UE9020300 | FLUID MECHANICS

OBJECTIVE

Investigate the fundamental characteristics of stationary and laminar flowing liquids by using the ultrasonic Doppler method

EXPERIMENT PROCEDURE

- Measure the Doppler frequency shift for different pump speeds and the pressure drops by standpipes.
- Determine flow rates, flow resistances, and dynamic viscosity of the doppler liquid by using the the continuity equation, Bernoulli's equation and the Hagen-Poiseuille equation.
- Calculate the Reynold numbers for different flow velocities and pipe diameters.

SUMMARY

Flow measurements according to the ultrasonic Doppler method are used to demonstrate fundamental laws governing the flow of liquids in pipes and their dependence on the flow velocity and the pipe geometry. The relationship between flow velocity and tube cross section (continuity condition) as well as between flow resistance and tube diameter (law of Hagen-Poiseuille) are examined.

REQUIRED APPARATUS

Quantity	Description	Item Number
1	Ultrasonic Doppler Apparatus	1022330
1	Ultrasonic Probe, 2 MHz	1018618
1	Set of Doppler Prisms and Flow Tubes	1002572
1	Riser Tubes for Pressure Measurement	1002573
1	Doppler Phantom Fluid	1002574
1	Centrifugal Pump	1002575
1	Ultrasonic Coupling Gel	1008575

BASIC PRINCIPLE

The applications of the Doppler Effect in the medical diagnostics are at the investigation of running movements and moving structures as in cardiologic diagnostics, arterial and venous blood vessels, brain blood circulation and postoperative blood vessel control.

A stationary flowing liquid is characterized by a constant flow of liquid at each point of the system. Therefore the continuity equation for two different tube areas A_1 and A_2 results as:

(1) $$A_1 v_1 = A_2 v_2 = \dot{V} = const.$$

v_1 and v_1 being the mean velocities in the respective section and V the flow rate (volume per time unit). The static pressure in a flowing liquid is always smaller than in a motionless liquid, and reduces the greater the flow velocity is (Bernoulli equation). For the flow through a horizontal tube (without gravity pressure) the total pressure p_0 is:

(2) $$p + \frac{1}{2}\rho v^2 = p_0$$

Only in a friction-less liquid p_0 is constant. In a flow pertaining to friction the total pressure decreases in dependence on the viscosity η, the length *l*, the cross-section *A* of the passing through region and the flow rate *V*. For liquids with not too high flow velocities (laminar flow) in narrow tubes the Hagen-Poiseuille law is valid for the pressure drop Δp:

(3) $$\Delta p = R\dot{V}$$

(4) $$R = \frac{8}{\pi}\frac{l}{r^4}\eta$$

where *r* is the radius of the tube and *l* is the length. That means that a reduction of the diameter of the vessel to half results in an enhancement of the flow resistance to 16 times. By this principle blood vessels regulate the blood distribution between extremities and inner organs. A circulation is built consisting of 3 tube lines of equal lengths but different diameters. At the beginning and end of each line is a measuring point of equal diameter. At the tube lines the mean velocity is measured for 3 different flow rates (3 different voltages at the centrifugal pump) by means of the Doppler prism and the FlowDop. Knowing the measured flow velocities the flow rate can be determined after (1) and compared. At the measuring points the pressure drop due to the flow resistance can be measured. Calculating the flow rate from (1) the flow resistance can be determined after (4) and from this using the known geometry the dynamical viscosity of the liquid is obtained.

EVALUATION

From the flow rates measured and the specific crosssectional areas, the corresponding flow can be calculated. This is nearly equivalent in this experimental setup for all pipe diameters for the same settings of the centrifugal pump, thus satisfying the continuity equation. As a further result, the diagram below shows the flow resistance *R* determined for different pipe diameters and different flows. This shows the strong dependence on the pipe radius *r* to be expected from the Hagen-Poiseuille equation:

$$R \sim \frac{1}{r^4}$$

Fig.1 shows that the flow rate calculated from the measured velocity and the area is nearly the same at all tube diameters for equal voltages and therefore the continuity equation is fulfilled.

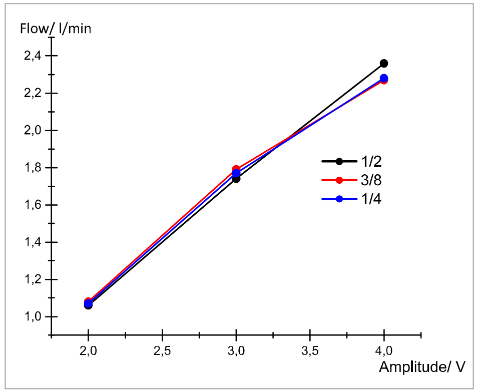
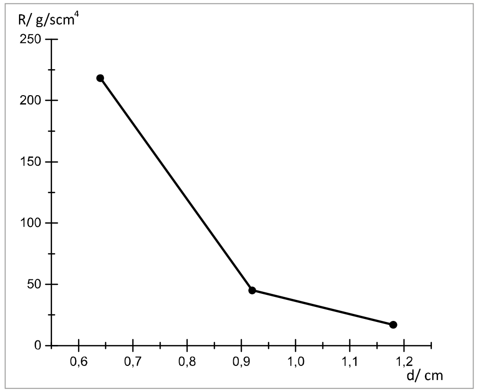


Fig1.: Flow rates for different tube diameters



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