FLOW TRANSITION AND MASS TRANSFER IN SINUSOIDAL WAVY DUCTS

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Flow channels consisting of sinusoidal corrugated plates in free-flow arrangement are characterized through an almost constant duct spacing. Such structures find a large field of application i.e. as plate heat exchangers for fluids containing fibers and particles, as they are especially found in the area of food technology, but also in numerous other technical applications.

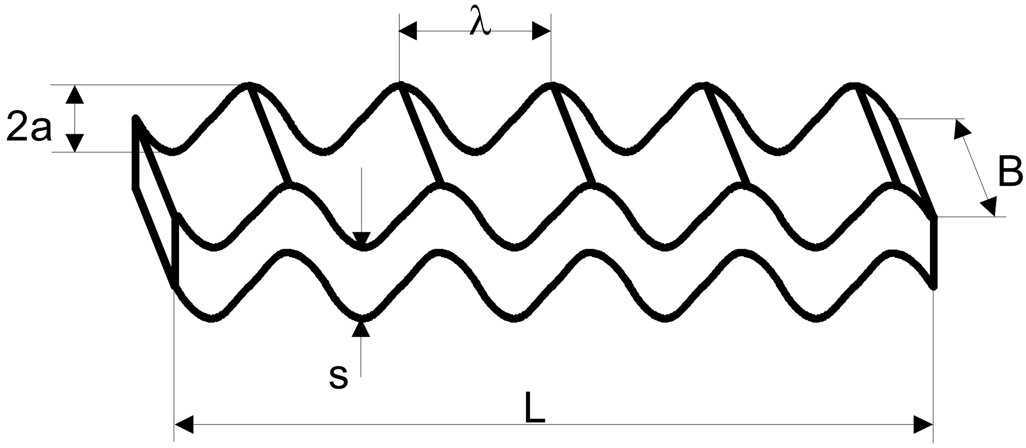

Figure 1: Sinusoidal wavy duct in free flow arrangement.

In the concave part of sinusoidal wavy ducts in free-flow arrangement for small spacings a flow instability can be observed experimentally, leading to longitudinal vortices comparable to the Görtler-instability at concave walls (Görtler[1], 1941) or the Dean-instability (Dean[2], 1928) in tube flows. The development of these vortices over the flow length as well as the flow phenomena for varying Re-number and the influence of corner vortices is visualized.

Figure 1 shows a scheme of the sinusoidal wavy duct used for visualization with constant wavelength λ = 76 mm, amplitude a =9 mm, the dimensionless wavelength λ/a = 8.45 and the duct height s= 18. The Reynolds number (based on the duct height s) is varied in a wide range 50 -2.000 with air as working fluid. For the flow visualization a laser-sheet-technique with a 150 mW argon-ion-laser was employed using a transparent channel. Flow was visualized in flow and spanwise direction.

The longitudinal vortices appear in pairs for small spacings, are small after their generation and grow to a constant size along the flow length of the concave channel. In the following wall region they are dampened again. This amplification and dampening mechanism leads to their mostly regular alternating phase shift appearance in two succeeding waves. Specific regions exist in the channel, where the vortices on top and bottom wall oppose each other (are in phase) and other regions exist, where the vortices alternate to each other (have a phase shift).

A comparison with the effect of the flow on the near-wall mass transfer is made. For the visualization and determination of the local mass transfer in gas flow a physico-chemical method is used based on absorption, chemical reaction and coupled colour reaction (Kottke and Blenke[3], 1978). The surface is coated with a wet filter paper or membrane. The mass to be transferred (ammonia) is added as a short gas pulse. The locally transferred mass is visible as colour density distribution and the colour intensity directly corresponds to the locally transferred mass.

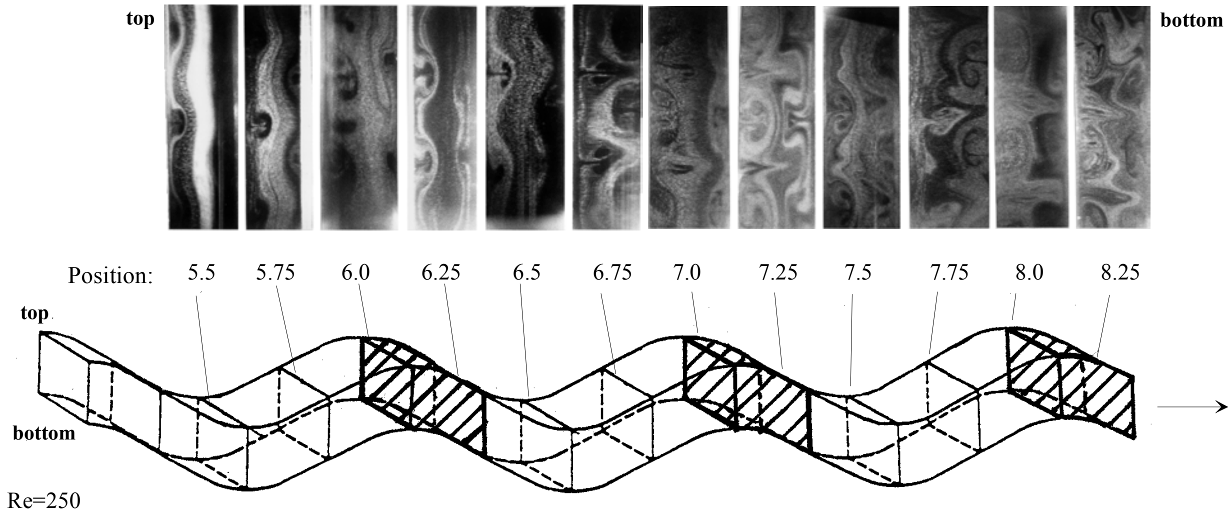

Fig. 2: Assignment of laser-sheets and channel positions, Re_s=250, λ/a=8.45, s/a=2.0, B/a=33.32.

For small Reynolds-numbers the flow is two-dimensional. In the transition region to turbulence the centrifugal instability leads to an amplification of longitudinal vortices over the whole duct length. These centrifugal forces, which amplify the vortex, can be described through the Görtler or Dean parameter in a stability diagram. The range of existence of the vortices in the Görtler-diagram is the larger, the larger the dimensionless wavelength λ/a is. With increasing λ/a the maximal s/a in the measured region, up to which longitudinal vortices can occur, also increases.

With rising Re-number the range of existence of the longitudinal vortices decreases constantly. For large wavelength λ/a and higher Re_s-numbers the vortices do not alternate between two succeeding waves. On the contrary, they can shoot through a number of wavelengths and larger wavelengths λ_v can appear, from which the transition to turbulence can be deducted.

Mass transfer is analyzed in the technical field of application. Pressure drop for the range of application is presented as well as the enhancement efficiency of these transitional structures on the heat and mass transfer, compared to the flat plate, evaluated with different criteria.

REFERENCES

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