The theoretical background needed for the laboratory measurements of the Flow Measurements

(The chapters from the Az áramlástan alapjai textbook pertaining to the measurements conducted in the laboratory for the subject Flow Measurements)

Information for those who are conducting their measurements in the large recirculating wind tunnel or the NPL wind tunnel, and for those who are investigating the flow around a cylinder:

In the 3rd or 4th edition of the Az áramlástan alapjai textbook (These topics can be found in many other textbooks and sources as well): 2.1.1. Pathline, streamline, streakline, 2.1.3. Flow visualization, 3.3.3. Static, dynamic and total pressure, 3.4.1. The Euler equations given in the streamline coordinate system, 3.4.2. Applications, 6.2.4. Measurement equipment which measures with the help of elastic or deformable bodies, 6.2.5. Problems arising during pressure measurements, 6.3.1. Velocity measurements based on dynamic pressure measurements, 8.5.2. Requirements for having similarity between flows, 9.1.1. Characteristics of the boundary layer, 9.2.2. The development of the boundary layer in the streamwise direction, 9.3.1. Shear stress arising in the boundary layer, 9.3.2. Boundary layer separation, 9.3.3. Flow around a cylinder, 9.3.5. Avoiding and influencing boundary layer separation, 10.1.2. Dimensional analysis, 10.1.3. Application of dimensional analysis 11.1.1. Flow induced forces, 11.1.2. Flow induced forces acting on a cylinder, 11.2.2. Flow induced force acting on a prism

Large recirculation wind tunnel   Assignment "A"
SZ.1.1. Shear layer control; investigation of the interaction of the driver cabin, spoilers, guiding elements, and charge cabin; using a segmented truck model
Dr. Viktor Szente (szente@ara.bme.hu)

In the case of segmented vehicles, the fluid mechanical interaction between the vehicle parts (driver cabin, charge cabin) is of practical importance from the viewpoint of aerodynamic drag (and thus, fuel consumption).

Assignment: experimental investigation and understanding of such interaction.

During the 45 minute measurement, the following activities are to be carried out:

a) Calibration of the balance (in 2-3 points, using weights),
b) Investigation of 4-6 varieties of spoilers and guiding elements, at flow incidence parallel to the longitudinal axis:
c) By visualization using oil smoke and taking photographs,
d) By force measurements,
e) By static pressure measurements.

Available equipment:

- Approx. 1:10 scaled-down truck model with pressure taps; various spoilers and guiding elements to be fixed to the model,
- Balance located in the wind tunnel measurement section, capable for measuring longitudinal force,
- Pitot-static probe for wind velocity measurements,
- Oil smoke generator,
- Pipe and probe for introduction of the oil smoke,
- Manometer.

A camera is to be provided by the measurement group. Possibility is given for testing customized driver cabins and flow guides prepared by the measurement group.

Further information necessary for those who are conducting measurements with regard to vehicles: *From the 4th edition of Az áramlástan alapjai textbook: Chapter 11., Forces acting on objects placed in flows, particularly 11.3.1. The role of and approaches used in vehicle aerodynamics, 11.3.2. Dividing up the fluid volume around a vehicle, drag forces occurring at the fore-body and its reduction, 11.3.3. The aft-body, underbody and side-body drag, 11.3.4. Flow around busses and semi trucks,* ***Further suggestions:*** *From the 4th edition of Az áramlástan alapjai textbook, chapter 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/ ***Materials related to the subject vehicle aerodynamics:****http://www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMG10/2010-2011-II/ea/*

Keywords for searching the literature: vehicle aerodynamics, drag force, drag coefficient, forebody drag, base drag, boundary layer separation, pressure coefficient, wheel, pressure distribution, drag reduction, underbody flow, front spoiler, shear layer, shear layer conditioning, bluff body, two bluff bodies in tandem.

Large recirculation wind tunnel Assignment “B”

THIS MEASUREMENT IS BEING SUBSTITUTED BY MEASUREMENT SZ.1.1 ASSIGNMENT “A”,

SZ.1.2.

Dr. Viktor Szente (szente@ara.bme.hu)

Large recirculation wind tunnel   Assignment "C"
SZ.1.3. Bluff body aerodynamics
Márton Balczó (balczo@ara.bme.hu)

Previous wind tunnel studies proved that a relationship exists between the static pressure in the wake of a bluff body and the angle of separation and mean flow direction at the separation point. The larger this angle, the smaller the pressure in the wake.

This effect is to be investigated using several spherical shells. The methods of investigation are:

- oil fog visualization and photography of the flow to determine the angle of mean flow and separation
- measurement of drag force on the body using a load cell
- measurement of flow velocity using a Pitot-static tube
- measurement of static pressure in the separation bubble

During the 45 minute measurement, the following activities are to be carried out:

a) Check of balance calibration (mount set in horizontal position, using weights),
b) Investigation of 4 configurations:
- By force, velocity and wake pressure measurements,
- By visualization, using oil smoke and taking photographs.

Available equipment:

- ¼, ½, ¾ and full spherical shells (each can be turned towards or against the flow direction, resulting in 7 different configurations),
- Sphere mount equipped with a load cell capable for measuring longitudinal force,
- Pitot-static probe for wind velocity measurements,
- Pitot-static probe for measurement of static pressure in the wake (using the static holes)
- Oil smoke generator,
- Pipe and probe for introduction of the oil smoke,
- Manometer.

A camera is to be provided by the measurement group.

Further information necessary for those who are conducting measurements on bluff bodies: *From the 4th edition of Az áramlástan alapjai textbook: Chapter 11., Forces acting on objects placed in flows, 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/

Keywords for searching the literature: boundary layer separation, drag coefficient, drag force, forebody drag, pressure coefficient, shear layer, shear layer conditioning, bluff body

NPL Wind tunnel   Assignment "A"

N1. Car fore-body surface: Investigation on the flow past a simplified, mirrored car front surface model, with special regard to the drag force, for various chassis geometries

Anikó Rákai (rakai@ara.bme.hu)

No drag force acts on bodies exposed to the flow of an ideal fluid. In the case of accelerating flow, e.g. developing in the vicinity of the front wall (fore-body) of a personal car, the boundary layer is thin. For this reason, the flow in the vicinity of the front wall is similar to the ideal, inviscid flow. As a result, the fore-body drag coefficient of the car (being nearly equal to the mean pressure coefficient) is nearly zero. The total pressure slightly away from the front wall is nearly constant.

Assignment: justification of the above assumptions and gathering experiences about the flow in the vicinity of the car fore-body. In order to model the ground (impermeable boundary), two symmetrically arranged fore-body models are available. Pressure taps are installed inside the model as well as in the symmetry plane related to one of the two part-models. By this means, the pressure distribution can be measured on the fore-body and in the separation bubble. The drag force can also be measured by means of a balance. The depression inside the model (i.e. in the separation bubble), multiplied by the maximum cross-section of the model, is to be subtracted from the drag force. By this means, the fore-body drag can be estimated.

During the 45 minute measurement,

a) The balance is to be calibrated (by means of weights, in 2 or 3 points),
b) The flow characteristics are to be examined by oil smoke flow visualization,
c) The drag force acting on the balance arm w/o the model is to be determined,
d) For 3 different velocities, the drag force acting on the models as well as the static pressure inside the models (relative to the pressure in the measurement section) is to be determined, when the models are equipped with wheels,
e) Repetition of the measurements w/o wheels with open and closed wheelhouse, and with modifications to the fore-body geometry: e.g. sharp inlet edge above the windshield, spoiler below the fore-body.

Available equipment:

- Balance protruding into the measurement section of the wind tunnel, by means of which the drag force being parallel to the flow direction can be measured, and by means of which the static pressure inside the model can be tapped,
- 2 symmetrical car fore-body models, of which one is equipped with static pressure taps,
- Oil smoke generator,
- Pipe and probe for introduction of the oil smoke,
- Manometer.

A camera is to be provided by the measurement group.

Further information necessary for those who are conducting measurements with regard to vehicles: *From the 4th edition of Az áramlástan alapjai textbook: Chapter 11., Forces acting on objects placed in flows, particularly 11.3.1. The role of and approaches used in vehicle aerodynamics, 11.3.2. Dividing up the fluid volume around a vehicle, drag forces occurring at the fore-body and its reduction, 11.3.3. The aft-body, underbody and side-body drag, 11.3.4. Flow around busses and semi trucks,* ***Further suggestions:*** *From the 4th edition of Az áramlástan alapjai textbook, chapter 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/ ***Materials related to the subject vehicle aerodynamics:***

http://www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMG10/2010-2011-II/ea/

Keywords for searching the literature: vehicle aerodynamics, drag force, drag coefficient, fore-body drag, aft-body drag, boundary layer separation, pressure coefficient, wheel, front wheel, wheelhouse, pressure distribution, drag reduction, underbody flow, front spoiler.

NPL Wind tunnel   Assignment "B"

N2. Race car wheel: Drag force acting on the front wheel of a Formula 1 race car, and its reduction by means of shear layer conditioning

Anikó Rákai (rakai@ara.bme.hu)

A significant portion of the aerodynamic drag acting on a Formula 1 race car is the force acting on the two front wheels. The boundary layer is separated from the plate normal to the flow and located upstream of the wheel near the ground. Downstream of the plate, a separation bubble develops, in which depression occurs. This depression moderates the overpressure on the lower part of the wheel, and thus, the force acting on the wheel decreases (shear layer conditioning).

Assignment: Investigating different possibilities for modifying the flow field in order to reduce the drag. In order to model the ground (impermeable boundary), two symmetrically arranged wheel models are available. Deflector plates of various sizes and positions can be tested.

During the 45 minute measurement,

1. The flow characteristics are to be examined by oil smoke flow visualization,
2. For 3 different velocities, the drag force acting on the models is to be determined,
3. The drag force is to be measured again with plates installed,
4. For a given velocity, the static pressure around the wheel is to be measured with and without the plates.

Available equipment:

- Balance protruding into the measurement section of the wind tunnel, by means of which the drag force being parallel to the flow direction can be measured,
- 2 Formula 1 wheel models,
- Deflector plates, attachable to the wheels, interchangeable, adjustable
- Oil smoke generator,
- Pipe and probe for introduction of the oil smoke,
- Manometer.

A camera is to be provided by the measurement group.

Further information necessary for those who are conducting measurements with regard to vehicles: *From the 4th edition of Az áramlástan alapjai textbook: Chapter 11., Forces acting on objects placed in flows, particularly 11.3.1. The role of and approaches used in vehicle aerodynamics, 11.3.2. Dividing up the fluid volume around a vehicle, drag forces occurring at the fore-body and its reduction, 11.3.3. The aft-body, underbody and side-body drag, 11.3.4. Flow around busses and semi trucks,* ***Further suggestions:*** *From the 4th edition of Az áramlástan alapjai textbook, chapter 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/ ***Materials related to the subject vehicle aerodynamics:****http://www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMG10/2010-2011-II/ea/*

Keywords for searching the literature: vehicle aerodynamics, drag force, drag coefficient, fore-body drag, aft-body drag, boundary layer separation, pressure coefficient, wheel, front wheel, pressure distribution, drag reduction, underbody flow, front spoiler.

NPL Wind tunnel Assignment "C"
N.3 Shear layer conditioning of a cylindrical body blown parallel to the symmetry axis
Anikó Rákai (rakai@ara.bme.hu)

Shear layer conditioning contributes to the reduction of the drag coefficient of a cylindrical body blown parallel to the symmetry axis.
Assignment: The investigation of shear layer condition mechanism and the reduction of the drag coefficient with circular bodies placed in front of the cylinder. The distance between the cylinder and the circular bodies can be varied.

During the 45 minutes of the measurement,

1. The flow characteristics are to be examined by oil smoke flow visualization without shear layer conditioning,
2. The measurement of the static pressure on the front surface without shear layer conditioning,
3. The drag force is to be determined without shear layer conditioning and with two cylindrical bodies placed at three different distances from the front surface of the cylinder.
4. Flow characteristics examination by oil smoke flow visualization of the case with the least drag force and the measurement of the static pressure on the front surface.

Available equipment:

- Balance protruding into the measurement section of the wind tunnel, by means of which the drag force being parallel to the flow direction can be measured,
- Cylindrical body with static pressure taps
- Circular bodies
- Oil smoke generator, pipe and probe for introduction of the oil smoke,
- Manometer

A camera is to be provided by the measuring group.

Further information necessary for those who are conducting measurements with regard to vehicles: *From the 4th edition of Az áramlástan alapjai tankönyv: Chapter 11., Forces acting on objects placed in flows, particularly 11.3.1. The role of and approaches used in vehicle aerodynamics, 11.3.2. Dividing up the fluid volume around a vehicle, drag forces occurring at the fore-body and its reduction, 11.3.3. The aft-body, underbody and side-body drag, 11.3.4. Flow around busses and semi trucks,* ***Further suggestions:*** *From the 4th edition of Az áramlástan alapjai tankönyv 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/ ***Materials related to the subject vehicle aerodynamics:****http://www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMG10/2010-2011-II/ea/*

Keywords for searching the literature: boundary layer separation, drag coefficient, drag force, fore-body drag, pressure coefficient, shear layer, shear layer conditioning, bluff body, two bluff bodies in tandem,

Trolley 1 Assignments “A”, “B”, “C”

K.1.2. Air curtain: Curvature of a planar free jet due to pressure difference; investigation on an air curtain applied to an industrial hall

Eszter Lukács (lukacs@ara.bme.hu)

Cold air curtains can be used in order to close off the doorway of an industrial hall that is to be otherwise open because of transportation reasons, i.e. in order to moderate the heat and mass transfer between the hall and the surroundings. The difference between the internal and ambient pressure is balanced by means of the curvature of the vertical, planar free jet introduced on one side of the door.

Assignment: Investigate the behavior of the air curtain model, as a function of the outlet velocity, outlet slot width, outlet angle, door width, and pressure difference. The air volume flow rate entering the protected enclosure is to also be determined as a function of the pressure difference. The mass and heat transfer is to be observed with the help of oil smoke flow visualizations.

During the 45 minutes of the measurement,

a) The entering flow rate is to be determined, for a given rounded outlet slot geometry, door width, outlet velocity and angle, and depression. The parameters of the operating state related to zero inflow are also to be determined.
b) Assignment a) is to be repeated for another outlet angle and outlet velocity.
c) At a given outlet angle, the effect of the door width is to be examined.
d) By introducing the oil smoke and making photographs, the shape of the curved jet and the mass transfer through the jet are to be studied.

Available equipment:

- Equipment for generation of an air curtain,
- Industrial hall model, with variable free jet outlet angle, door width, and depression (using a fan of variable speed), and with an inlet element calibrated for flow rate measurements,
- Pitot and Pitot-static probes for velocity measurements,
- Oil smoke generator,
- Pipe and probe for introduction of the oil smoke,
- Manometer.

A camera is to be provided by the measurement group.

Information necessary for those who are conducting measurements with regard to air curtains: *In the 3rd or 4th edition of the Az áramlástan alapjai textbook (These topics can be found in many other textbooks and sources as well): 2.1.1. Pathline, streamline, streakline, 2.1.3. Flow visualization, 3.3.3. Static, dynamic and total pressure, 3.4.1. The Euler equations given in the streamline coordinate system, 3.4.2. Applications, 6.2.4. Measurement equipment which measures with the help of elastic or deformable bodies, 6.2.5. Problems arising during pressure measurements, 6.3.1. Velocity measurements based on dynamic pressure measurements, 7.5 Free jets, 7.6 How air curtains work, 8.5.2. Requirements for having similarity between flows, 9.1.1. Characteristics of the boundary layer, 9.2.2. The development of the boundary layer in the streamwise direction, 9.3.1. Shear stress arising in the boundary layer, 9.3.2. Boundary layer separation, 9.3.3. Flow around a cylinder, 9.3.5. Avoiding and influencing boundary layer separation, 10.1.2. Dimensional analysis, 10.1.3. Application of dimensional analysis 11.1.1. Flow induced forces, 11.1.2. Flow induced forces acting on a cylinder, 11.2.2. Flow induced force acting on a prism.*

Further suggestions: *From the 4th edition of Az áramlástan alapjai tankönyv 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/

Keywords for searching the literature: air curtain, jet, plane jet

Trolley 2

K.2.1. Measurement of the pressure distribution and pressure difference fluctuations (drag and transversal force) on a cylinder; the effect of a splitter plate

Csaba Horváth (horvath@ara.bme.hu)

Knowing the characteristics of the flow past a cylinder is important in many practical applications. At low Reynolds numbers, the von Kármán vortex street develops behind a cylinder.

Assignment: Determine the pressure difference between the atmospheric pressure and that found on the surface of the cylinder, as well as its fluctuation (amplitude and frequency) while rotating the cylinder; study the effects of using flow conditioners of various sizes, aligned parallel to the incoming flow ("splitter plates"), on the distribution of pressure and its fluctuation.

During the 45 minute measurement:

a) Temporally varying pressure measurements are to be made around the surface of the cylinder in the square cross-sectioned wind tunnel, at a given velocity
b) Study a) is to be repeated at 2 further velocities
c) Study a) is to be repeated at a given velocity, with the application of 2 splitter plates of various sizes.

Available equipment:

- Square cross-sectioned wind tunnel, in which it is possible to adjust the flow velocity
- Cylinder, which is rotatable about its axis, with a single pressure tap, and a built in pressure sensor, which is capable of measuring the fluctuating pressure with the help of a PC for data acquisition
- Software for processing and evaluating results
- 2 splitter plates of various sizes
- Pitot-static probe for velocity measurements,
- Manometer.

Information necessary for those who are conducting the measurements: *In the 3rd or 4th edition of the Az áramlástan alapjai textbook (These topics can be found in many other textbooks and sources as well): 2.1.1. Pathline, streamline, streakline, 2.1.3. Flow visualization, 3.3.3. Static, dynamic and total pressure, 3.4.1. The Euler equations given in the streamline coordinate system, 3.4.2. Applications, 6.2.4. Measurement equipment which measures with the help of elastic or deformable bodies, 6.2.5. Problems arising during pressure measurements, 6.3.1. Velocity measurements based on dynamic pressure measurements, 7.5 Free jets, 7.6 How air curtains work, 8.5.2. Requirements for having similarity between flows, 9.1.1. Characteristics of the boundary layer, 9.2.2. The development of the boundary layer in the streamwise direction, 9.3.1. Shear stress arising in the boundary layer, 9.3.2. Boundary layer separation, 9.3.3. Flow around a cylinder, 9.3.5. Avoiding and influencing boundary layer separation, 10.1.2. Dimensional analysis, 10.1.3. Application of dimensional analysis 11.1.1. Flow induced forces, 11.1.2. Flow induced forces acting on a cylinder, 11.1.3, Flow induced forces acting on non-circular cylinders, flat plates and spheres, 11.2.2. Flow induced force acting on a prism.*

Further suggestions: *From the 4th edition of Az áramlástan alapjai textbook, chapter 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Structural elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/

Keywords for searching the literature: Strouhal number, Karman vortex street, vortex, separation, Reynolds number, resonant frequency, frequency, vortex shedding flowmeters, vortex flowmeters, Fourier transform, spectrum, sampling rate (Nyquist-Shannon sampling theorem), drag coefficient, drag force, lift coefficient, lift force, pressure coefficient, splitter plate

Trolley 2

K.2.2. Measurement of the pressure distribution and pressure difference fluctuations (drag and transversal force) on a square cross-sectioned pole; the effect of a splitter plate

Csaba Horváth (horvath@ara.bme.hu)

Knowing the characteristics of the flow past a square cross-sectioned pole is important in many practical applications. At low Reynolds numbers, the von Kármán vortex street develops behind a square cross-sectioned pole.

Assignment: Determine the pressure difference between the atmospheric pressure and that found on the surface of the pole, as well as its fluctuation (amplitude and frequency) while rotating the pole; study the effects of using flow conditioners of various sizes, aligned parallel to the incoming flow ("splitter plates"), on the distribution of pressure and its fluctuation.

During the 45 minute measurement:

a) Temporally varying pressure measurements are to be made along the surface of the pole in the square cross-sectioned wind tunnel, at a given velocity
b) Study a) is to be repeated at 2 further velocities
c) Study a) is to be repeated at a given velocity, with the application of 2 splitter plates of various sizes.

Available equipment:

- Square cross-sectioned wind tunnel, in which it is possible to adjust the flow velocity
- Pole, which is rotatable about its axis, with a single pressure tap on four sides and 5 pressure taps on one side, and a built in pressure sensor, which is capable of measuring the fluctuating pressure with the help of a PC for data acquisition
- Software for processing and evaluating results
- 2 splitter plates of various sizes
- Pitot-static probe for velocity measurements,
- Manometer.

Information necessary for those who are conducting the measurements: *In the 3rd or 4th edition of the Az áramlástan alapjai textbook (These topics can be found in many other textbooks and sources as well): 2.1.1. Pathline, streamline, streakline, 2.1.3. Flow visualization, 3.3.3. Static, dynamic and total pressure, 3.4.1. The Euler equations given in the streamline coordinate system, 3.4.2. Applications, 6.2.4. Measurement equipment which measures with the help of elastic or deformable bodies, 6.2.5. Problems arising during pressure measurements, 6.3.1. Velocity measurements based on dynamic pressure measurements, 7.5 Free jets, 7.6 How air curtains work, 8.5.2. Requirements for having similarity between flows, 9.1.1. Characteristics of the boundary layer, 9.2.2. The development of the boundary layer in the streamwise direction, 9.3.1. Shear stress arising in the boundary layer, 9.3.2. Boundary layer separation, 9.3.3. Flow around a cylinder, 9.3.5. Avoiding and influencing boundary layer separation, 10.1.2. Dimensional analysis, 10.1.3. Application of dimensional analysis 11.1.1. Flow induced forces, 11.1.2. Flow induced forces acting on a cylinder, 11.1.3, Flow induced forces acting on non-circular cylinders, flat plates and spheres, 11.2.2. Flow induced force acting on a prism.*

Further suggestions: *From the 4th edition of Az áramlástan alapjai textbook, chapter 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Structural elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/

Keywords for searching the literature: Strouhal number, Karman vortex street, vortex, separation, Reynolds number, resonant frequency, frequency, vortex shedding flowmeters, vortex flowmeters, Fourier transform, spectrum, sampling rate (Nyquist-Shannon sampling theorem), drag coefficient, drag force, lift coefficient, lift force, pressure coefficient, splitter plate

Trolley 2

K.2.2. Measurement of the pressure distribution and pressure difference fluctuations (drag and transversal force) in order to examine the effect of a splitter plate on the pole;

Csaba Horváth (horvath@ara.bme.hu)

Knowing the characteristics of the flow past a square cross-sectioned pole or a cylinder is important in many practical applications. At low Reynolds numbers, the von Kármán vortex street develops behind them.

Assignment: Determine the pressure difference between the atmospheric pressure and that found on the surface of the pole, as well as its fluctuation (amplitude and frequency) while rotating the pole; study the effects of using flow conditioners of various sizes, aligned parallel to the incoming flow ("splitter plates"), on the distribution of pressure and its fluctuation.

During the 45 minute measurement:

a) Temporally varying pressure measurements are to be made along the surface of the pole in the square cross-sectioned wind tunnel, at a given velocity
b) Study a) is to be repeated at 2 further velocities
c) Study a) is to be repeated at a given velocity, with the application of 2 splitter plates of various sizes.

Available equipment:

- Square cross-sectioned wind tunnel, in which it is possible to adjust the flow velocity
- Square cross-sectioned pole and a cylinder, which are rotatable about their axis, with a single pressure tap on four sides and 5 pressure taps on one side of the square cross-sectioned pole, and one pressure tap on the side of the cylinder, a built in pressure sensor, which is capable of measuring the fluctuating pressure with the help of a PC for data acquisition
- Software for processing and evaluating results
- 2 splitter plates of various sizes
- Pitot-static probe for velocity measurements,
- Manometer.

Information necessary for those who are conducting the measurements: *In the 3rd or 4th edition of the Az áramlástan alapjai textbook (These topics can be found in many other textbooks and sources as well): 2.1.1. Pathline, streamline, streakline, 2.1.3. Flow visualization, 3.3.3. Static, dynamic and total pressure, 3.4.1. The Euler equations given in the streamline coordinate system, 3.4.2. Applications, 6.2.4. Measurement equipment which measures with the help of elastic or deformable bodies, 6.2.5. Problems arising during pressure measurements, 6.3.1. Velocity measurements based on dynamic pressure measurements, 7.5 Free jets, 7.6 How air curtains work, 8.5.2. Requirements for having similarity between flows, 9.1.1. Characteristics of the boundary layer, 9.2.2. The development of the boundary layer in the streamwise direction, 9.3.1. Shear stress arising in the boundary layer, 9.3.2. Boundary layer separation, 9.3.3. Flow around a cylinder, 9.3.5. Avoiding and influencing boundary layer separation, 10.1.2. Dimensional analysis, 10.1.3. Application of dimensional analysis 11.1.1. Flow induced forces, 11.1.2. Flow induced forces acting on a cylinder, 11.1.3, Flow induced forces acting on non-circular cylinders, flat plates and spheres, 11.2.2. Flow induced force acting on a prism.*

Further suggestions: *From the 4th edition of Az áramlástan alapjai textbook, chapter 6.4.1. When to use wind tunnels, 6.4.2.Wind tunnel categories, grouped according to speed and layout, 6.4.3. Structural elements of a wind tunnel and different measurement section layouts, 6.4.4. Practical aspects in wind tunnel measurements, an/or Bradshaw, P., Mehta, R.: Wind tunnel design* www-htgl.stanford.edu/bradshaw/tunnel/

Keywords for searching the literature: Strouhal number, Karman vortex street, vortex, separation, Reynolds number, resonant frequency, frequency, vortex shedding flowmeters, vortex flowmeters, Fourier transform, spectrum, sampling rate (Nyquist-Shannon sampling theorem), drag coefficient, drag force, lift coefficient, lift force, pressure coefficient, splitter plate

Pipeline Assignment „A”
Calibration of the inlet orifice
Balázs Istók (istók@ara.bme.hu)

Inlet orifices are often used by engineers in order to measure the volume flow rate. The flow coefficient can be approximated taking certain principle into consideration, but there is no standard for doing this.
The assignment is to calibrate inlet orifices to a standard orifice plate. The inlet orifice needs to be placed upstream of the standard orifice plate, and the pressure drops across the orifices need to be measured at multiple volume flow rates. This data, together with the geometric properties of the setup can be used in order to calculate the inlet orifices flow coefficient.

Available equipment:

- Straight circular pipes and elbows, inlet and standard orifices, pressure taps and access holes for making velocity measurements.
- micromanometers.

Information necessary for those who are conducting the measurements: *From the 4th edition of Az áramlástan alapjai textbook, chapter 10. Hydraulics, 6.3.Measuring velocity and volume flow rate*

Keywords for searching the literature: volume flow rate, error of flow rate measurements, orifice, Pitot-static tube, velocity distribution

Pipeline Assignment „B”

The characteristics of flow in a pipe and how these characteristics affect the measurement of volume flow rate in the case of a standard orifice

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In order to make precise measurements, the length of straight pipe required to condition the flow before a standard through flow orifice is given in the standards. The standard gives several different lengths, which dictate the preciseness of the measurements. The lengths vary depending on what types of elements precede the straight pipe and how the elements are arranged.

The assignment is determine the relationship between the measurement error and the flow conditions upstream of the standard orifice (the length of the straight pipe found ahead of the standard orifice, as well as what kind, and how great of a disturbance precedes the straight pipe length) by making a series of measurements. Velocity measurements should be used in order to determine the character of the velocity profile upstream of the standard orifice.

Available equipment:

- Straight circular pipes and elbows, inlet and standard orifices, pressure taps and access holes for making velocity measurements.
- An inlet orifice which is calibrated to a standard through flow orifice in order to measure the true volume flow rate,
- Pitot-static tube for measuring the velocity
- Positioning system for positioning the velocity measurement devices
- laptop for controlling the positioning system
- micromanometers.

Information necessary for those who are conducting the measurements: *From the 4th edition of Az áramlástan alapjai textbook, chapter 10. Hydraulics, 6.3.Measuring velocity and volume flow rate*

Keywords for searching the literature: volume flow rate, error of flow rate measurements, orifice, Pitot-static tube, velocity distribution

Pipeline Assignment „C"

The characteristics of flow in a pipe and how these characteristics affect the measurement of volume flow rate when velocity based measurement methods are applied

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Contraction based and velocity based volume flow rate measurements are often used. The exactness of these measurements is greatly influenced by the characteristics of the flow in the measurement cross-section.

The assignment is determine the relationship between the measurement error and the flow conditions upstream of the orifice or the velocity measurement cross-section (the length of the straight pipe found ahead of the measurement cross-section, as well as what kind, and how great of a disturbance precedes the straight pipe length upstream of it) by making a series of measurements. The preciseness of the 10 point and the log-linear methods need to be determined when measuring in multiple cross-sections downstream of one or two pipe elbows.

Available equipment:

- Straight circular pipes and elbows, inlet and standard orifices, pressure taps and access holes for making velocity measurements.
- Pitot-static tube for measuring the velocity
- Positioning system for positioning the velocity measurement devices
- laptop for controlling the positioning system
- micromanometers.

Information necessary for those who are conducting the measurements: *From the 4th edition of Az áramlástan alapjai textbook, chapter 10. Hydraulics, 6.3.Measuring velocity and volume flow rate*

Keywords for searching the literature: volume flow rate, error of flow rate measurements, orifice, Pitot-static tube, velocity distribution