IYPT

AUSTRIA

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ROTATION

1. Rotation

1. Assumption

Determining equipment parameters

- liquid containers
- rotating axle (material, diameter, surface)
- immersion level
- rotation velocity and direction

Liquid characteristics

- density
- viscosity
- elasticity

1. Rotation

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2. Equipment

- high speed drill (2580 rev.(revolution)/min.)
- steel rodaxis (diameter 0.01m, lubricated rod, immersion up to 0.03-0.04m)
- circular tray (diameter 0.14m or large square container)
- liquid level (0.04-0.05m)
- liquids: paraffin oil, water, water-flour mixtures in various ratios, liquid clay, dichlormethanol (contrast by PVC-granules or semolina)

Films and photographs for studies and measurement of vorticity

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1. Rotation

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3. Theory

1. Dynamic aspects

- friction (due to the structural properties of the liquids and interior forces: viscosity, density elasticity)
- momentum

2. Kinetic aspects

- radius r
- tangential velocity v
- rotation velocity ω

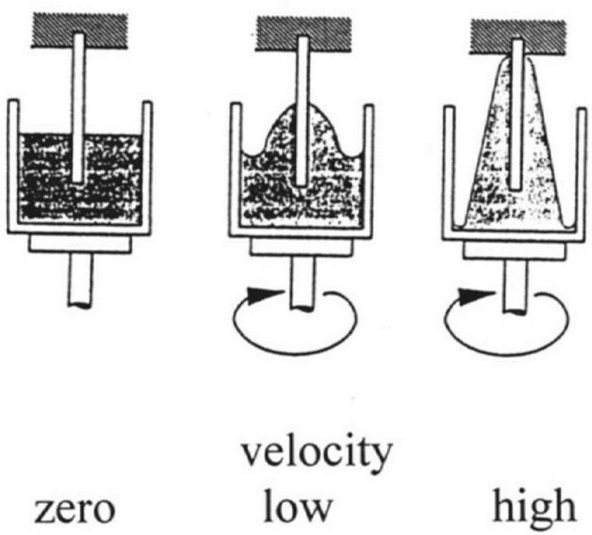
⇒ trajectories and gradients (thickness of the single layers)
⇒ up- and downward components of the motion of the liquid

1. Rotation

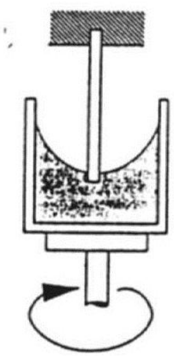
3. Theory (continued)

The Weissenberg- effect

liquids with Stokes' friction



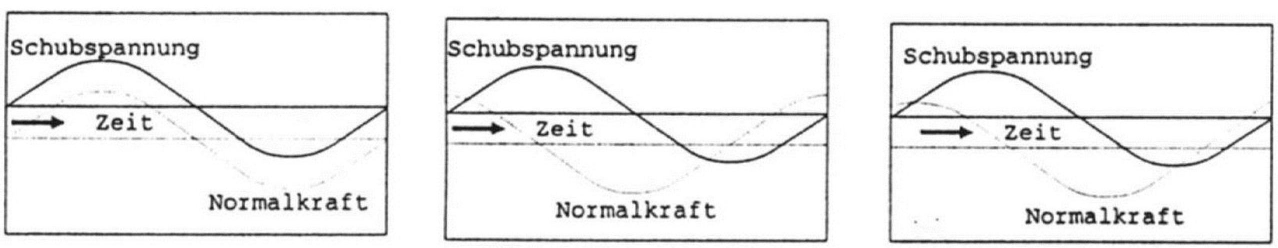
liquids with Newton's friction

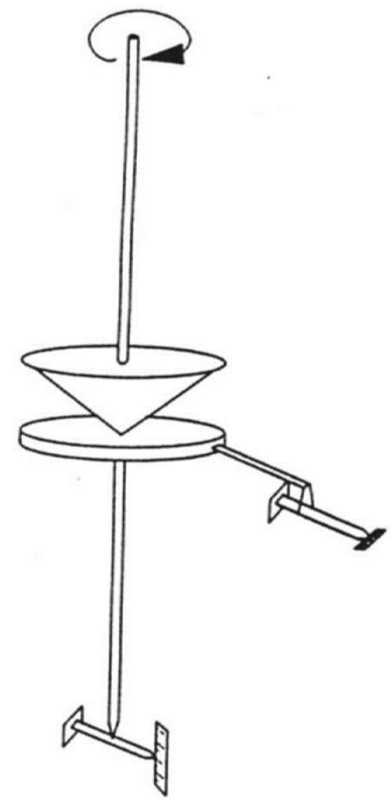


3. Theory (continued)

The Rheogoniometer

The vertical forces in an viscoelastic system can be measured. Vertical and tangential forces allow the calculation of the viscosity and elasticity of the sistem. (Fig.1)
The correlation of the vertical and tangential forces for a) only elastic (Stokes-)liquids, b) liquids with Newton's-friction and c)





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1. Rotation

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3. Theory (continued)

Viscoelastic characteristics is described by

Reynold’s number: $Re = v\delta/\nu$

ν...kinetic viscosity (η/ρ viscosity/density)
ω...rotational velocity
v...velocity

$\delta = \sqrt{\nu/\omega}$
$Re = (v\sqrt{\nu/\omega})/\nu$

- similar Re exhibits similar currents despite different geometries
- small Re exhibits high viscosity effects and insignificant momentum
- large Re exhibits low viscosity and significant moment.

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1. Rotation

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3. Theory (continued)

Re defines ratio between F_z and the radial component of tension F_R

F_R...... radial force

$F_R = F_T \cdot \sin\varphi$ and — F_T...... tangential force

$F_R = F_Z$ — F_Z...... centrifugal force

$F_R \approx \rho \cdot r \cdot \omega^2 \cdot \delta$ — $\delta = \sqrt{\nu/\omega} \Rightarrow$ Thickness of the layer in motion (independent of r)

Assuming an angular momentum T for “fluid Bags”:

$$T = r \times F$$
$$= (\rho\, r\, \omega^2\, \delta) \times X$$

Calculating X: $X = \cos\varphi\, AB$ (Fig.3, transperency 8)

1. Rotation

3. Theory (continued)

Movement of the particles:

Steady state : radial tension and centrifugal forces balance
⇒closed trajectories

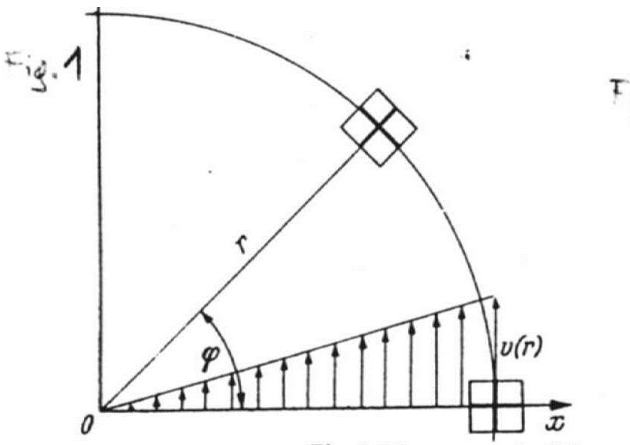

Fig. 1. Movement of solid particles around a centre

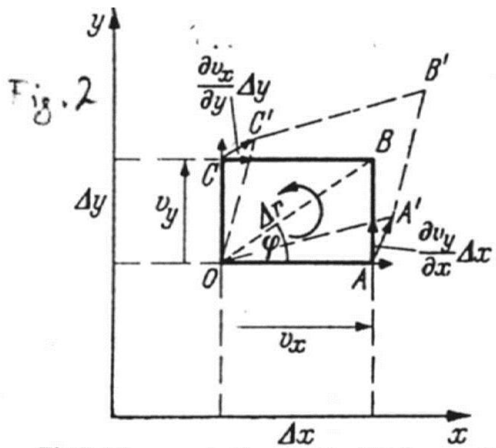

Fig.2. Movement of "fluid bags"ABCO changing extremely during the rotation

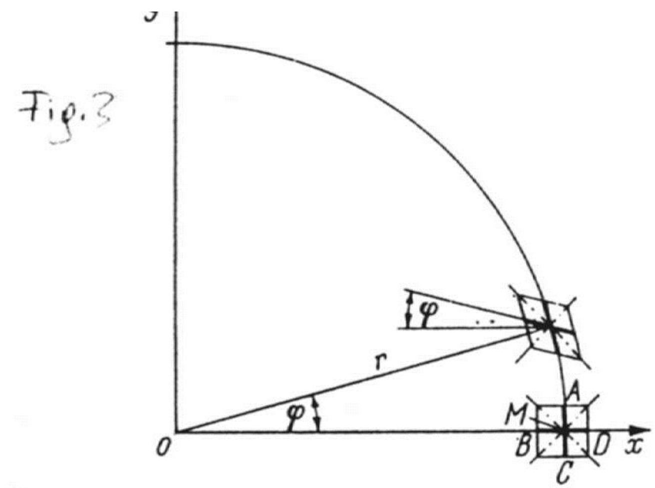

Fig. 3 Scheme of the deformed "fluid bag"

<u>**1.Rotation**</u>

4. Observations

<u>paraffin oil</u>

- square container
- liquid level: 0.05 m
- PVC-granule

The particles are moving in figure of eight. In the beginning stationary particles are pulled always to the end of the rod and then upward along the rod to the surface independent of the level at which the axis is immersed. Afterwards they are projected toward the walls of the container and sink to the bottom. Thereupon they are caught by the attraction of the axis and repeat the motion. The more or less regular movement gives the impression of an ellipse in which the movement in a figure of eight.

The surface is relatively smooth except for the depression near the rod. The particles outside the attraction remain on the bottom of the container.

4. Observation (continued)

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<u>water</u>

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- circular container
- liquid level: 0.04 m
- PVC- granule

The motion of the particles starts very slowly and only a limited number takes part. The particles not involved in the movement stay motionless on the surface of the water and around the rim of the container.

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4. Observation (continued)

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<u>dichlormethanol</u>

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- circular container
- liquid level: 0.04 m
- semolina and PVC- granule

Semolina is transported to the centre of the container, while the exterior rim remains clear. After the addition of the PVC-particles these are transported radially to the rim where they remain motionless (due to the dissolving of the particles). The surface becomes extremely turbulent and a clearly visible “crater” forms along the rod.

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1.Rotation

4. Observation (continued)

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liquid clay

- circular container
- liquid level: 0.04 m
- PVC- granule

Only the inner regions of the clay are affected by the rotation of the axis. This is demonstrated by the PVC-particles that remain on the surface near the rim. Observation of the particles beneath the surface is impossible because it is not possible to look through the clay. A visible downward “crater” could be seen and an arch appears around it. Moving up the rod there appears a cone upwards.

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1. Rotation

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5. Conclusions

motion of liquid depends on:

• ratio $F_Z : F_R$
• rational direction

If radius and rotational velocity are constant, the development of craters or hills depends on

ρ.....density of the liquid
δ.....thickness of the layer wich itself is dependent on:
γ.....kinetic viscosity
ω.....rotational velocity