HYDRODYNAMICS

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HYDRODYNAMICS – a branch of hydromechanics that deals with the laws of fluid motion and phenomena caused by the mutual interaction between the fluid flow and the body bordering the moving fluid.

CONTINUITY EQUATION – expresses the law of the conservation of matter: a change in density at a given point is always accompanied by the flow of matter either from that point or towards it:

$$A_1 \cdot v_1 = A_2 \cdot v_2$$

A_1 i A_2- cross-secetional areas of the pipe at the beginning and end of observed section
v_1 i v_2 - fluid velocities through the cross-sections

- the velocities of fluid flow in a pipe with different cross-sections in inversely proportinal to their respective corss-sectional areas
- the continuity equation is a result of the law of conservation of mass.

VOLUMETRIC FLOW RATE – the amount of fluid that passes throuhg a given cross-section of pipe per unit of time:

$q = A \cdot v$

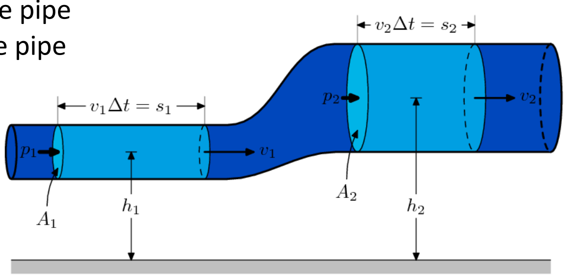
q – volumetric flow rate→ unit of measurement … [m^3/s]
A – cross-sectional area thorugh which the fluid flows
v – fluid velocity through that cross-section

- the velocity of a fluid in a pipe changes with position and time
- it significantly differs between laminar and turbulent flow
- laminar or steady flow → smooth, uniform fluid flow in parallel layers with minimal mixing between them, and no turbulence
- turbulence → irregural, swirling motion.

BERNOULLI'S EQUATION FOR AN INCLINED PIPE – the fundamental law used to describe the motion of a fluid through a pipe, equating the pressures in different sections of the pipe:

$$p_1 + \varphi g h_1 + \frac{1}{2}\varphi v_1^2 = p_2 + \varphi g h_2 + \frac{1}{2}\varphi v_2^2$$

p_1 i p_2- fluid pressure at the beginning and end of the pipe
v_1 i v_2- fluid velocity at the beginning and end of the pipe
h - height of the fluid above the reference point
g – gravitational acceleration (9.81 m/s^2)
φ – fluid density



Representation of the pipe with the quantities used to define Bernoulli's equation (pressure, height at each side of the pipe, and fluid velocity).

BERNOULLI'S EQUATION FOR A HORIZONTAL PIPE – describes the law of conservation of energy for a fluid flowing through a pipe without height differences:

p_1i p_2- fluid pressure at the begginning and end of the pipe
φ – fluid density
v_1 i v_2 – fluid velocity at the beginning and end oft he pipe

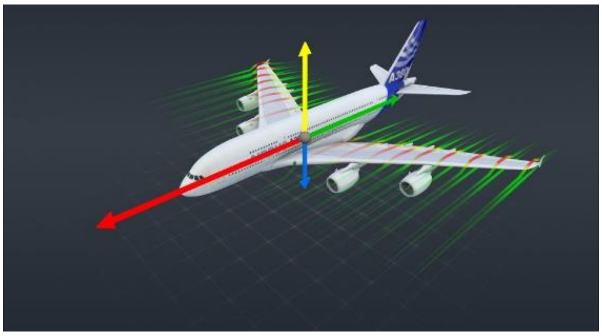
$$p_1 + \frac{1}{2}\,\varphi v_1^2 = p_2 + \frac{1}{2}\,\varphi v_2^2$$

- a horizontal pipe means there is no height deifference between the points, so potential energy is neglected (we take $h_1 = h_2 = 0$).
- Bernoulli's equation is a consequence of the law of conservation of energy.

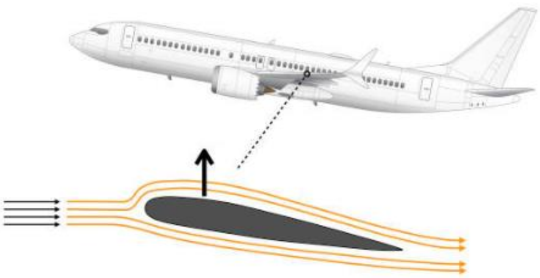
DYNAMIC BUOYANCY:

1. In hydrodynamics, dynamic buoyancy refers to the buoyant force that occurs when an object moves through a fluid, such as water, caused by differences in speed and pressure around the object. It is a crucial principle that enables the movement of ships, submarines, and is also applied in water sports and boat hull designs. The principle of dynamic buoyancy in hydrodynamics is based on Bernoulli's principle and the continuity equation.

2. If a plate is positioned at an angle smaller than 90° relative to the direction of flow, due to the asymmetry of the forces acting on both sides of the plate, a force will act on the plate with its point of application not located at the geometric center of the plate. If the plate moves horizontally, dynamic buoyancy will push it upward. Dynamic buoyancy enables the flight of aircraft, or generally, the flight of objects denser than air.



Red arrow – thrust force, green arrow – drag force, blue arrow – weight of the aircraft, yellow arrow – dynamic buoyancy force.



The cross-section of an aircraft wing (left image – dark gray color) with its flight oriented to the left.
The airflow is directed to the right – airflow lines (yellow color) – airflow lines go above and below the aircraft wing.
Above the aircraft wing, conditions prevail with faster airflow and lower pressure.
Below the aircraft wing, conditions prevail with slower airflow and higher pressure.
The result of the pressure difference above and below the wing allows the aircraft to lift (thick black arrow).