocity profile and its uniformity are verified by comparing it with the average velocity derived from the flow rate measurement using the inlet flange. The average velocity can be determined according to the measurement requirements related to Pitot tube measurements by measuring at specific points within the cross-section (see point-wise velocity measurement). It is advisable to take measurement points at 20 mm intervals across the measurement cross-section. The results should be presented in tabular form and as a diagram, compared with the average velocity obtained from the inlet flange flow rate measurement and the velocity distribution at the outlet cross-section.

3.3 Measurement of the Velocity Profile Using a Prandtl Tube and Hot-Wire Anemometer at the Outlet Cross-Section of the Channel

At the outlet cross-section of the channel, velocity measurements are performed using a Prandtl tube and a hot-wire anemometer. One outlet of the Prandtl tube measures the total pressure, while the other measures the static pressure; the difference between these gives the dynamic pressure, from which the velocity can be calculated. With the correct connection of the digital manometer, the dynamic pressure can be read directly. In the hot-wire measurement, the velocity values can be read directly. The velocity profile obtained from both measurements, as well as its uniformity, is compared with the average velocity value derived from the inlet flange flow rate measurement for verification. The average velocity can be determined according to the measurement requirements for the Prandtl tube by taking measurements at specific points in the cross-section (see point-wise velocity measurement). During both measurements, the same measurement points should be used, and it is advisable to take these points at 20 mm intervals across the measurement cross-section. The measurement results should be presented in tabular form and as a diagram, compared with the average velocity obtained from the inlet flange flow rate measurement and the velocity distribution at the inlet cross-section.

Note: The "head" of the Prandtl tube should be aligned parallel to the flow. The "tip" of the Prandtl tube should be positioned at the desired measurement cross-section. If the pressure gauge shows negative values, the silicone tubes connected to the pressure gauge should be swapped.

For measurements using the hot-wire anemometer, it is necessary to download the Testo Smart App on a mobile phone. The measured velocity values can be read through the application. It is recommended to install the app before the lab session.)

3.4 Measurement of the Flow Rate

A pressure taps downstream of the intake measuring rim should be connected to one channel of the digital manometer. The other outlet of the channel should remain open to atmospheric pressure. For each inserted object, the pressure difference Δp_{mp} between the atmospheric pressure and the pressure downstream of the measuring rim should be recorded. It is important to verify the constancy of the Δp_{mp} value during the time of pressure measurements on the surface of the object. If the value changes, it should be recorded. The flow rate can be determined using the Δp_{mp} value.

3.5 Determination of the Pressure Distribution along the Surface of the Object Placed in the Flow through Measurement

Alongside the velocity field, another important characteristic of fluid flows is the pressure value prevailing in the flowing medium. Changes in the flow pattern are generally accompanied by corresponding modifications in pressure. In this measurement, it is necessary to determine the pressure distribution along the surface of the examined body and to make observations about its relationship with the established flow pattern. The pressures along the wall of the body can be determined using a digital pressure gauge at the pressure tapping points created on the surface of the body. One connection of the pressure gauge should be linked with a rubber tube to the pressure tapping point where we want to measure the pressure value. The other connection of the manometer is attached to the pressure tapping located on the side of the inlet section of the channel, allowing the pressure gauge to measure the excess pressure or depression value at the specific measurement point relative to the surrounding undisturbed flow's static pressure. In this way, by measuring the pressures individually, we can obtain the complete pressure distribution along the wall. Considering the measuring equipment used for the investigation and the nature of the task, it is advisable to take the measurement points at intervals of 5 degrees for cylindrical bodies. For square prisms and airfoil sections, the distribution of measurement points is limited due to the design of the measuring equipment, as they are spaced at fixed distances. The results of the measurements should be presented in a diagram. With the flow pattern and pressure distribution in hand, it is advisable to compare them and identify and record the relationship between them.

4. EVALUATION

Depending on the calibration results, calculations should be performed using either the measured pressure values or the pressure values corrected with the calibration factor.

4.1 Determination of the static pressure coefficient, the drag force acting on the body placed in the flow, and the drag coefficient

During the evaluation, the measured pressure differences should be represented in a diagram as a function of angle or spatial coordinate. The values of the pressure coefficient (c_p) must be determined based on (1), which should also be illustrated in a diagram similar to the above.

$$c_{p,i} = \frac{p_i}{\frac{\rho_{lev}}{2} \cdot v^2} \tag{1}$$

ahol

$c_{p,i}$	[-]	Pressure coefficient at the i-th measurement point
p_i	[Pa]	pressure difference at the i-th point
ρ_{lev}	[kg/m^3]	density of the flowing medium
v	[m/s]	undisturbed flow velocity

The density of the flowing medium and the undisturbed flow velocity can be determined from the measured data:

$$\rho_{lev} = \frac{p_0}{R \cdot T_0} \tag{2}$$

$$v = \frac{q_v}{A_{sz}} \tag{3}$$

ahol

p_0	[Pa]	atmospheric pressure
R	[J/kgK]	specific gas constant for air
T_0	[K]	temperature
A_{sz}	[m^2]	tunnel flow area
q_v	[m^3/s]	volumetric flow rate

The volume flow rate q_v is measured with an inlet measuring flange connected to the radial fan's suction pipe. We assume that air enters the system only through the inlet measuring flange and exits at the outlet cross-section of the measuring space. The other parts of the device are airtight, so due to the constancy of density, the volume flow rates at any cross-section of the measuring system are the same. From the pressure difference Δp_{mp} measured with the inlet measuring flange, the volume flow rate q_v can be determined using the following relationship:

$$q_v = \alpha \cdot \varepsilon \cdot \frac{d^2 \cdot \pi}{4} \cdot \sqrt{\frac{2 \cdot \Delta p_{mp}}{\rho_{lev}}} \quad (4)$$

ahol

α	[-]	The flow coefficient, which depends on the ratio of the cross-section constriction and the Reynolds number. The value of α can be determined from tables compiled based on experiments. In the case of the inlet measuring flange, for the current measurement, the flow coefficient can be approximately taken as 0.6.
ε	[-]	The expansion coefficient, which can be taken as 1 due to the relatively small pressure changes occurring during the current measurement.
d	[m]	inner diameter of the measurement flange

The presented investigation methods serve for a detailed analysis of the flow phenomena occurring around the body. However, in daily engineering practice, such a detailed description is often unnecessary. Instead, it is often sufficient to know the forces acting on the body, including drag and lift forces, as well as the dimensionless quantities determined in relation to them, namely the drag and lift coefficients.

The force acting on a body placed in the flow can be determined by dividing the fully surrounded surface of the body into partial surfaces corresponding to the individual pressure measurement points, such that the pressure measurement point falls at the centroid of the partial surface. The vector sum of the forces resulting from the pressures acting on the partial surfaces gives the total force acting on the body.:

$$\underline{F} = \sum_{i=1}^{n} \underline{F_i} = \sum_{i=1}^{n} p_i A_i (-\underline{e_n}) = \sum_{i=1}^{n} p_i h_i L (-\underline{e_n}) \quad (5)$$

ahol

$\underline{F}$	[N]	Resultant Force Acting on a Body Placed in the Flow
n	[db]	number of measurement points and sub-surfaces
$\underline{F_i}$	[N]	force acting on the i-th sub-surface
p_i	[Pa]	Pressure Measured at the i-th Partial Surface
A_i	[m^2]	area of the i-th sub-surface
$\underline{e_n}$	[-]	Unit Vector Normal to the Surface
h_i	[m]	width of the sub-surface segment
L	[m]	height of the sub-surface segment

The resultant force $\underline{F}$ can be expressed in terms of its components in the x and y directions using the known trigonometric relationships, as outlined in equations (6) and (7). The individual angles φ_i must be taken according to what was observed in the wind tunnel and as shown in Figure 3, with the stagnation point corresponding to 0°.

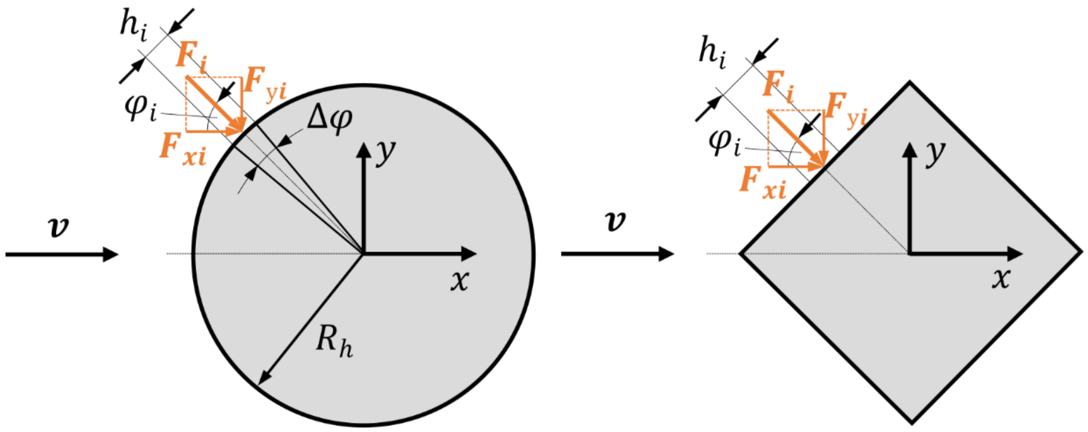
$$F_x = \sum_{i=1}^{n} F_{xi} = \sum_{i=1}^{n} p_i h_i L (\cos \varphi_i) \quad (6)$$

$$F_y = \sum_{i=1}^{n} F_{yi} = \sum_{i=1}^{n} p_i h_i L (\sin \varphi_i) \quad (7)$$

The width h_i of the partial surface can be determined differently for each type of measuring body. For a square cross-section measuring body, it can be calculated simply by dividing the length of a side of the square by the number of measurement points, as the measurement holes are uniformly distributed. In the case of a circular cross-section measuring body, we can approximate the surface of the cylindrical shell with a flat surface in the vicinity of the hole, thus allowing us to calculate it based on the angle of rotation $\Delta\varphi$ and the radius R_h of the cylinder:

$$h_i = 2 \cdot R_h \cdot \sin\left(\frac{\Delta\varphi}{2}\right) \tag{8}$$

For the interpretation of the introduced variables, see Figure 3.



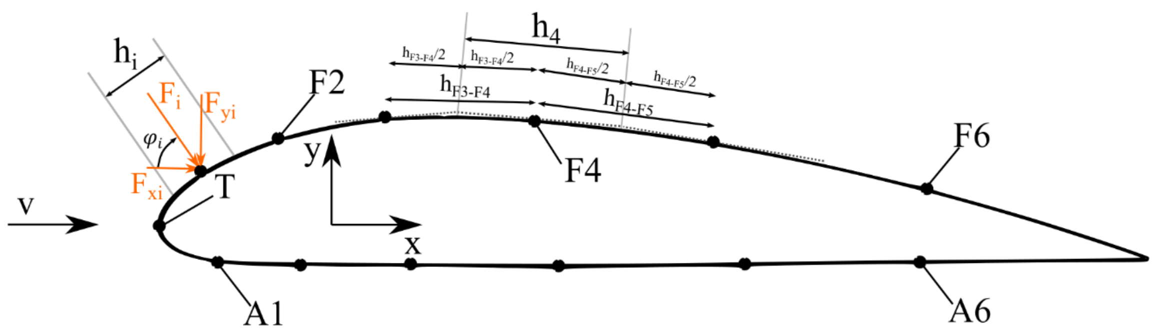
3. ábra Interpretation of the Variables for Circular (Left) and Square (Right) Cross-Section Measuring Bodies

The surface of the airfoil is also approximated with flat surfaces in such a way that the segment between the pressure measurement points is divided in equal proportions among the neighboring pressure points. The last pressure measurement points located on each side are exceptions, as the corresponding flat surfaces extend to the end of the airfoil. The width of the approximate surfaces associated with each pressure point (h_i), the normal to the surface, and the angle (φ_i) formed by the chord of the airfoil are shown in Table 1. The pressure measurement point numbered 1 is located at the leading edge of the airfoil, thus positioned at 0° angle of attack at the stagnation point. For angles of attack other than 0°, the orientation of the surfaces must be corrected. For the interpretation of the individual variables, see Figure 4.

Ssz.	φ_i[°]	h_i[mm]
T	0	9,7
F1	32	10
F2	72	12,75
F3	84,5	17,5
F4	94	22,5

Ssz.	φ_i[°]	h_i[mm]
F5	100,5	27,25
F6	104,5	46,75
A1	81	10,7
A2	89	13,25
A3	90	17,5

Ssz.	φ_i[°]	h_i[mm]
A4	90	22,5
A5	90	24,8
A6	92	44,3



4. ábra Interpretation of the Variables for Airfoil

The F_x component is the force component parallel to the flow, which is referred to as the drag force (F_e) in fluid dynamics. The component perpendicular to the flow, in this case F_y , is known as the lift force (F_f).
Using the drag force, the drag coefficient (c_e) characteristic of the body can be determined based on the relationship in (9).
Using the lift force, the lift coefficient (c_f) characteristic of the body can be determined based on the relationship in (10).

$$c_e = \frac{F_e}{\frac{\rho_{lev}}{2} \cdot v^2 \cdot A_\perp} \quad (9)$$

$$c_f = \frac{F_f}{\frac{\rho_{lev}}{2} \cdot v^2 \cdot A_\perp} \quad (10)$$

ahol

F_e	[N]	drag force
F_f	[N]	lift force
ρ_{lev}	[kg/m^3]	density of the flowing medium
v	[m/s]	undisturbed flow velocity
$A_\perp$	[m^2]	the projected area of the body perpendicular to the flow

Note: Table 2 contains informative data on the drag coefficients of several bodies as a function of the blowing direction. It is possible that the value of the drag coefficient in the examined case is higher than the value found in the literature. This is because the blowing velocity somewhat differs from the undisturbed flow velocity calculated in equation (3), as the flow cross-section of the air around the body decreases in relation to the wind tunnel's cross-section A_S due to the magnitude of the projection of the body in the direction perpendicular to the flow, $A_\perp$. Thus, due to the continuity equation, the flow velocity increases. The increase in blowing velocity depends on several factors, such as the shape of the examined body. However, correcting for these factors exceeds the scope of this measurement.

5. DOKUMENTÁCIÓ

5.1 Entry exam

During the first measurement session, known as the preparatory measurement, the students must complete a quiz to demonstrate that they have read the measurement description. The quiz can be completed with knowledge of the measuring equipment, the measured quantities and their measurement methods, as well as the calculated quantities derived from the measured quantities.

5.2 Measurement plan

Upon successful completion of the quiz, students must prepare for the measurement by creating a handwritten measurement plan and then conduct a preparatory measurement.
The measurement plan must include the following:

- Title, location, and date of the measurement
- List of participants in the measurement
- Name of the supervising instructor, with a prepared signature on each page
- Objective of the measurement, briefly stated in their own words
- Description of the measurement task
- Tabulated listing of the necessary equipment and its specifications (name, serial number, measuring range, uncertainty, etc.), allowing for the inclusion of additional equipment
- Planned calculations and explanations of the quantities in the formulas
- Listing of the quantities to be measured
- Steps of the measurement process

- Creation of a table for the measured quantities (for all measurement tasks), allowing for expansion and comments, separately for once-measured quantities (e.g., environmental values, geometry of the measuring field, etc.) and multiple-measured quantities (e.g., pressures)
- Conducting a test measurement or preparatory measurement according to the measurement task
- Graphical representation of a characteristic measured quantity in accordance with the measurement task's instructions, which will be used to evaluate the measurement setup and method
- Instructor's signature on each page

Following the appropriate preparatory measurement, an Excel spreadsheet (or program code) used for calculations must be prepared before the next measurement session, and a verification code must be obtained using the measured and calculated results. The next measurement session can only begin if the measurement group possesses a valid verification code.

5.3 Report

A measurement report must be prepared on the conducted investigations, which includes the results of both the preparatory and the second measurement sessions.
The report can be created by digitizing the measurement plan and then supplementing it with calculations and the presentation of results and visualizations.
The cover page of the report should follow the departmental template, containing the title, location, and date of the measurement, as well as a list of the measuring personnel and the name of the supervising instructor. Following this, the report should include the objective of the measurement, a brief description of the measurement task, and an explanation of the measuring equipment (with a diagram) and the tools used. The description should be concise, and it is important that the authors express it in their own words. (Copying text from the measurement manual or other sources is not allowed!)
After describing the measuring equipment and the measurement task, the measured data must be presented, along with the method of calculation and the calculated quantities. It is also essential to provide information about the calibration of the digital manometer and the calibration factor used or neglected. The obtained results need to be evaluated. The evaluation should describe the following:

- Based on the relevant literature or our personal knowledge, what results were we expecting?
- How closely were we able to approach the expected results?
- If the expected and obtained results differ, what could be the reason for this?

At the end of the document, the handwritten measurement plan signed by the supervising instructor during the preparatory measurement, as well as the diagram of the quantities measured during the session, must be attached.
When preparing the report, attention must be paid not only to the content but also to the formal appearance. A good score can only be awarded to a well-presented, aesthetically pleasing report! The formal requirements can be found in the instructions given during the laboratory preparation classes, as well as in the MINTA_Meresi_jegyzokonyv.doc file available in source [2].

5.4 Presentation of Results

- In every case, the flow pattern formed around the bodies must be recorded, presented with streamlines, supplemented with drawings and explanations.
- The measured pressure distributions and the calculated pressure coefficients must be plotted in a diagram.

5.5 Error calculation

A calculation of error for the drag and lift coefficients must be performed, which can be done as follows:

I) The equations for the drag coefficient (9) and lift force (10) must be substituted with the relevant relationships. At the end of the substitution, the measured quantities—those that introduce uncertainty into the result—should appear directly. It may happen that, after simplifications, some measured quantities do not appear in the equation.

II) The derivatives $\partial c_e/\partial X_i$ and $\partial c_f/\partial X_i$must be determined. The equation obtained in point I) should be differentiated with respect to each measured quantity X_i. The individual p_i pressures must be considered separately, as each measurement introduces additional uncertainty into the result.
The measured quantities X_i and their associated measurement errors are:
$X_1 = p_0$ $\delta p_0 = 100\ Pa$
$X_2 = T_0$ $\delta T_0 = 1\ K$
$X_3 = p_i$ $\delta p_i = 2\ Pa$
$X_4 = \Delta p_{mp}$ $\delta \Delta p_{mp} = 2\ Pa$

III) Based on the derivatives and the given measurement errors, the absolute (11 - 12) and relative errors (13-14) must be calculated:

$$\delta c_e = \sqrt{\sum_{i=1}^{n}\left(\delta X_i \frac{\partial c_e}{\partial X_i}\right)^2} \tag{11}$$

$$\delta c_f = \sqrt{\sum_{i=1}^{n}\left(\delta X_i \frac{\partial c_f}{\partial X_i}\right)^2} \tag{12}$$

$$\frac{\partial c_e}{c_e} \tag{13}$$

$$\frac{\partial c_f}{c_f} \tag{14}$$

6. DURING THE MEASUREMENT, DO NOT FORGET

- Before turning on the measuring device and generally during its operation, always ensure that accident-free working conditions are met. Workers in the vicinity of the equipment should be warned of any changes made during the startup and measurement process.
- Record the atmospheric pressure and room temperature at every measurement session!
- Note the units of measurement for the values read from the measuring instruments, as well as any other related factors.
- Record the type of measuring instruments, their manufacturing numbers, and the density of the measuring fluid used!
- Ensure the units of measurement for the quantities read from the instruments match those used in subsequent calculations.
- Be aware of the calibration of the digital pressure gauge!
- When connecting the pressure gauge, handle the connectors for the "+" and "-" branches carefully and select the measurement range with caution. Ensure that the rubber hose is carefully placed on the pressure gauge connectors.
- During the assembly of the examined channel in the measurement area, take care with the airtight assembly, as any gaps that form can allow air to escape or enter, significantly altering the originally intended flow characteristics.
- It is advisable to check the rubber or silicone tubes for pressure transmission before and possibly during the measurement to ensure there are no cracks or breaks. A punctured measuring tube could invalidate all previous measurements. Critical points include the connections to the instruments and pressure outlets.
- Before submitting the report, it is strongly recommended to seek consultations.

7. REFERENCES

[1] Lajos Tamás: Az áramlástan alapjai, Műegyetemi Kiadó, Budapest 2004
[2] https://simba.ara.bme.hu/oktatas/tantargy/NEPTUN/BSc_LABOR/MAGYAR/

2. táblázat Ellenállás tényezők $Re=10^3 \div 10^5$ Reynolds-szám tartományban

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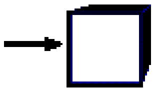
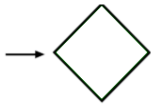
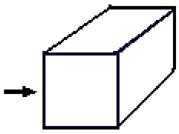
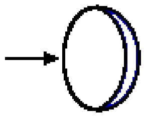
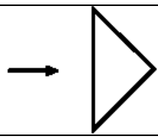
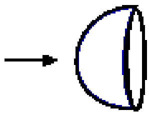
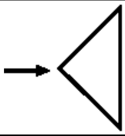
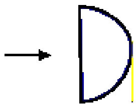
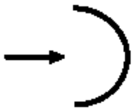
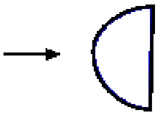
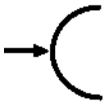
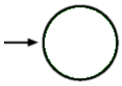
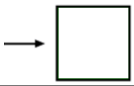
	1.05		1.55
	2.05		2.01
	1.42		2
	0.38		1.55
	1.17		2.3
	0.42		1.2
	0.04		1.17
			2.05