LIQUID FILM INSTABLITIES

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Jet wiping is a decisive operation in coating industries using dipping techniques. A liquid film is dragged on the surface of a moving web, and undergoes the effect of air knives created by two-dimensional slot nozzles. The excess liquid flows back to the coating bath, and the final film thickness is reduced and controlled through the wiping parameters. Productivity gains are limited by the occurrence of free surface instabilities downstream the wiping jet. They appear as rippling over the free surface of the film, as shown in figure 1. The final coating aspect being closely related to its stability in the liquid state, those instabilities are generally harmful to the coating quality, which requires high uniformity and smoothness. The detailed analysis of the wave patterns and its description (wavelength, amplitude, velocity) is unavoidable for the understanding of the instability mechanism, and a better control of the coating process.

The aim of this thesis is to identify and quantify the triggering factors of the instability, which are evidently related to the impacting air jet. The second step is to evaluate the wiping conditions that allow minimizing the phenomenon without altering the efficiency of the wiping process.

For that purpose, an experimental investigation is performed on a model test facility where a rotating cylinder simulates the moving strip. The most distinctive features of the unstable film being its very low absolute thickness (100-800 µm) and its high frequency content (10-100Hz), the development of measurement techniques for that type of flow remains challenging since they have to fulfill the subsequent requirements in terms of time and spatial resolution. A number of techniques have been developed, which includes visualization by light reflection, laser triangulation, and a method based on light absorption. The effect of different wiping parameters on the wave characteristics is investigated. The occurrence of distinctive wave regimes, as illustrated in figure 1, is found to depend on the dimensional distance *Z* between the nozzle and the substrate. The spectral analysis of the gas jet velocity flow field shows that in the presence of a liquid film, the dominant fluctuation frequencies of the jet drop to very low values with respect to the case of a jet impinging on a dry surface (figure 2). It is thus inferred that there exists a strong interaction mechanism between the liquid film and the incoming gas stream. Regarding the theoretical approach, the amplification factor and group velocity of long-wave perturbations are derived analytically through linear theory, using the regular perturbation method. A dimensionless instability criterion is derived in terms of film Weber number, which is in reasonable agreement with the dominant wavelengths observed experimentally for given wiping conditions.

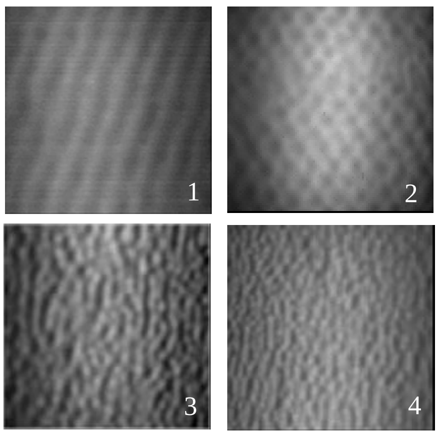

Figure 1: Typical images of rippling for Z≤12 mm (1 and 2), and Z>12 mm (3 and 4).

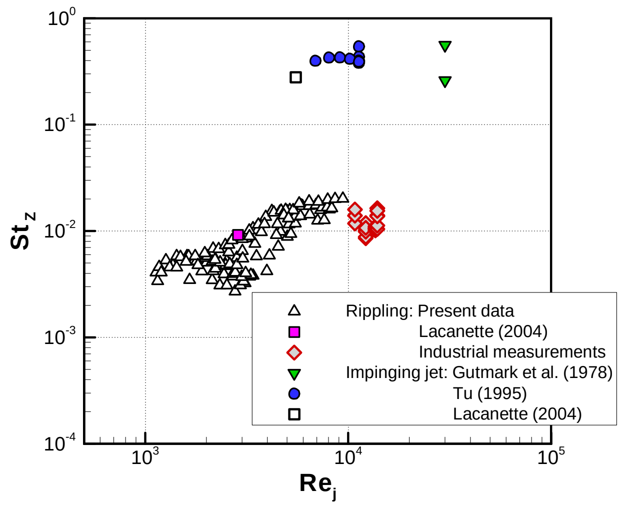

Figure 2: Comparison of the Strouhal number of ripples on wiped liquid films (experiments), and the Strouhal number corresponding to the dominant frequencies of impinging jets on dry surfaces (literature).