4. Stability of an Axisymmetric, Laminar Flow of Two Liquids.

Ranz [28] suggested that mixing of liquids widely differing in viscosity and density can be strongly retarded by the flow instability. A strict analysis of destabilization of deforming flows performed by Hickox [55] (in a context of fluid dynamics) explains how and why the segregated structures can grow. However, there is still a lack of experimental evidence in the literature, confirming these theoretical predictions. In this chapter such evidence will be provided and interpreted theoretically on the basis of the method of small perturbations and the linear stability analysis. The investigations are concerned with the stability of a steady, laminar and axisymmetric flow of two Newtonian, incompressible and fully miscible liquids.

4.1. Experimental System and Experimental Procedure.

The experiments were conducted in a on-line mixer shown in figure 4.1. The mixer consisted of: a reservoir (1) of capacity 10 dm^3, a connector pipe (2), a cone-shaped nozzle (3), a dosing pipe (4), a flexible hose (5) and a syringe (6) of capacity 0.3 dm^3.

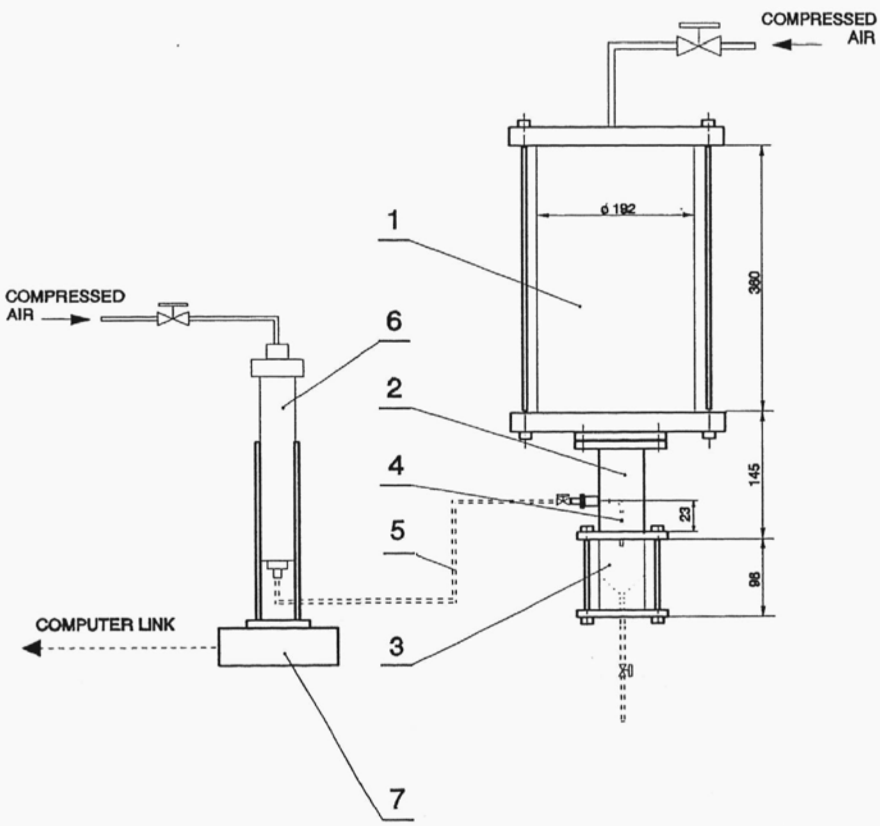

Figure 4.1. Scheme of the on-line mixer.

The nozzle and the reservoir were made of plexiglass, whereas the connector pipe was made of stainless steel. The dosing pipe was made of copper mounted to a leak-proof brazen socket connecting it with the polypropylen syringe via the silicon hose. The liquids were fed into the mixer from the reservoir and the syringe using a compressed air. The core-annular flow was formed in the cylindrical part of the mixer and then stretched in the cone-shaped section of the nozzle (figure 4.2). The reduction of the flow cross-section area was 1:100. Afterwards, the liquids were flowing out through a cylindrical tube. The overall flow rate through the mixer was measured by weighing the outflowing liquid, collected during a specified period of time. The discharge rate of the syringe was determined from the loss of its weight detected by a balance (item 7 in figure 4.1) and recorded by a computer.

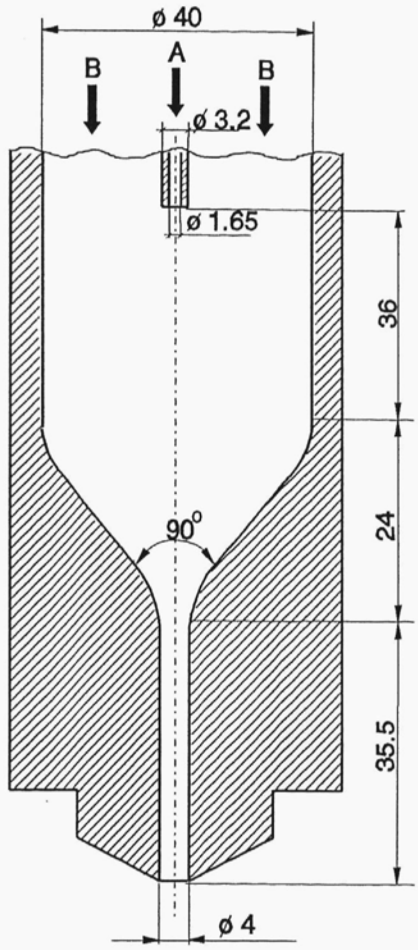

Figure 4.2. Mixer nozzle.

Each series of the experiments was started from filling the nozzle, the connector pipe and the reservoir with a solution composed of water, starch syrup as the viscosity increasing agent and sodium thiosulfate. The syringe was filled up with a solution containing water, starch syrup and iodine. Optionally, potassium iodide was added to iodine solution to increase its density. In all experiments density of iodine solution was either equal to or slightly higher than density of thiosulfate solution. After initiating the flow from the reservoir, the syringe was placed on the balance, pressure applied to it and the stop-cock at the connecting hose opened letting iodine solution to flow into the mixer nozzle. When the flow rates were stabilized at the desired levels, the shape of a black iodine stream flowing out from the dozing pipe was photographed. The experiments were conducted at T=20°C.

To compare flow of liquids of the same viscosity and density with the flow of liquids differing in viscosities and densities experiments were carried out for both kinds of systems.