# Variety of interfacial patterns in miscible fluids induced by vibrations

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*Summary*. A system of two miscible liquids layers is set into motion via imposed horizontal vibrations along its interface. Depending on amplitude and frequency of vibration and the gravitations level the interface pattern is prone to departure from its equilibrium state and to the consequent development of wavy structures. This problem is investigated experimentally and numerically in ground experiments and under microgravity conditions of parabolic flight. In a gravity field, a spatially periodic saw-tooth frozen structure is generated in the interface which dissipates at long times. By contrast, under the low gravity conditions of a parabolic flight, the long lived pattern consists of a series of vertical columns of alternating liquids.

## Introduction and general problem

Interfacial instabilities occurring between two fluids are of fundamental interest in fluid dynamics, biological systems and engineering applications such as liquid storage, solvent extraction, oil recovery and mixing, in particular, in microfluidic geometry. The topic of our study is dynamics miscible liquid/liquid interface subjected to vibration with direction which is perpendicular to the concentration gradient under reduced gravity conditions. The aim of this investigation is concerned to space experiment VIPIL (Vibrational Phenomena in Liquids) which is devoted to the analysis of instabilities in systems composed by two layers of miscible/immiscible liquids. Recent experiments [1- 4] presented evidence that an interfacial instability exists between two miscible liquids of similar (but non-identical) viscosities and densities.

The considered system has two layers of binary mixtures of the same constituents (water–alcohol mixtures of different percentage): 90% (mass) of water in isopropanol and a 50% (mass) of water in isopropanol. The imposed vibrations have been chosen for frequency and amplitude within the ranges 2–24Hz and 1.5–16mm, respectively and directed horizontally along the interface initial disposition. The both liquids are injected into the transparent cell (15.0mm×7.5mm×5.0mm) simultaneously by two identical syringe pumps through the orifice at the bottom (the denser liquid) and top (the lighter liquid) walls. Our experiments have been performed in Earth gravity conditions and during 59$^{th}$ and 60th ESA parabolic flight campaigns.

## Results and discussion

Our study demonstrates that vibrations produce deformations of the interface as well as an oscillatory flow in the bulk and mean flows. Viscous mean flows are coupled dynamically with the evolution of the surface waves. Consideration of averaged equations and mean flows suggested a physical explanation to the emergence of waves along the contact line. Three distinctive regimes of the mean flow, repeating over time, allow not only to reveal the mechanism of wave formation, but also to shed light on the modulation of the interfacial waves. The situation is strikingly different when vibrations are applied to the system under reduced gravity. After the formation of the waviness in the interface, the growth of the amplitude does not stop, but continues until the interface reaches the upper/bottom wall. The vibrational Froude number can be used as the control parameter for miscible fluids. In the Fig. 1 the results of experiment in ground and microgravity conditions are presented.

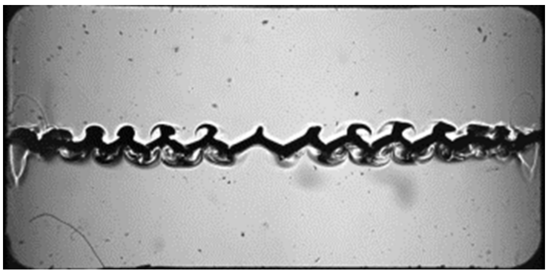
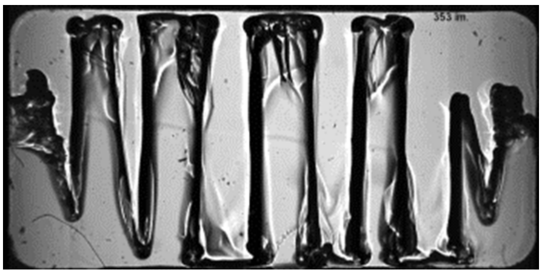

Fig. 1. Pattern in gravity when f = 22.5 Hz, A =3.64 mm (left) and microgravity when f = 20 Hz, A = 4.08 mm (right) experiments for the comparable Froude numbers.

In addition, a new generic type of pattern generated by bounding walls on the interface between miscible liquids. At the threshold of interfacial instability, a competition develops between the new “fishspine” pattern and frozen waves, while above the threshold these two kinds of patterns may coexist in spatially separated domains. A theoretical model for the formation mechanism of the fish-spine pattern and its spreading along the interface are proposed in [3]. The results corresponding to this instability are shown in Fig.2. The snapshots, presented at the same phase of oscillations, allow us to recognize that the freshly born wave near the wall (marked with arrows) has a shape and amplitude similar to those observed during the previous oscillation period.

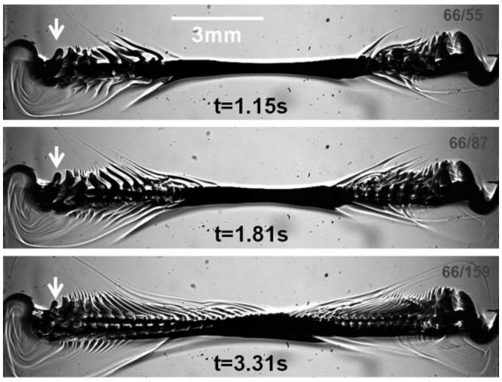


Fig. 2. Evolution of the flow pattern for the case of large amplitude below the onset of interfacial instability; f = 6 Hz and A = 16.60 mm

## Acknowledgements

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## References

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