EFFECT OF DRAG REDUCING POLYMERS ON THE TRANSITION OF UNSTEADY VELOCITY PROFILES WITH REVERSE FLOW

Shashank H.J.[1] & Sreenivas K.R. [1]
[1] *Engineering Mechanics unit, Jawaharlal Nehru centre for advanced scientific research, Bangalore, India*

Abstract
The effect of drag reducing polymers on the onset of instability in a pipe with reverse flow is investigated. Reverse flow is established by using a piston cylinder mechanism, the programmed motion of which imparts a known impulse to the fluid. An inflection point is formed, leading to flow instability above a critical Reynolds number. The effect of the drag reducing polymers (Poly-ethylene oxide, dissolved in water) is observed using dye visualization and PIV. The time of onset of instability and the wavelength of the instability are studied in systems with and without Poly-ethylene Oxide (PEO). The experiments show that the wavelength increases in systems with PEO when compared to water. The flow due to forward motion of the piston is solved analytically to obtain the velocity profiles after the piston stops. Stability analysis is also performed to compare the behaviour of systems with and without PEO.

INTRODUCTION AND EXPERIMENTAL SETUP

Das [1] performed experiments in a water filled pipe which was driven by a piston cylinder mechanism. When the piston stops at the end of the stroke, fluid inertia causes the core fluid in the pipe to continue in the same direction. In order to conserve mass, the fluid close to the boundary moves in the opposite direction, thereby causing reverse flow. The inflectional velocity profile thus obtained was studied as a function of the Reynolds number of the forward motion of the piston. The instability was characterized by means of the wavelength of instability and the time of onset of instability. In the present work, the effect of drag reducing polymer additives on the above mentioned instability mechanism is studied.

The present experimental setup consists of a piston cylinder mechanism, which is used to impart a known impulse to the fluid in the pipe. Experiments are performed at constant impulse i.e., the piston properties are kept constant for both water as well as polymer runs. The polymer used in current experiments is Poly Ethylene Oxide (PEO) dissolved in water and is in the dilute regime. The viscosity of the polymer solution is measured using a rheometer at different shear rates. For the concentrations used in the present study, the viscosity remains invariant to changing shear rate, which means that the shear thinning behaviour of the polymer is non existent. A schematic of the experimental setup is shown below.

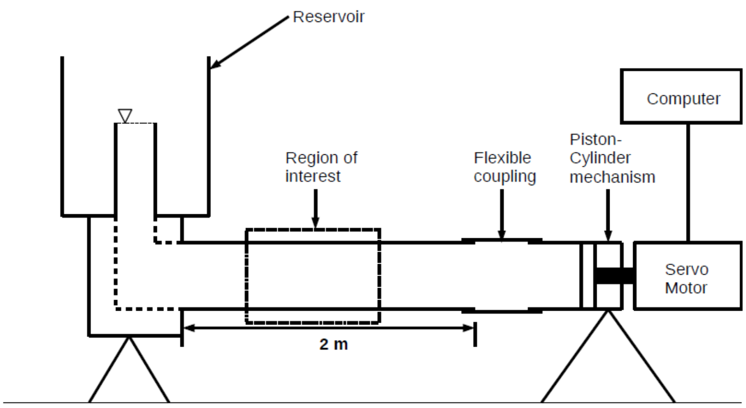

Figure 1. Sketch of the experimental setup.

EXPERIMENTS PERFORMED AND RESULTS

The various parameters of the reverse flow instability, i.e. wavelength of instability and time of onset of instability are studied with the help of dye visualization and PIV. Dye visualization is performed by injecting a line of dye at the bottom as well as the top of the pipe before starting the motion of the piston. The evolving dye line is then extracted by image processing following which, using fast fourier transform (FFT), the wavelength of the instability waves is extracted. This procedure is performed for runs of both water and PEO. On comparing the wavelengths of instability for water and polymer solution, it is seen that the wavelength of PEO is longer than that of water.

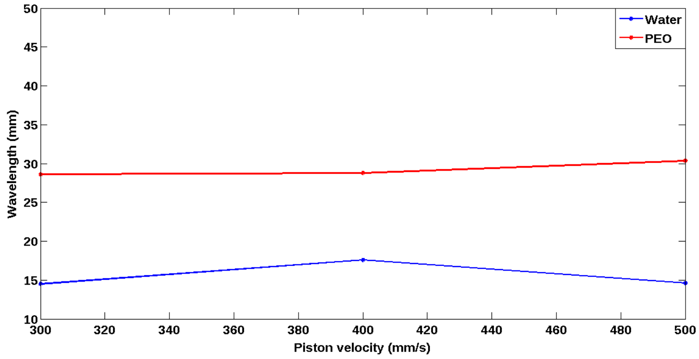

Figure 2. Dye visualization - Wavelength of instability vs. Piston velocity

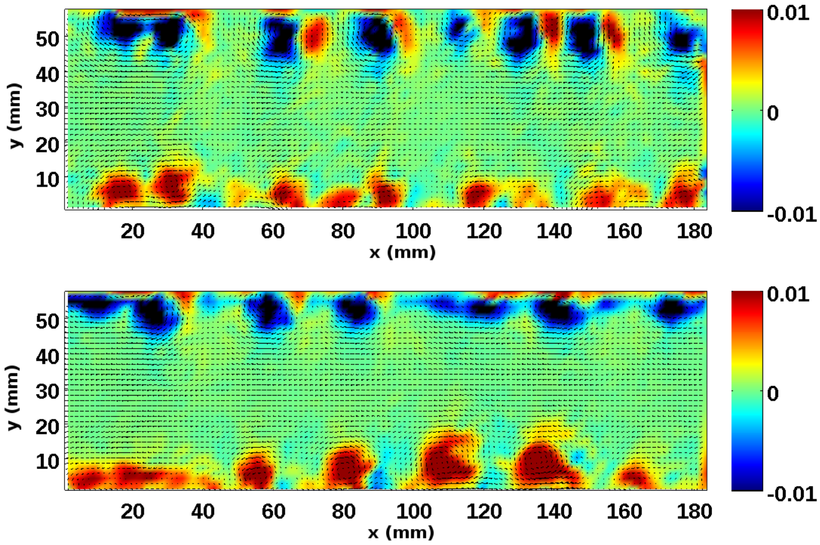

Figure 3. PIV - Vorticity field at velocity 500mm/s, stroke 250mm for water (top) and PEO (bottom), 1.5s after stopping piston

PIV is performed to quantify the observations of dye visualization experiments. Fluorescent particles are used in conjunction with a long pass filter in order to remove the reflections caused by the pipe. The above figure shows a snapshot of the vorticity field taken at 1.5 seconds after the piston was stopped at constant impulse. The water snapshot shows counter rotating vortices (at the top of the pipe), whereas the PEO snapshot shows that the counter rotating vortices are absent. The absence of the counter rotating vortices can explain the increase in wavelength of PEO.

In addition to the above experiments, the forward motion of the piston is being solved for polymer solution case using a laplace transform technique [1]. This will provide an analytical framework to the inflectional velocity profiles that are observed. A stability analysis is also being performed on these velocity profiles in order to decipher the role of the polymer additives on the stability of the flow.

References

[1] DEBOPAM DAS and JAYWANT H. ARAKERI. Transition of unsteady velocity profiles with reverse flow. *Journal of Fluid Mechanics*, **374**:251–283, 11 1998.