A Research Methodology to Study Jet Wiping Processes

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This paper presents the research methodology followed at the von Karman Institute (VKI) to study jet wiping. In this process, a strip is withdrawn from a bath of liquid and then wiped by impinging gas jets to control the final coating thickness.

The final products demand high surface quality and production rates. However, the achievable coating uniformity is limited by the formation of surface wiggles. Several hypotheses on the origin of these free surface undulations have been formulated over the last decade: they have been attributed to the instabilities of the liquid interface, to vibrations of the steel sheet or to the buckling of the impinging jet [1-4]. Nevertheless, the underlying physics remains poorly understood and requires systematic investigation. The methodology developed at VKI aims to capture the physical mechanism responsible for coating undulation by studying the jet wiping process on a set of simplified scenarios, each of which providing an insight on the phenomenon from a different perspective.

The research started on a laboratory scale model of the industrial line, using an air jet as wiping knife, a large rotating cylinder entraining the liquid film, glycerine and dipropilene glycol as working liquids. The facility was equipped with a Light Absorption test section for film thickness characterization and Hot Wire Anemometry for jet frequency analysis. This configuration was used to reproduce the undulation phenomenon, characterize the different patterns as a function of the process parameters, and study simultaneously frequency content of the gas jet and the liquid film.

This configuration was also reproduced on a 3D simulation in OpenFOAM, using VOF to track the liquid interface and LES to simulate the turbulent gas jet flow. The simulation predicted a coating undulation pattern in agreement with the experimentally observed and captures a hydrodynamic feedback between the impinging jet and the unsteady confinement due to the wiped, runback, liquid flow.

To test whether the pulsations in the runback flow are a triggering source or a consequence of the hydrodynamic feedback, a second laboratory model was designed: it consists of a slot air jet impinging on a liquid film falling along a fixed wall, with a flow rate pulsing at controlled frequencies and amplitudes. The resulting thickness perturbations were characterized using Light Absorption, while the impingement was analyzed with three dedicated experimental techniques: Level Detection and Recording (LeDaR) for liquid interface tracking, Image Processing Thresholding (IPT) for jet centerline monitoring and Particle Image Velocimetry (PIV) for flow field analysis. The results have shown that the impingement instability originates from the asymmetric confinement of the gas flow and confirmed that the hydrodynamic feedback between the two flows relies on recirculation structures bounding the wiping jet.

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