# Empirical Scaling Analysis of Atomising Annular Liquid Sheets

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**Abstract**

Annular liquid sheets are canonical, unstable multiphase shear flows. Many numerical, theoretical and empirical investigations of such flows have been undertaken, however agreement between studies is limited. This is due in part to the lack of agreed definitions for the gas-liquid momentum scaling and the lack of a canonical geometry, among other factors. Few scaling theories for the periodic driving instability that characterises the atomisation mechanism have yet been proposed which show repeatability between different experimental studies. There have been particularly few investigations into sheet thickness effects, due to the difficulty of manufacturing a test nozzle with a variable thickness. We present a large, parametric, experimental study of a non-swirling annular water sheet exposed to separately metered dual air co-flows over an order of magnitude variation in Reynolds and Weber Numbers. Three sheet thicknesses and a wide range of gas co-flow rates have been considered. We have considered a temporal analysis of the primary interfacial instability using Fourier techniques. From empirical data, a geometry-independent temporal scaling based on a non-dimensional momentum ratio is proposed, which shows good agreement with empirical data on low pressure air-water annular flows over a range of geometries, Re & We. This scaling is counter-intuitively different from that of the more well-known planar sheet. Through the use of Dynamic Mode Decomposition, the leading Koopman modes of the primary instability provide a spatially resolved reconstruction of the spatial growth rate and amplification profile of the instability. Sheet thickness effects are observed to dominate over all other scaling variables with regard to the amplitude of the instability, within the limits of experimental error. We demonstrate a comparison between the empirically derived complex wavenumber and linear stability analysis. The measured wavenumber approaches the linear solution as we move toward the nozzle. The temporal scaling of annular sheets may follow a predictable scaling, but the spatial scaling behaviour shows a much more complex behaviour dominated by sheet thickness effects due to both non-linearity and non-parallelism.

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