Vortex enhancement in streaming with viscoelastic fluids

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Oscillations of immersed bodies are known to generate steady streaming flows, originating from Reynolds stresses within the viscous boundary layer in the vicinity of the object. This phenomenon is very similar to acoustic streaming generated by sound or ultrasound waves within a fluid. Streaming flows have applications in fluid homogenization and mixing especially in microfluidics, in heat transfer enhancement, in particle sorting or in fluid pumping. A typical situation is that of a cylinder oscillating perpendicularly to its axis, generating two pairs of counter-rotating vortices due to the transfer of vorticity from the inner boundary layer. Outer vortices can be observed far from the object as a result of convection of vorticity [1]. Here, we consider the situation of a viscoelastic fluid : by using PIV, we carry out an experimental study of the streaming flow structure and magnitude varying both the amplitude and frequency of the cylinder oscillations. The fluid (HPAM + 1% NaCl) is chosen such that the relaxation time of its extensional viscosity is of the same order as the period of oscillations.

A systematic comparison with a purely Newtonian fluid has been carried out and results showed several qualitative differences. First, when elasticity is significant enough, we observe that the inner boundary layer vortices are much larger than for a Newtonian fluid of the same viscosity. This is generally associated to the disappearance of outer vortices. We propose that extensional viscosity is involved in the enlargement of inner vortices (Figure 1).

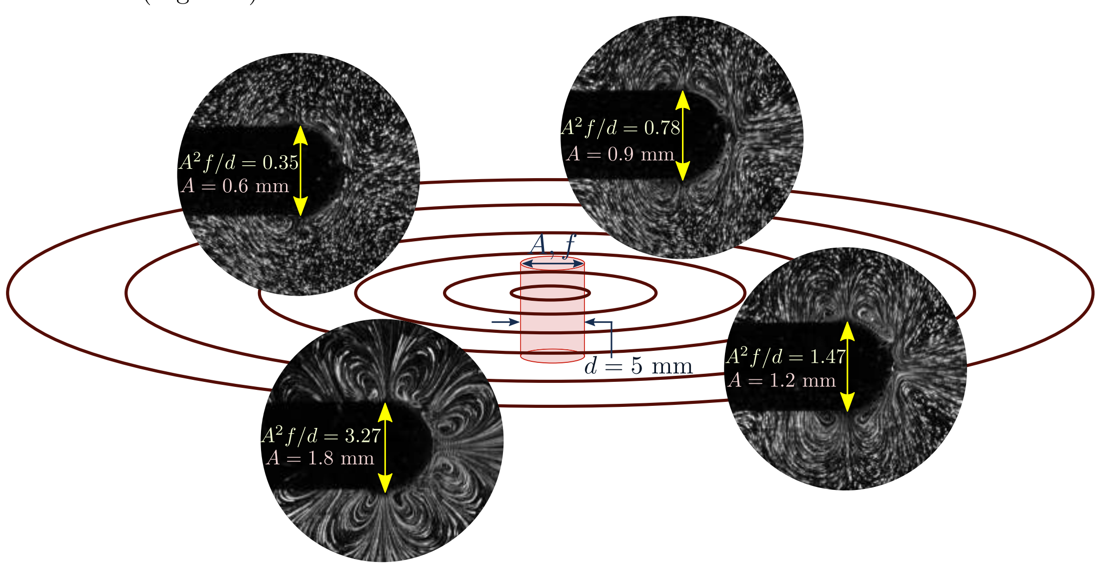

Figure 1. Enlargement of inner vortices within the secondary steady flows for $f = 20$ Hz.

Second, for strong enough forcing, the streaming flow moves away from the usual the four-vortices pattern. Indeed, a more complex structure can appear where each initial vortex splits into two smaller ones, showing a steady multiple vortices structure. To the best of our knowledge, these phenomena were unobserved so far.

Références

1. S. A. Bahrani, N. Périnet, M. Costalonga, L. Royon and P. Brunet, Exp. Fluids **61**, 91 (2020).