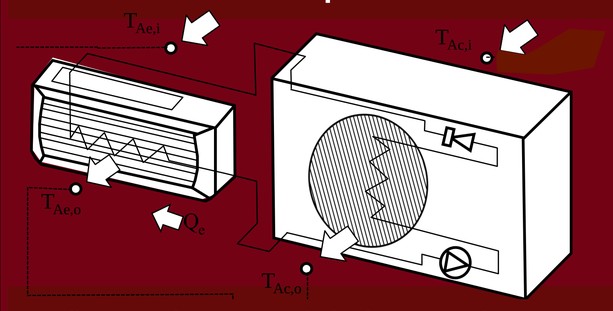
Niccolo` Giannetti

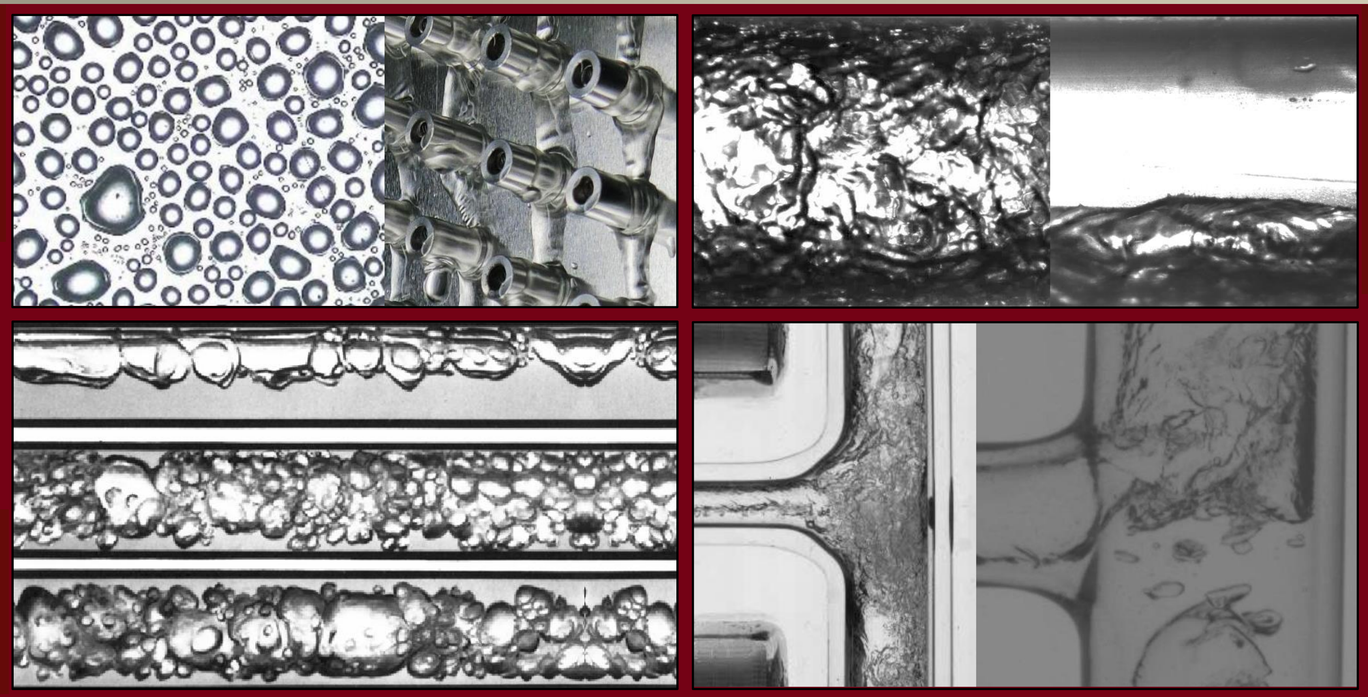
Waseda Institute for Advanced Study, Waseda University

A VARIATIONAL FRAMEWORK FOR OPTIMAL DESIGN AND CONTROL OF THERMAL SYSTEMS

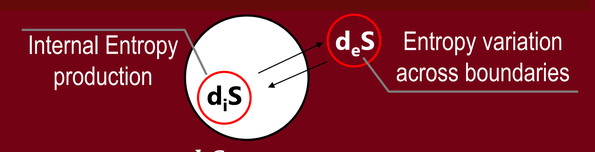
Design and control of thermal systems still relies on empirical models and trial & error procedures



Complex multiphase heat and mass transfer without a solid theoretical background

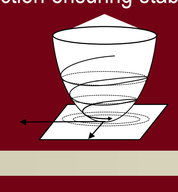


Variational principles of nonequilibrium thermodynamics may indicate the stability of dissipative processes



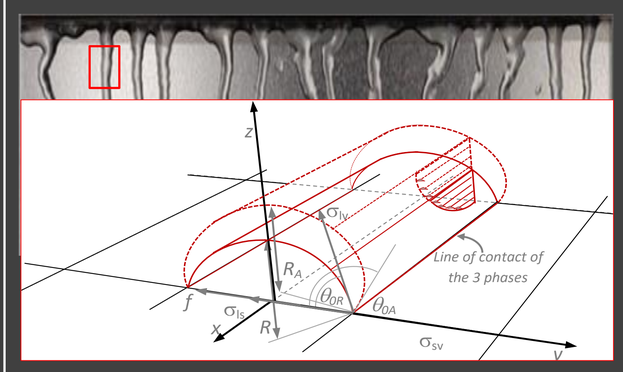
$$\frac{d_iS}{dt} = \sum_j J_j X_j \geq 0$$

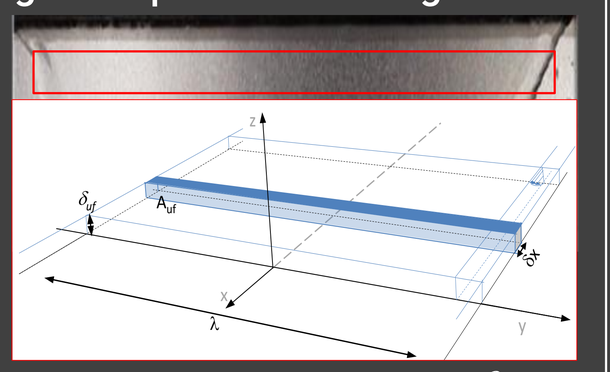
"For Linear nonequilibrium processes Entropy production is a Lyapunov function ensuring stability out of equilibrium"



| PURPOSE | Develop a general theoretical representation of the essence of thermal systems to support design and control development of this technology for its effective digitalization and efficient total energy management.

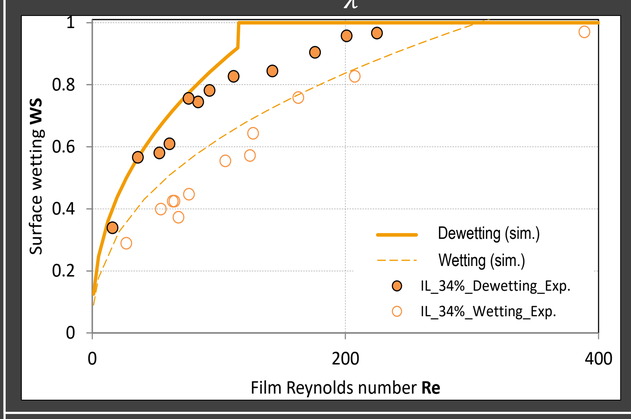
Variational model of falling-film partial wetting

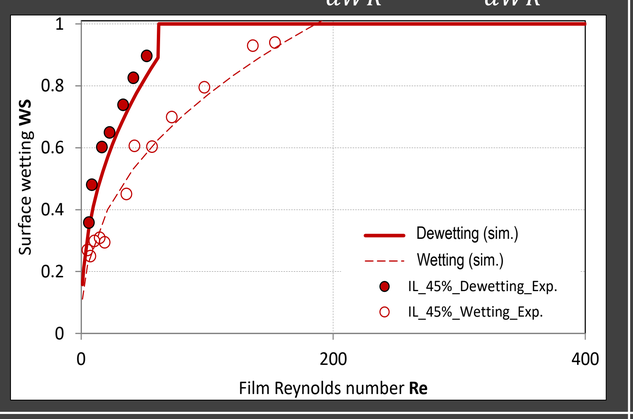




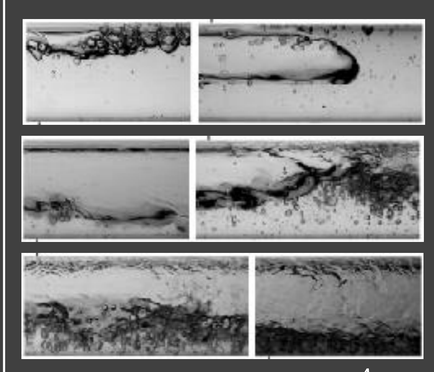
Wetting ratio $WR = \frac{2Rsin\theta}{\lambda}$

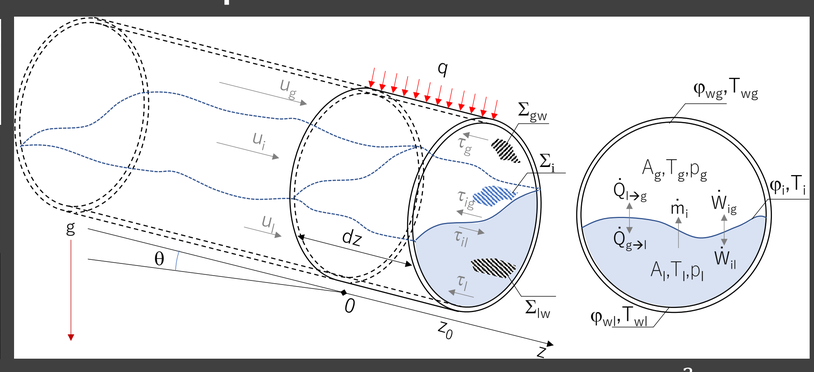
Rivulet and film stability and wettability $\frac{dE}{dWR} = 0\ ,\ \frac{d^2E}{dWR^2} > 0$





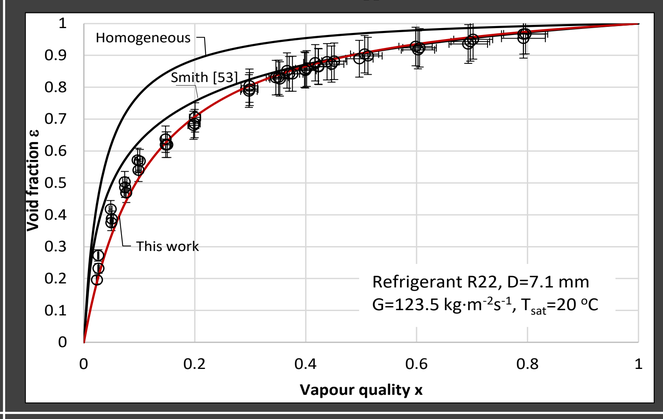
Variational model of two-phase flow void fraction

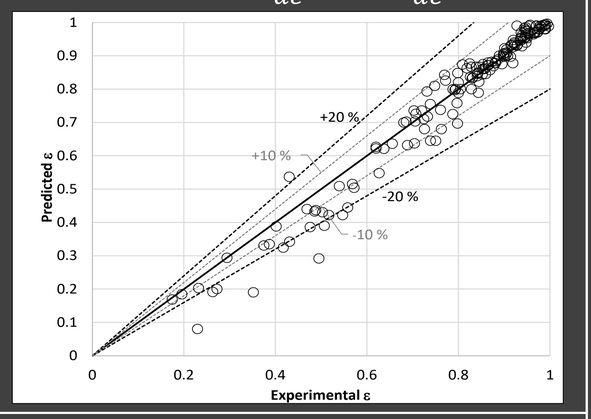




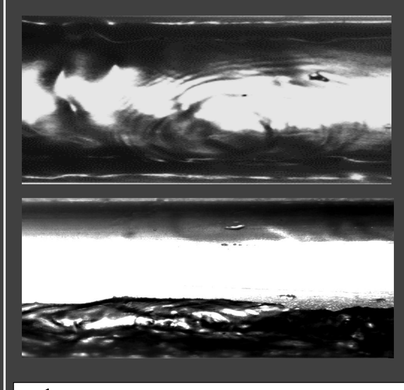
Void fraction $\varepsilon = \frac{A_g}{A}$

Void fraction stability $\frac{d_iS}{d\varepsilon} = 0\ ,\ \frac{d_i{}^2S}{d\varepsilon^2} > 0$





Variational model of two-phase flow regime transition



Stratified flow stability

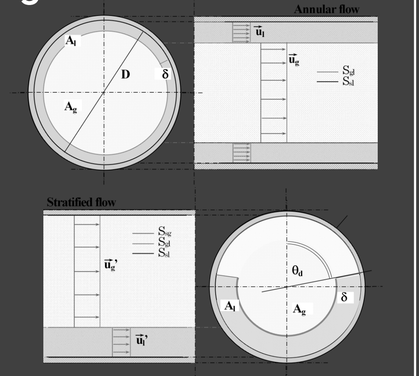
$$\frac{dE}{dWR} = 0\ ,\ \frac{d^2E}{dWR^2} > 0$$

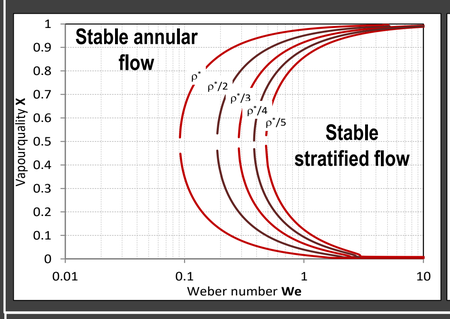
Annular flow stability

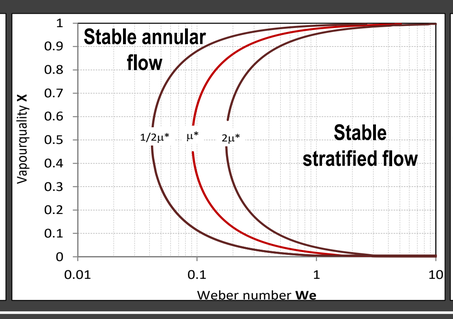
$$\frac{dE}{d\varepsilon} = 0\ ,\ \frac{d^2E}{d\varepsilon^2} > 0$$

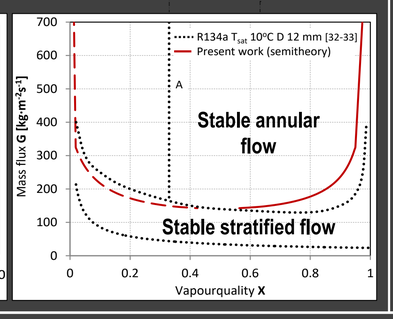
Flow regime transition

$$E_a(\varepsilon_{a,0}) = E_s(\varepsilon_{s,0}, WR_{s,0})$$

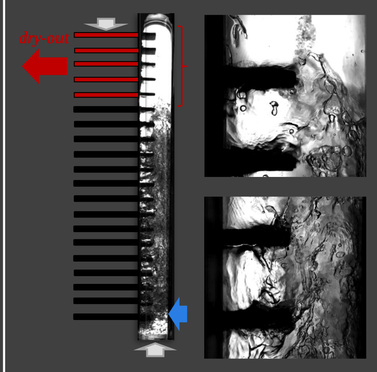








Variational model of two-phase flow distribution



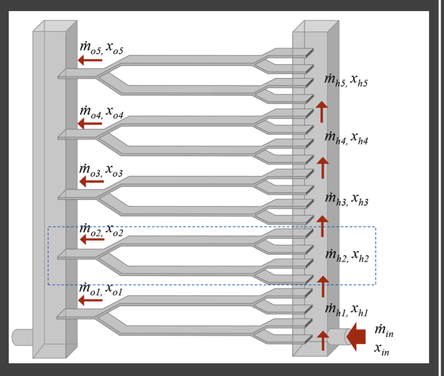
Distribution ratio

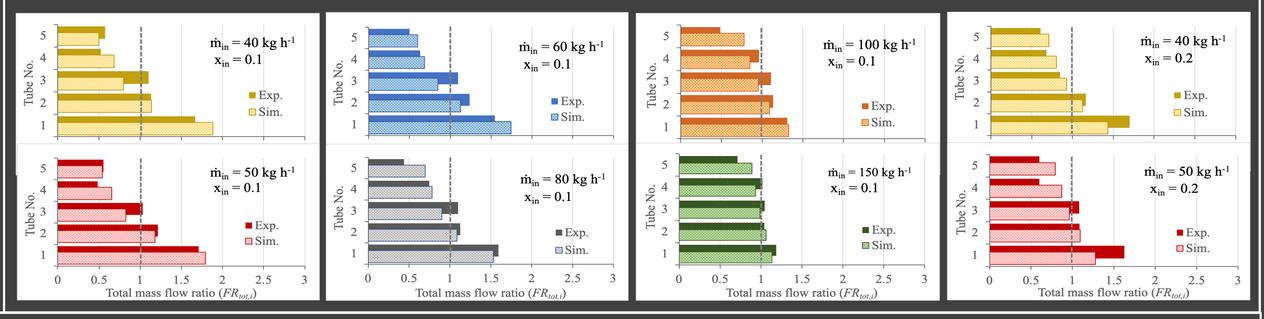
$$\Gamma_i = \frac{\dot{m}_{oi}}{\dot{m}_{hi}}$$

Flow rate and phase distribution

$$\frac{\partial_i S}{\partial \Gamma_2} = 0;\quad \frac{\partial_i S}{\partial \Gamma_3} = 0;$$

$$\frac{\partial_i S}{\partial \Gamma_4} = 0;\quad \frac{\partial_i S}{\partial \Gamma_5} = 0;$$

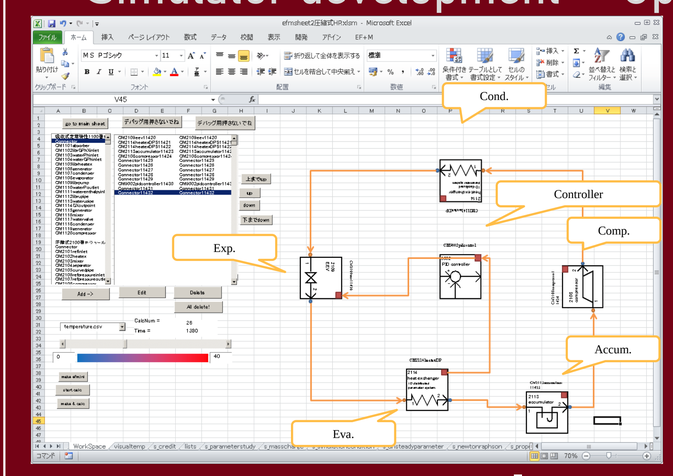


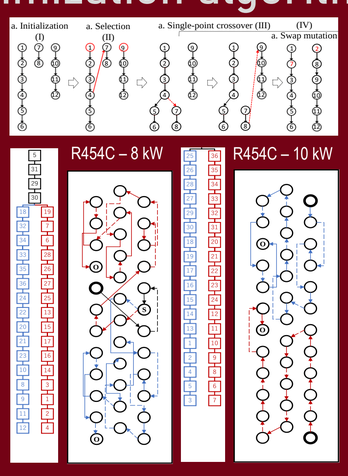


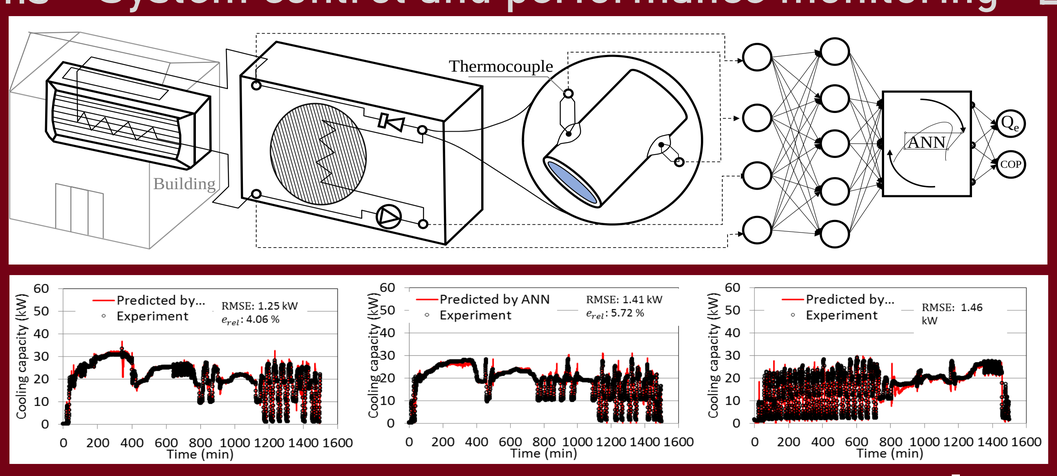
| CONCLUSIONS |

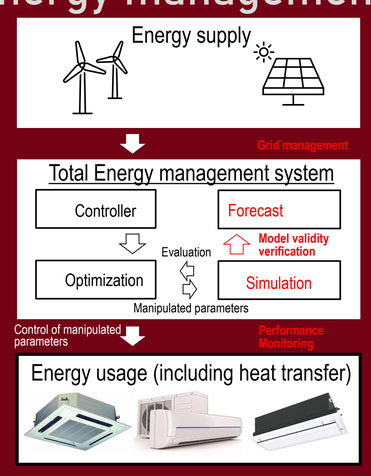
This research demonstrates the possibility of developing a general mathematical framework for the theoretical representation of the fundamental processes of thermal systems through the variational principles of nonequilibrium thermodynamics.

Simulator development | Optimization algorithms | System control and performance monitoring | Energy management









| Research developments and applications |

Integrating the developed models in a modular simulation platform enables components and systems design, analysis, optimization and control, ultimately improving the digitalization of these technologies and realizing total energy management.