PROPOSITION DE STAGE – MASTER 2 DET
Dynamique des fluides, Energétique et transferts
Université Toulouse 3 Paul Sabatier - Toulouse INP - INSA Toulouse - ISAE SUPAERO – IMT Mines Albi

Titre : Initiation of wind waves on viscous fluids

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Durée / période : 5 mois

Candidature [CV, lettre de motivation, références] à envoyer à : R. Mathis (romain.mathis@imft.fr)

General context

Waves are more the rule than the exception at sea surface, and observation of mirror-like surfaces are rare. It would be erroneous to assume that the surface remains entirely flat at low wind velocity. Indeed, even for moderate wind velocity, the flow in the air is unavoidably turbulent, and there are small surface deformations, which we call wrinkles (see figures 1 and 2), which are the imprints at the surface of the turbulent structures (streaks, streamwise vortices) traveling in the boundary layer. Yet a comprehensive understanding of the incipient wave generation process at the surface of a liquid under the action of a tangential gas flow has not been achieved. This knowledge would be valuable for wave forecasting and evaluation of air-sea exchanges of heat, mass and momentum on Earth [1], but also on natural satellites – see the recent debated issues on the observation of waves on hydrocarbon lakes on Titan [2]. Waves at gas-liquid interfaces are of practical importance in many engineering applications, such as coating (jet wiping), glass manufacturing and processing, cooling of solidifying surfaces, two-phase flows in ducts or gas transport in pipes [3]. Although interfacial wave generation under applied surface stress has inspired over a century of research, it still represents a standing challenge [4]. During the last decade, studies in turbulent boundary layer (smooth, rough, with or without pressure gradient) have shown that the large-scale coherent motions influence significantly the near-wall region as well as the wall shear-stress [5]. Recent investigations also suggested that these interactions are in turn influenced by the free-stream turbulence [6]. It is then natural to question how these structures act on the development of the waves.

Figure 1: Example of wrinkles generated by the wind at the surface of a lake.

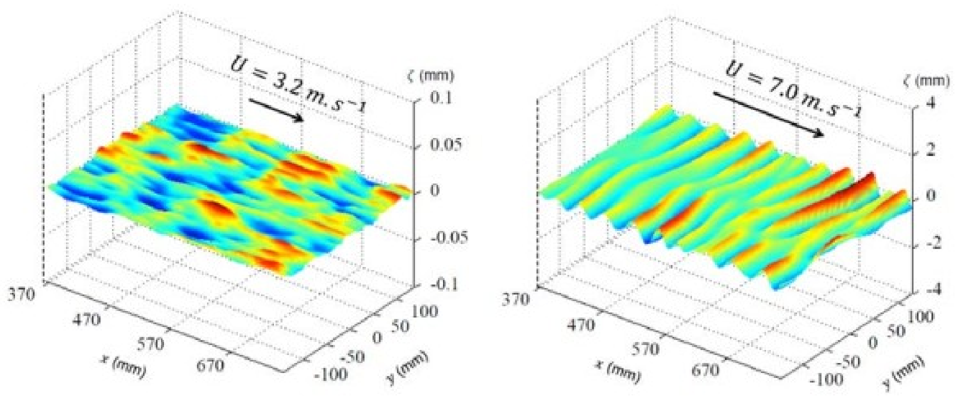

Figure 2: Instantaneous interfacial deformation measured by Free-Surface Synthetic Schlieren, in the wrinkle regime (left) and in the wave regime (right) [7]. Note the change in the vertical scale.

Objectives

The aim of the present project is to investigate how modifying the turbulent boundary layer may affect the onset velocity for wave amplification. More precisely, is it possible to decrease or increase the onset velocity by simply changing the nature of the incoming flow, in particular the turbulence level or geometrical features of the boundary layers? If the answer is yes, this would imply that, for given fluid properties, the wind velocity is not the single control parameter for the wave onset, which may explain the large uncertainty reported in the literature for the onset velocity in the classical air-water configuration. For this purpose, we are developing a new experiment aimed at modifying the properties of the incoming turbulence by using an active grid to control the level of the turbulence of the free-stream flow. These experiments will be performed in a closed-loop wind tunnel facility at IMFT for which a liquid tank is mounted on the bottom of the test section. Measurements will range from hot-wire anemometry (level of turbulence) to high-quality Particle Image Velocimetry systems (Free-Surface Synthetic Schlieren - see figure 2).

Skills requirement

On the scientific part of the problem, fluid mechanics and signal processing knowledges will be necessary. The project is mainly experimental, therefore good practical sense and organisation are required. Matlab will be use to drive the data aquisition during fluid mechanics measurements, as well as for the data post-processing. Knowledges of this software would be then a benefit.

References

[1] P. Janssen. *The interaction of ocean waves and wind*. Cambridge University Press, London, 1 edition, 2004.

[2] A.G. Hayes *et al.* Wind driven capillary-gravity waves on titans lakes: Hard to detect or non-existent? Icarus, 225(1):403 – 412, 2013.

[3] T. J. Hanratty. *Physics of Gas-Liquid Flows*. Cambridge University Press, London, 1th edition, 2013.

[4] P. P. Sullivan and J. C. McWilliams. Dynamics of winds and currents coupled to surface waves. *Annu. Rev. Fluid Mech.*, 42:19 – 42, 2010.

[5] R. Mathis, I. Marusic, S. I. Chernyshenko, and N. Hutchins. Estimating wall-shear-stress fluctuations given an outer region input. *J. Fluid Mech.*, 715:163 – 180, 2013.

[6] E. Dogan, R. Hanson, and B Ganapthisubramani. Interactions of large-scale free-stream turbulence with turbulent boundary layers. *J. Fluid Mech.*, 802:79 – 107, 2016.

[7] A. Paquier, F. Moisy, and M. Rabaud. Surface deformations and wave generation b wind blowing over a viscous liquid. *Phys. Fluids*, 27:122103, 2016.