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TALLINNA TEHNIKAÜLIKOOL
TALLINN TECHNICAL UNIVERSITY

Accelerating start-up pipe flows

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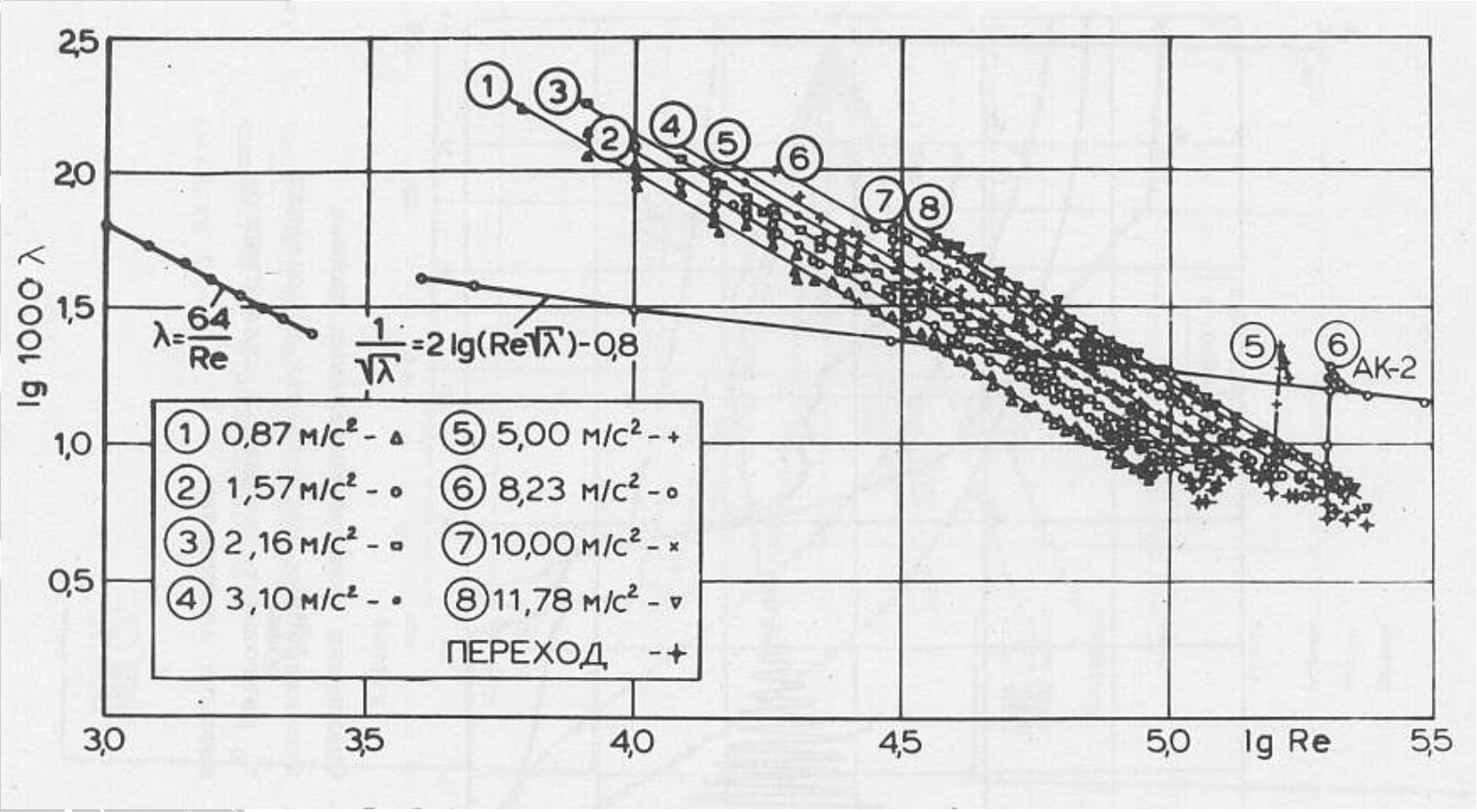
Contents

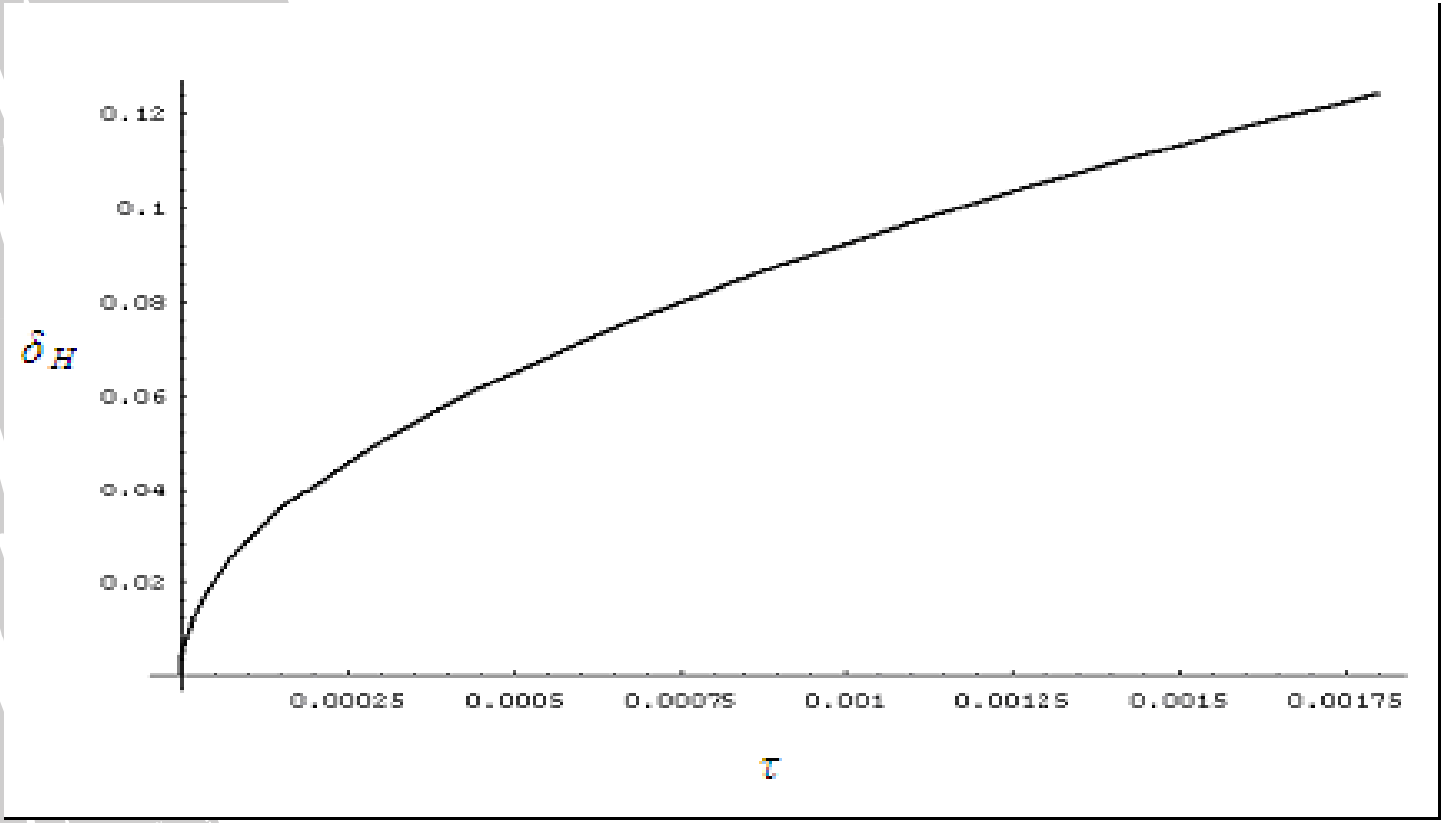
Start-up flow in pipes

- Szymanski (1932)
- Leutheusser, Lam (1977)
- Ohmi, Iguchi et al. (1980-1982)
- Kurokawa et al. (1985-1988)
- Lefebre, White (1989-1991)
- Moss, Da Silva, Greenblatt (1989, 1993, 2003)
- Das, Arakeri (1998)
- Zhao, Ghidaoui, Kolyshkin (2007)
- Nishihara, Knisley, Nakahata, Iguchi et al. (2007-2009)

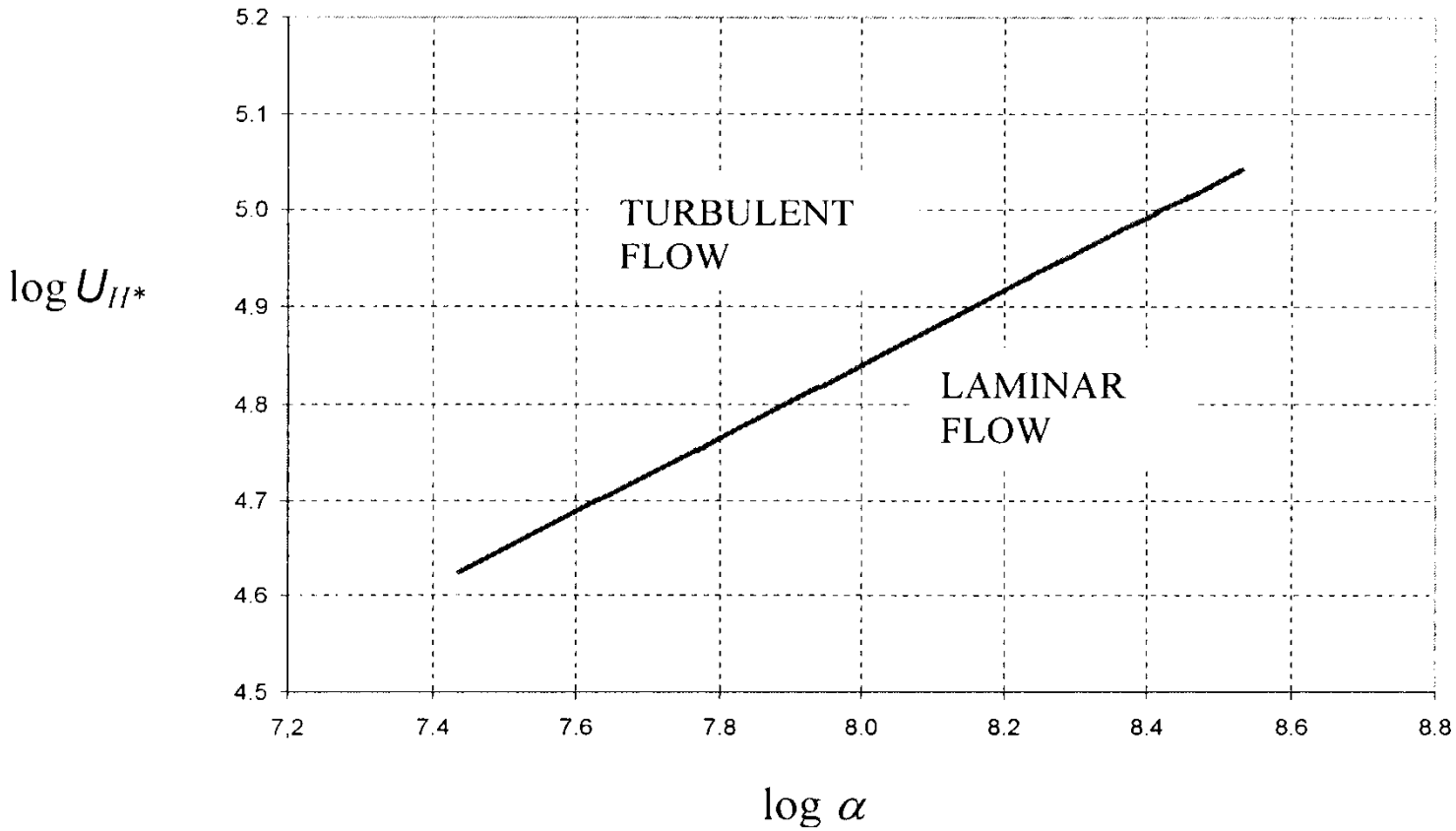
Start-up flow



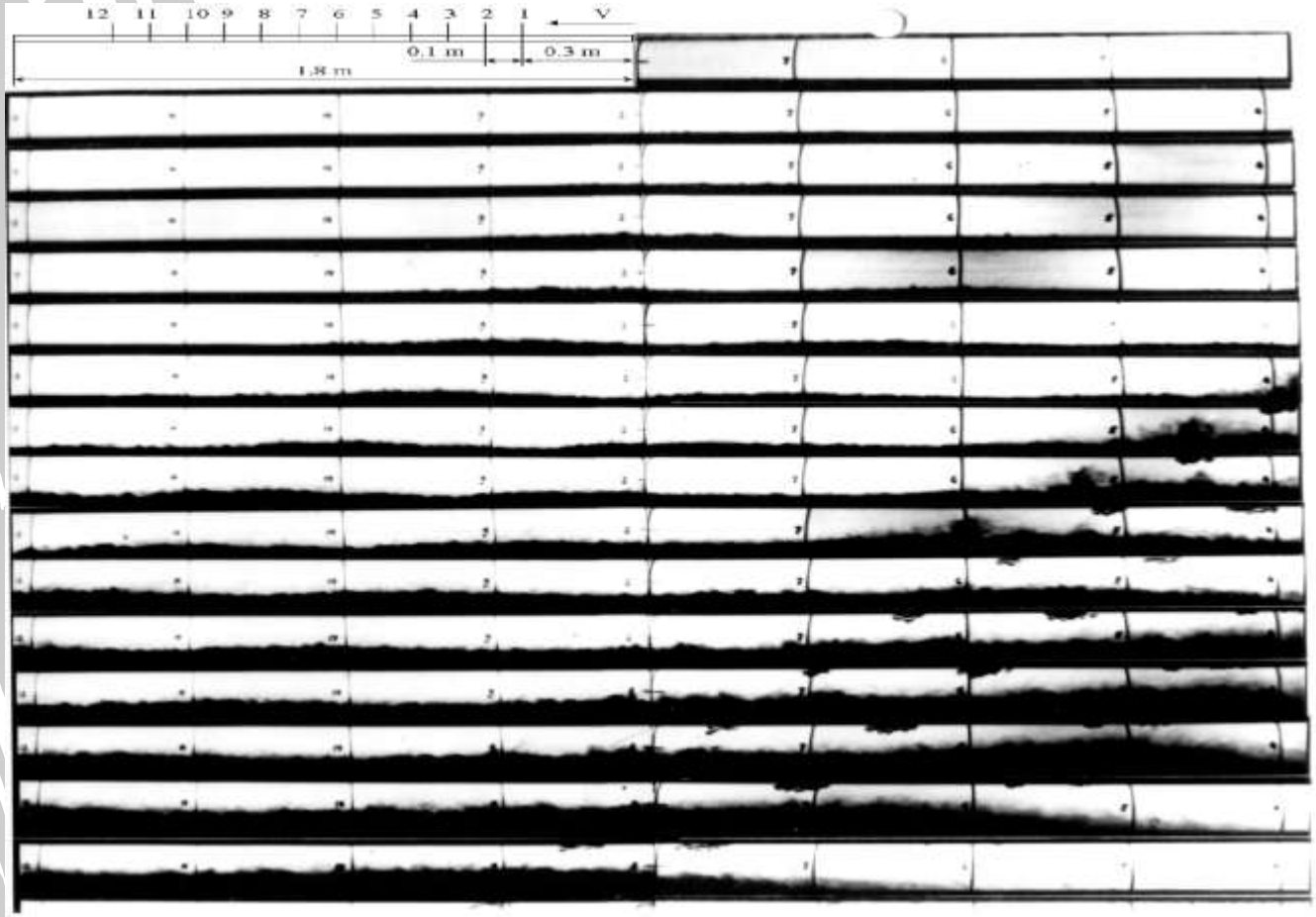
Development of the thicness of the boundary layer



Regions of laminar and turbulent flows



Turbulence generation



Dissipative model

$$\frac{\partial u}{\partial \tau} = -\frac{\partial q}{\partial \xi} + Dn\left(\frac{\partial^2 u}{\partial \eta^2} + \frac{1}{\eta}\frac{\partial u}{\partial \eta}\right),$$

$$\frac{\partial q}{\partial \eta} = 0$$

$$\frac{\partial q}{\partial \tau} + \frac{\partial u}{\partial \xi} + \frac{\partial v}{\partial \eta} + \frac{1}{\eta} v = 0,$$

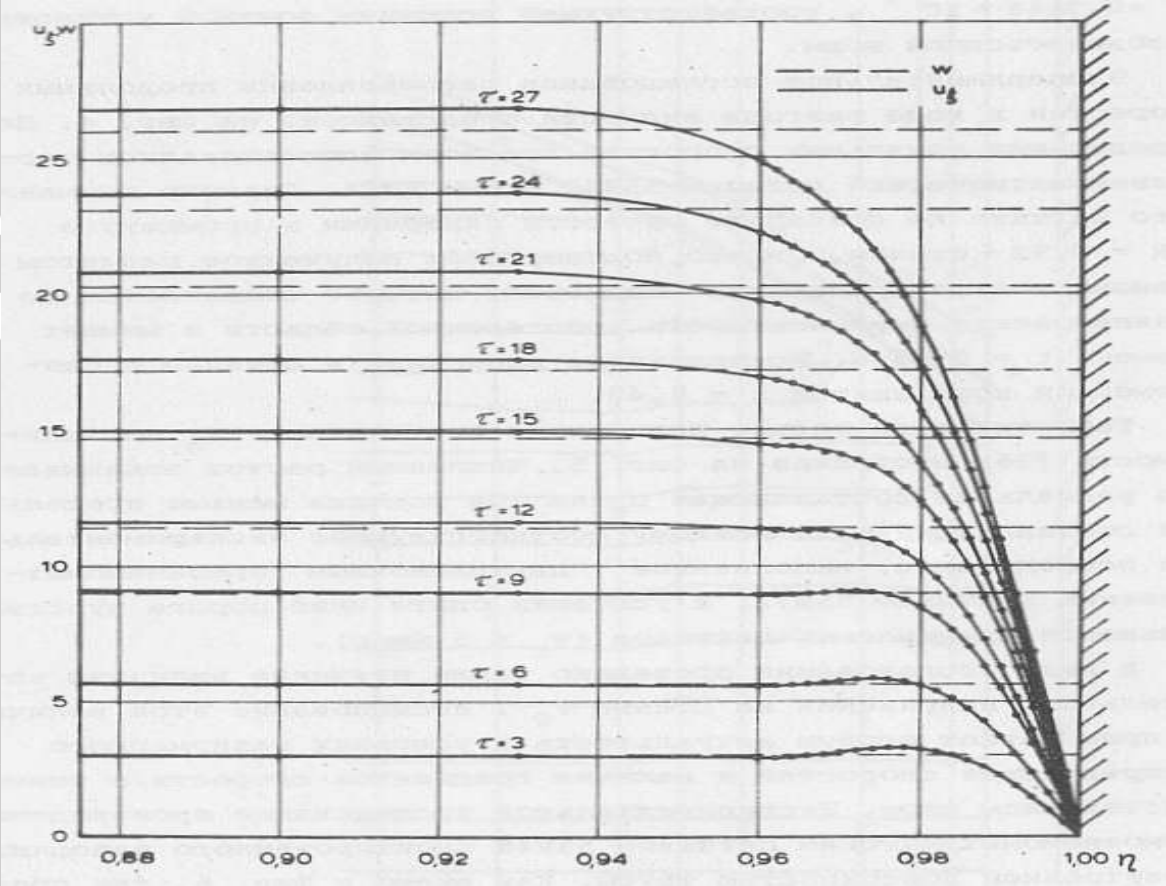
Flow with constant acceleration

$$\frac{\partial U}{\partial \tau} = \alpha = const. \qquad \frac{\partial q}{\partial \xi} = -\alpha\left(1 + \frac{4}{\sqrt{\pi}}\sqrt{\tau} + 3\tau + \frac{5}{\sqrt{\pi}}\tau\sqrt{\tau}\right).$$

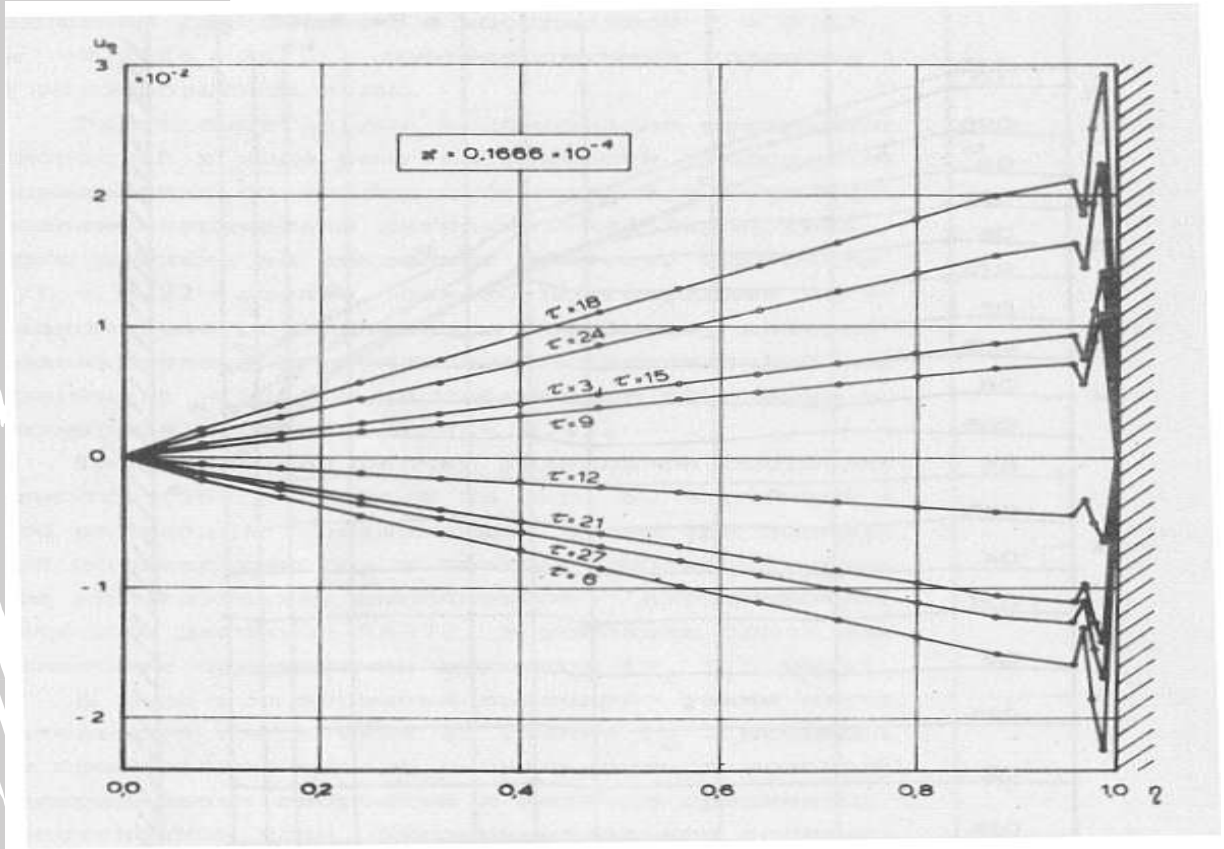
$$u(\vartheta,\tau) = \alpha\int_0^{\tau}\left(1 + \frac{4}{\sqrt{\pi}}\sqrt{\tau}\right)K(\vartheta,\tau)d\tau$$

$$K(\eta,\tau) = 1 - \frac{1}{\sqrt{\eta}}\left[\left(1 + \frac{(1-\eta)^2}{8\eta}\right)erfc\,\beta - \frac{1-\eta}{4\eta^{3/2}}\sqrt{\frac{\tau}{\pi}}e^{-\beta^2} + \cdots\right],$$

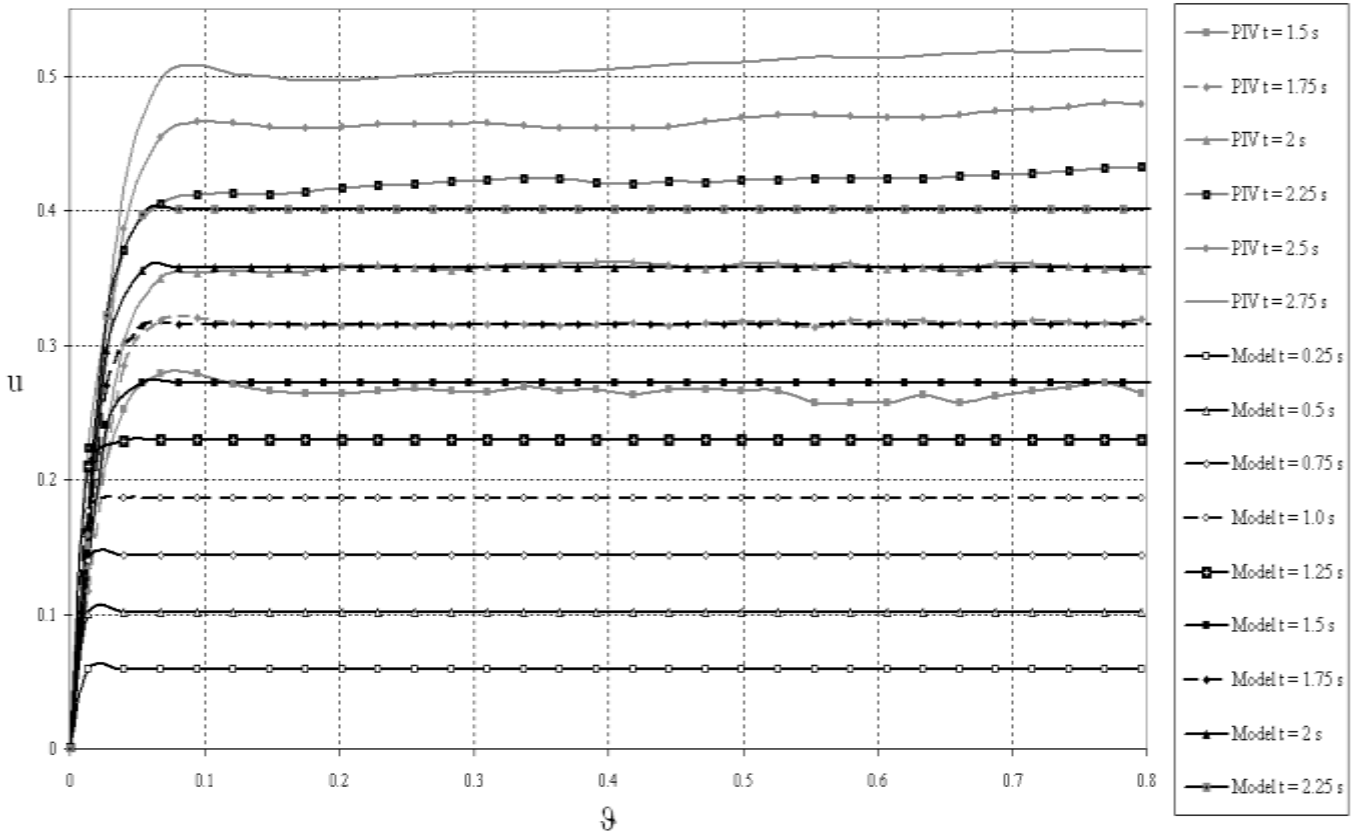
Velocity distribution



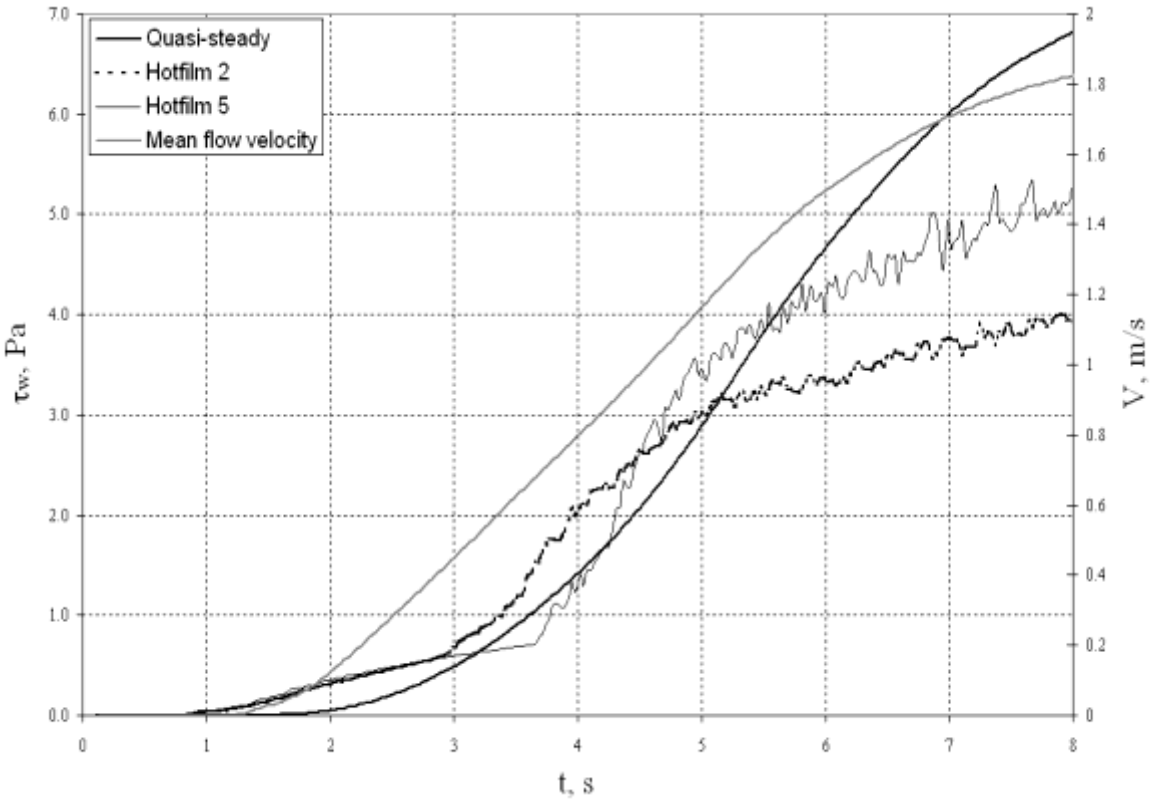
Radial velocity



Velocity distribution



Quasi-steady and ensemble-average wall shear stress



Thank You for Your Attention!

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