Validity of Reynold's number and Froude number.

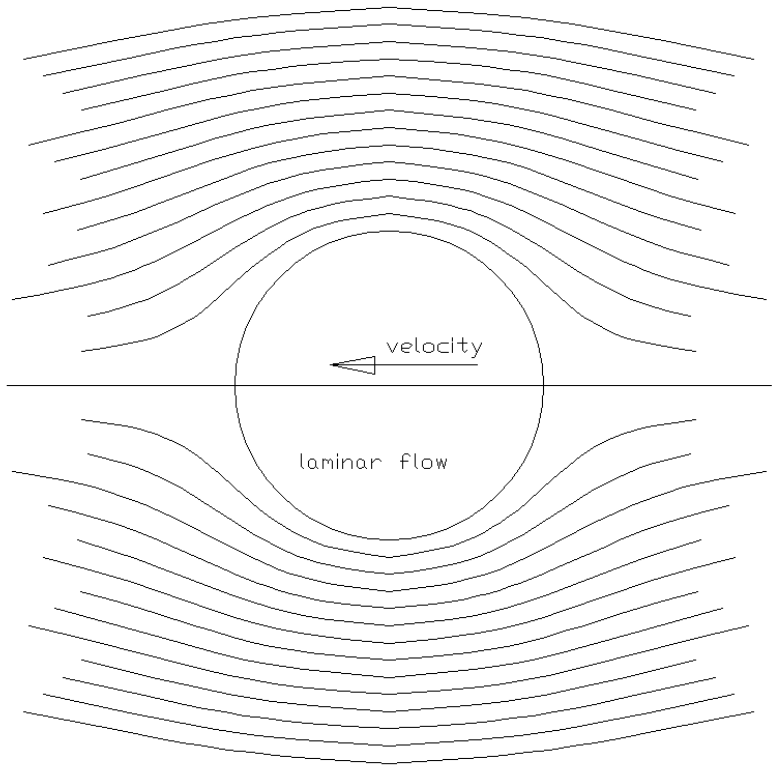
Definition of Reynold's number

$$Re = \frac{F_{viscous}}{F_{inertia}}$$

Definition of Froude number

$$Fr = \frac{F_{inertia}}{F_{gravity}}$$

Moving particle flow resistance through a gas or liquid.



Drawing 1 Particle moving through a medium at low velocity

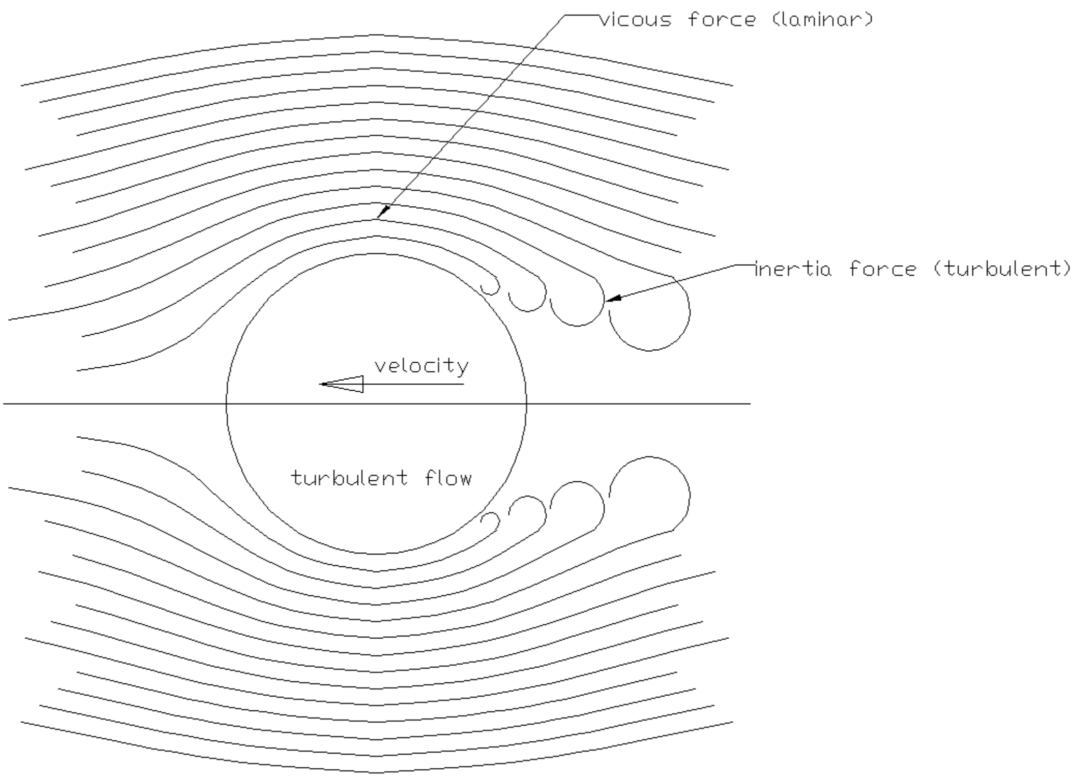
A moving particle through a medium, forces the medium to pass around the particle.
In front of the moving particle a pressure rise, equal to the dynamic pressure is generated.
Along the particle, the medium flows to the back side of the moving particle, to fill the void, that is left behind, after the particle is moved on to the next position.
The pressure along the particle is lower, due to to the increased velocity

At the back side of the moving particle, the medium closes again, whereby the velocity becomes zero again and the pressure rises again

The backside pressure is always lower than the frontside pressure, because there ar flow losses along the particle is involved.

The difference in frontside and backside pressure is representing the resistance force, required to force the particle through the medium.

At low velocities, the viscous resistance forces in the flow around the particle are dominant.



Drawing 2 Particle moving through a medium at high velocity

At high velocities, the inertia resistance forces (vortices) become dominant.

From this theory follows that the flow resistance of a particle is depending on the ratio viscous forces/inertia forces.

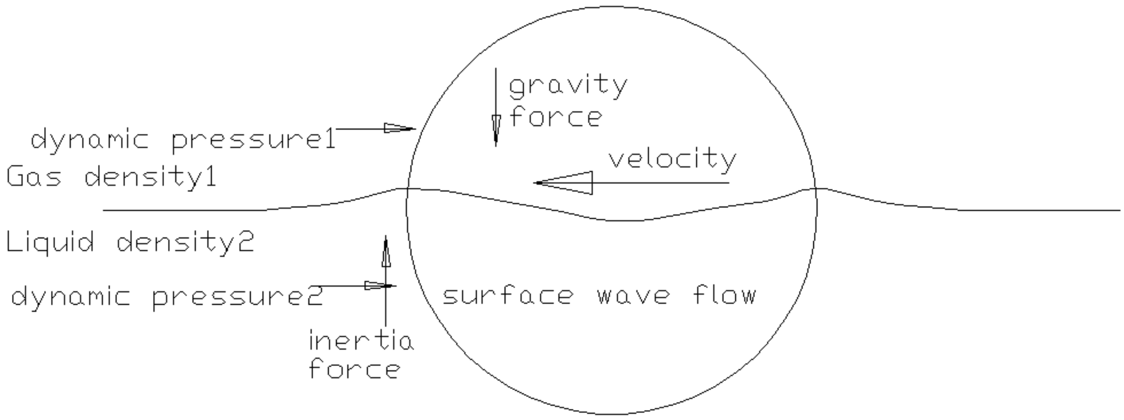
This ratio is defined as the Reynold number

$$Re = \frac{F_{viscous}}{F_{inertia}}$$

According Bernoulli, the drag force of a particle is given as:

$$F_{drag} = \Delta p_{gas} * A = \frac{1}{2} * \rho_1 * \zeta_{drag} * v^2 * A$$

Moving particle wave resistance at the boundary of a liquid and a gas.



Drawing 3 Particle moving at the boundary (surface) of 2 mediums

In the situation, whereby the lower part of a particle moves through a liquid and the upper part moves through the gas.

Here, the dynamic pressure in front of the particle is different in the gas region from the liquid region.

$$\Delta p_{gas} = \frac{1}{2} * \rho_1 * \zeta_{drag} * v^2$$

$$\Delta p_{liquid} = \frac{1}{2} * \rho_2 * \zeta_{drag} * v^2$$

Due to $\rho_2 > \rho_1$:

$$\Delta p_{liquid} = \frac{1}{2} * \rho_2 * \zeta_{drag} * v^2 > \Delta p_{gas} = \frac{1}{2} * \rho_1 * \zeta_{drag} * v^2$$

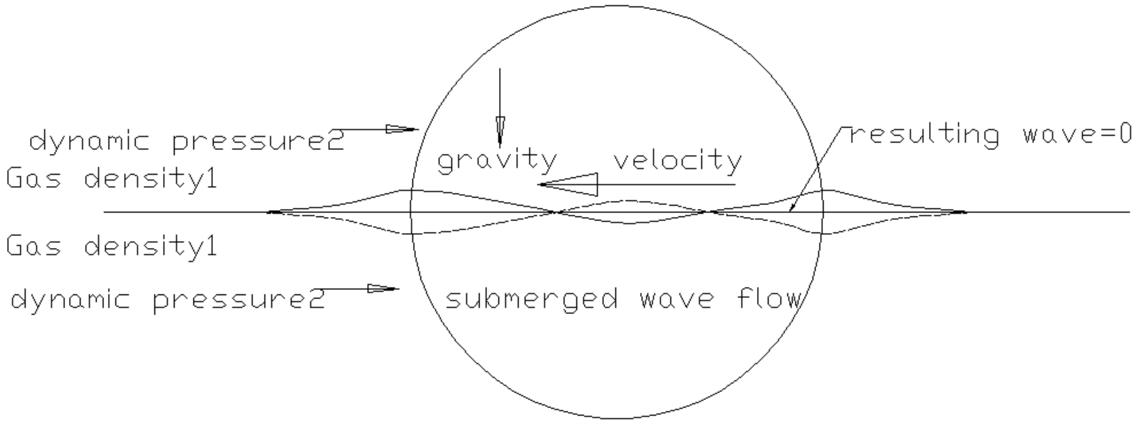
The pressure $p_2 > p_1$ and causes the liquid to elevate against gravity and build a wave top.

In this situation, the ratio inertia forces/gravity forces is related to the particle wave resistance.

This ratio is defined as the Froude number

$$Fr = \frac{F_{inertia}}{F_{gravity}}$$

Moving particle wave resistance submerged in a liquid or gas.



Drawing 4 Particle moving (submerged) through a medium

In the situation, the lower part of a particle and the upper part of the particle move through a liquid or gas of equal density.

Here, the dynamic pressure in front of the particle is equal in the upper region and the lower region.

$$\Delta p_{upper} = \frac{1}{2} * \rho_{medium} * \zeta_{drag} * v^2$$

$$\Delta p_{lower} = \frac{1}{2} * \rho_{medium} * \zeta_{drag} * v^2$$

Due to $\rho_2 = \rho_1$:

$$\Delta p_{upper} = \frac{1}{2} * \rho_{medium} * \zeta_{drag} * v^2 = \Delta p_{lower} = \frac{1}{2} * \rho_{medium} * \zeta_{drag} * v^2$$

The pressure $p_2 = p_1$ and no elevation effects are caused. A gravity wave is not generated and therefore, the wave resistance of a submerged moving particle is zero.

In this situation, the ratio inertia forces/gravity forces is irrelevant.

This ratio, defined as the Froude number $Fr = \frac{F_{inertia}}{F_{gravity}}$ is then also irrelevant.

Pipe flow

A pipe flow can be regarded as derived for a particle submerged and moving in a medium.
The Froude number is then also irrelevant.