Hydrodynamics and heat transfer in vertical falling films

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General properties of falling film units

• A thin liquid film flowing down an inclined or vertical wall

• Excellent heat and mass transport characteristics (large contact areas and high heat transfer at low flow rates)

• Numerous applications - food and pulp & paper industry

• Large units with long plates or tubes as heat transfer surfaces

• Energy intensive - improving the energy efficiency substantially improves the overall energy economy
Complex and challenging from perspective of fluid mechanics.
Goals

• Understand hydrodynamics and heat transfer of large-scale units

• Introduce measures for improving heat transfer – and understand possible improvements
Backflow

Curvature of the wave grows

Pressure gradient increases

Fluid is forced into internal recirculation (with a negative velocity)

Increased bulk mixing

(normalized film thickness)

(pressure gradient)

(streamwise velocity)
Measurements: laser + high-speed imaging

Synchronized film thickness measurements with high-speed imaging

Two observed waves have collided into a single larger wave
From measurements on smooth surfaces
And if modification of heat transfer surfaces is introduced...
...the results are promising
Wave dynamics significantly different in the two cases

**Modified** heat transfer surfaces

**Smooth** heat transfer surfaces
Possible explanation in the existence of **recirculation zones** after surface modifications

Surface modifications  ➔  Improved bulk mixing  ➔  Improved heat transfer

Negative velocity
Summary of improvement factors in heat transfer

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<th>kg/ms</th>
<th>0.120</th>
<th>0.275</th>
<th>0.473</th>
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<td>0 m</td>
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<td>0.5 m</td>
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Shape 1

\( t = 1, 1, 1.95, 1.66, 1.42 \)