Resonant response of a Maxwell fluid to periodic forcing

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Abstract

We present experimental velocity profiles for a Maxwell and a newtonian fluid in a tube under an oscillatory pressure gradient. We obtained bulk velocity profiles (PIV technique) and interface velocity profiles (deflectometry technique). The bulk profiles are in good agreement with the prediction of a linear theory. Comparing the results obtained with the two techniques shows surface tension effects: velocity profiles at the interface are always smaller than at the bulk.

1. Introduction

Linearized momentum equation: $\rho\frac{\partial\vec{v}}{\partial t} = -\vec{\nabla}p + \vec{\nabla}\cdot\vec{\tau} \qquad (Re \ll 1)$

Continuity equation: $\vec{\nabla}\cdot\vec{v} = 0$

Linearized Maxwell model: $t_m\frac{\partial\vec{\tau}}{\partial t} = -\eta\,\vec{\nabla}\vec{v} - \vec{\tau}$

Fourier transform: *t* - ?

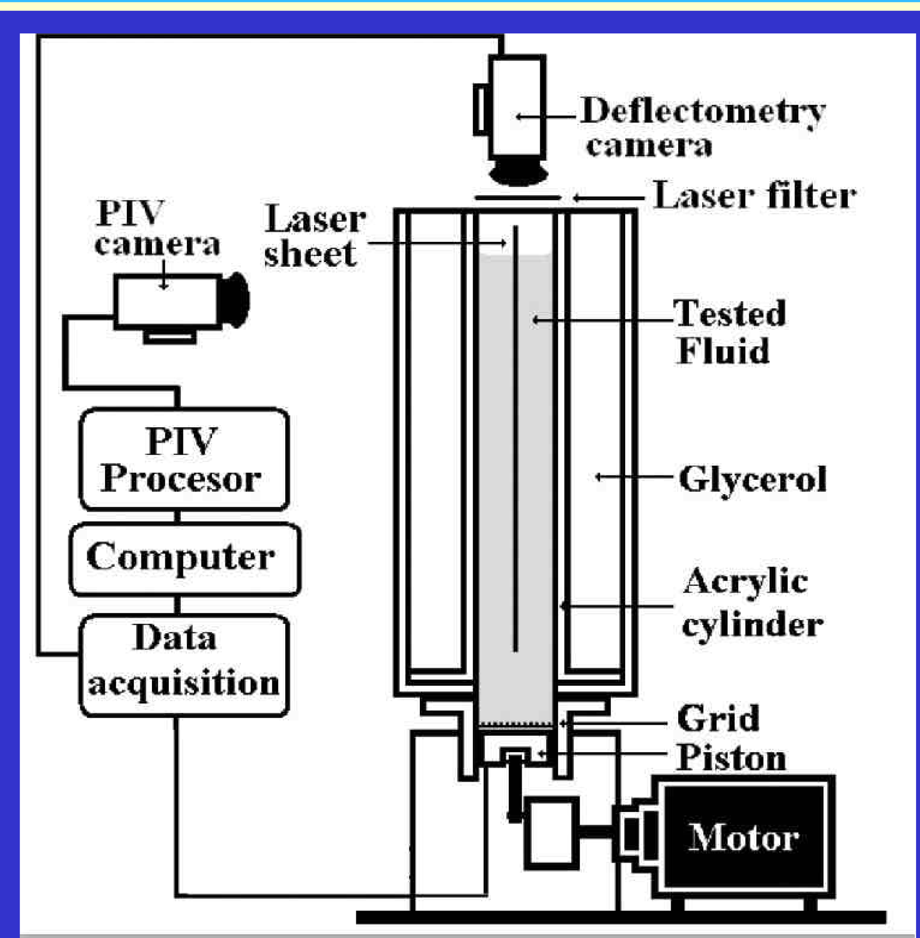
$$\rho\left(t_m\omega^2 + i\omega\right)\vec{V} + \eta\nabla^2\vec{V} = (1 - i\omega t_m)\,\vec{\nabla}P$$

Tube:
- cylindrical coordinates
- no-slip condition at the walls

$$V(r,\omega) = -\frac{(1-i\omega t_m)}{\eta\beta^2}\left[1 - \frac{J_0(\beta r)}{J_0(\beta a)}\right]\frac{dP}{dz}$$

$$\beta = \left(\frac{\rho}{\eta t_m}\left[(\omega t_m)^2 + i\omega t_m\right]\right)^{1/2}$$

2. Experimental setup



Newtonian fluid: glycerol

? = 1 Pa · s, ? = 1250 kg/m^3

Maxwell fluid: CPyCl/NaSal in water (100/60 mmol/l)

? = 60 Pa · s, ? = 1050 kg/m^3
t_m = 1.9 s

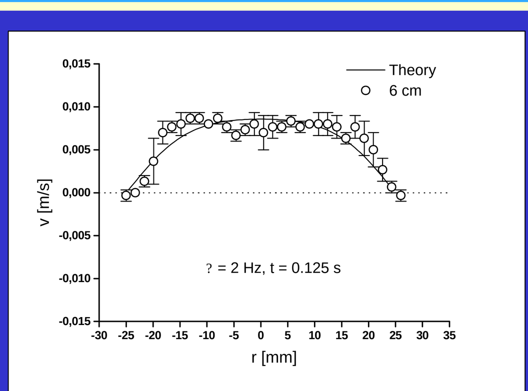
Deflectometry:
?t = 1/3.75 s between images

Particle Imaging Velocimetry:
Laser sheet thickness < 1 mm
?t = 0.066 s between 2 images
Measurement subsections 2.01?2.01 mm^2

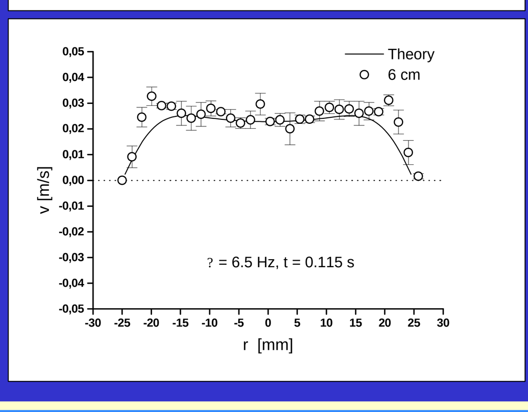
3. PIV: Bulk velicity profiles

Glycerol

2 Hz

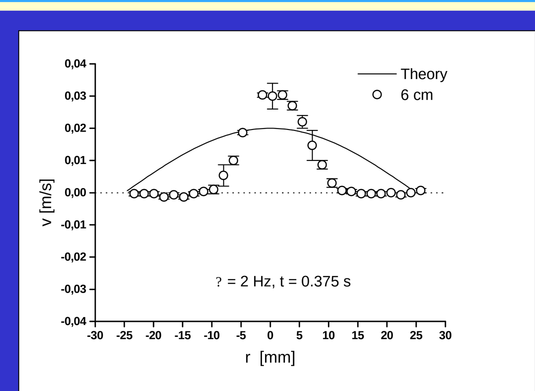


6.5 Hz

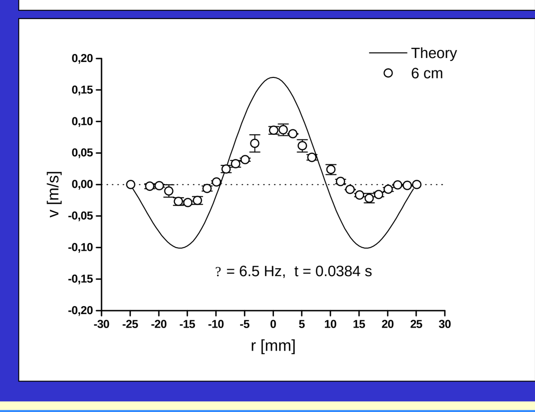


CPyCl/NaSal

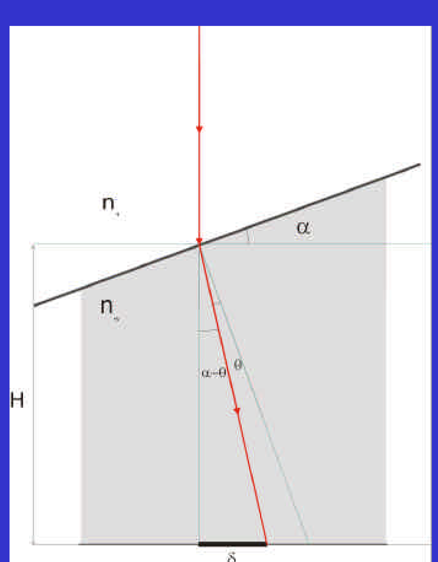
2 Hz



6.5 Hz



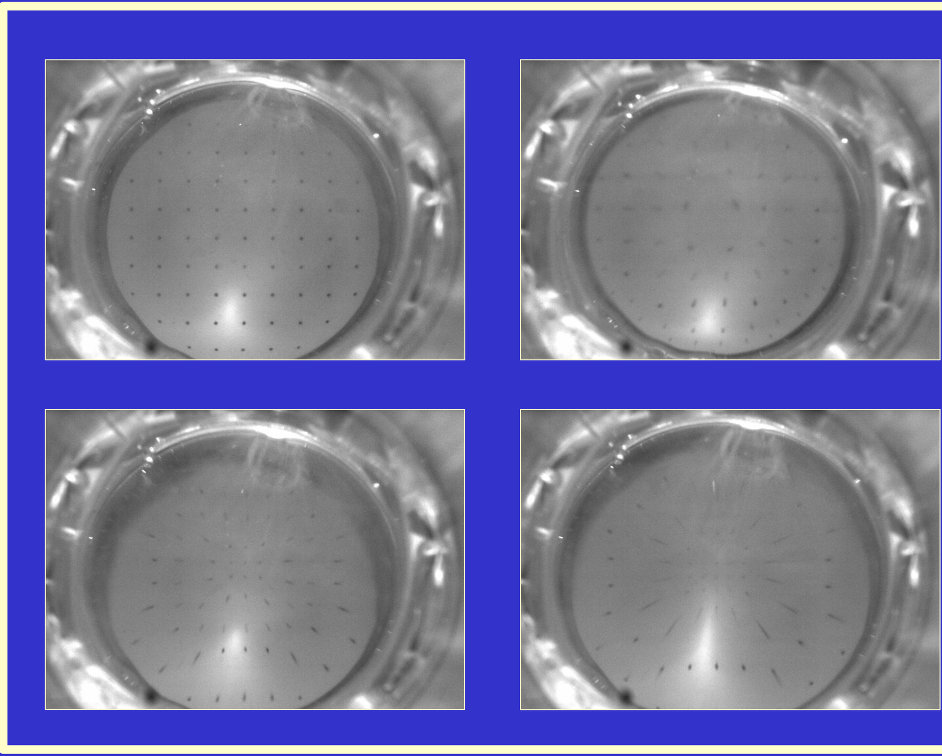
4. Deflectometry: Interface profiles



$$\alpha = \frac{1}{1-\frac{n_2}{n_1}}\arctan\left(\frac{\delta}{H}\right)$$

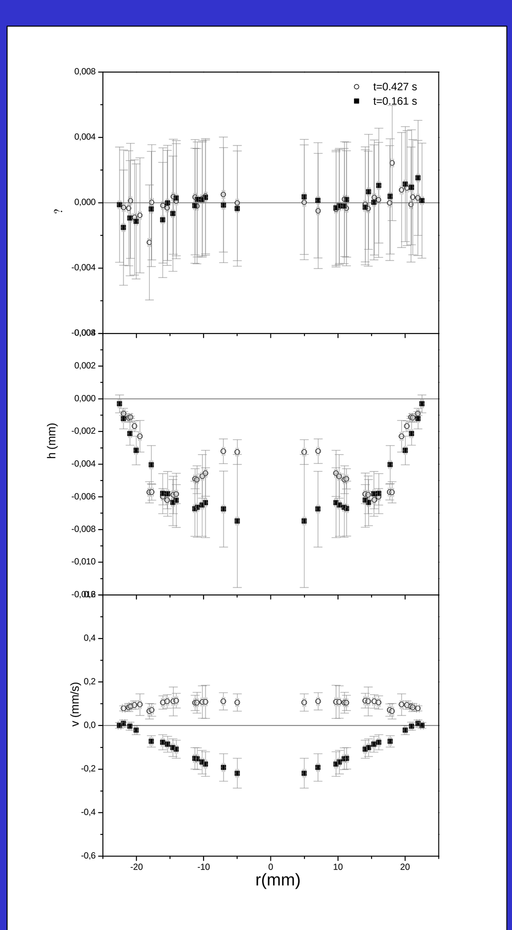
$$h(r,t) - h(R,t) = \int_r^R \alpha(r,t)dr$$

Grid: $d = 5, 5.5$ mm.
Column height: $H = 240.0 \pm 0.5$ cm.
Refractive Index:
Newtonian: n=1.473.
Maxwelian: n=1.33407.

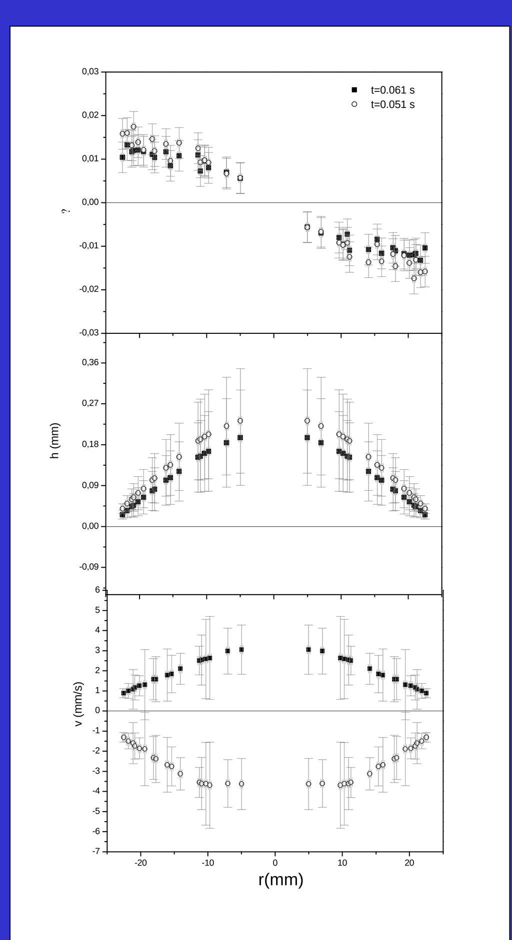


Glycerol

2 Hz

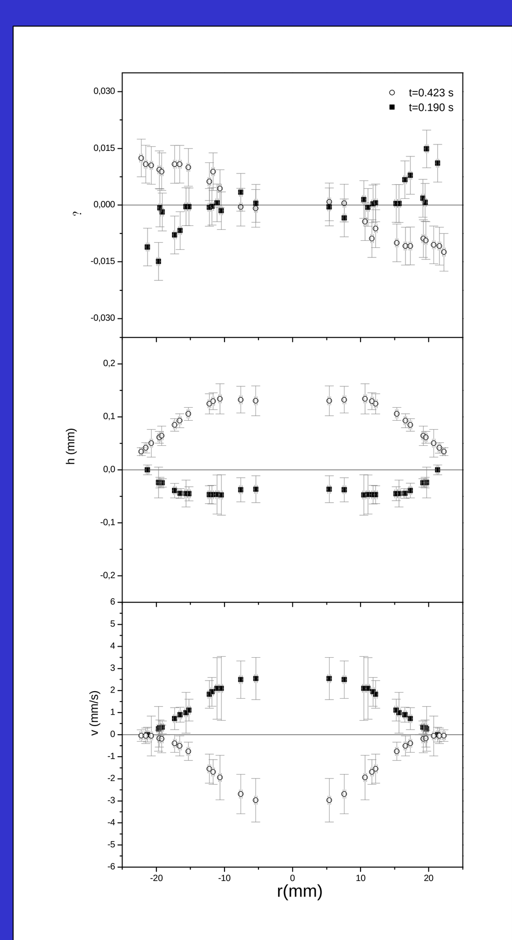


6.5 Hz

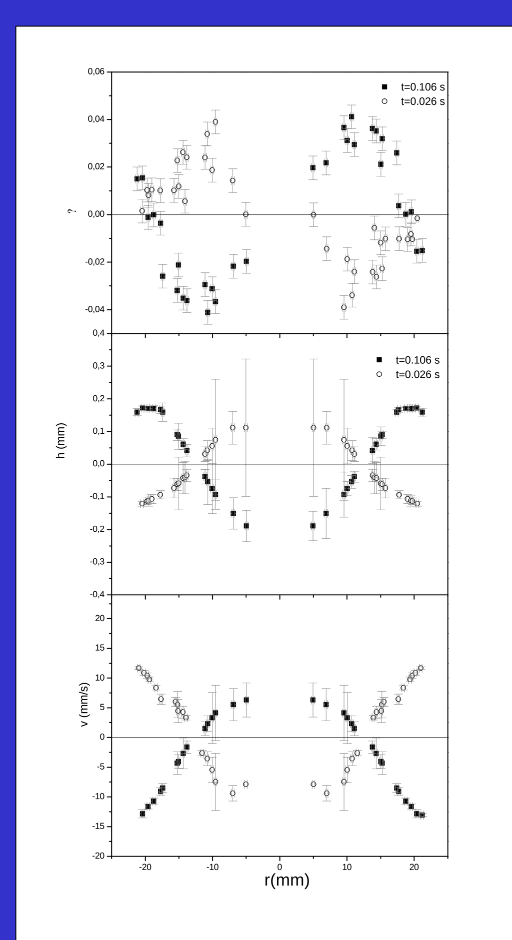


CPyCl/NaSal

2 Hz



6.5 Hz



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