A general method to predict the performance of brazed plate heat exchangers used in Organic Rankine Cycles

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Overview

- Context & Objective
- PHEX model
  - Methodology
  - Solver
- Validation
- Application to ORCs
- Conclusions

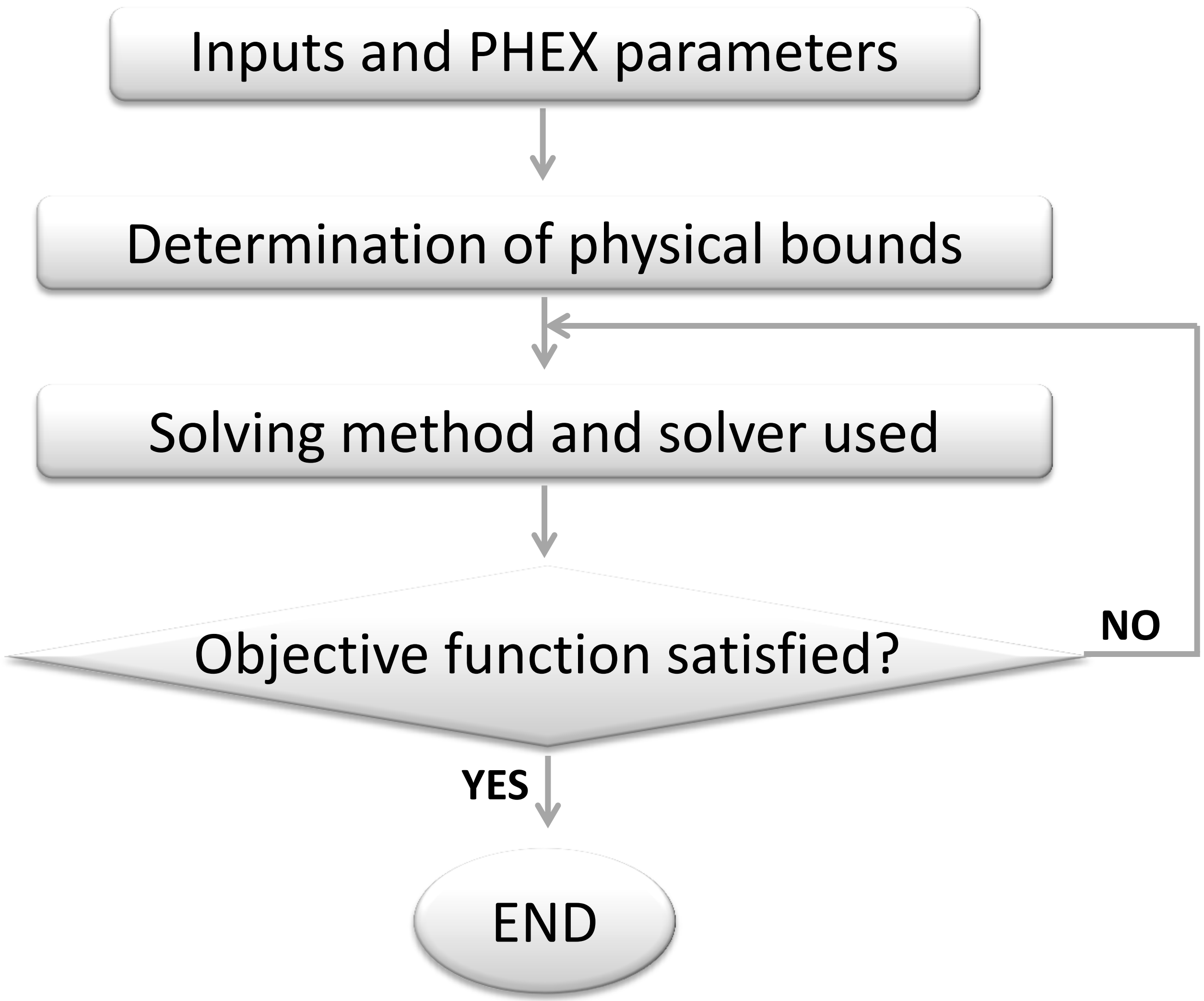
Context & Objective

- Brazed plate heat exchangers present different characteristics that make them suitable for use in ORC systems:
  - ✓ minimal risk of internal leakage,
  - ✓ compact design,
  - ✓ efficient heat transfers,
  - ✓ controllable pressure drops,
  - ✓ easy maintenance,

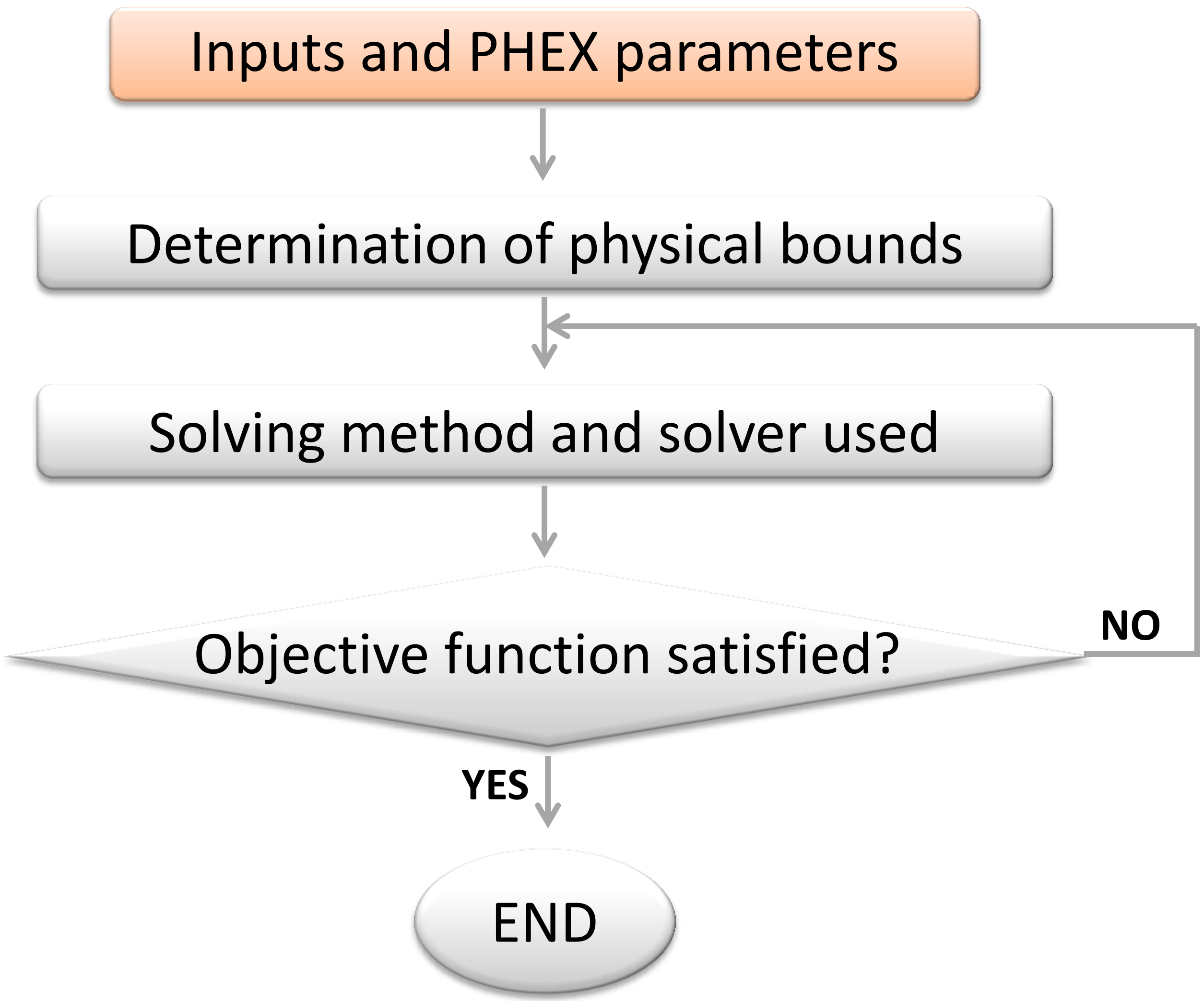
  and are therefore commonly used as the evaporator, condenser or regenerator.

- This work consists in the implementation of a unique solution to solve **moving boundaries brazed plate heat exchanger models** that allows handling **any flows configuration and steady state operating conditions possible** in the heat exchanger.

PHEX model - Methodology



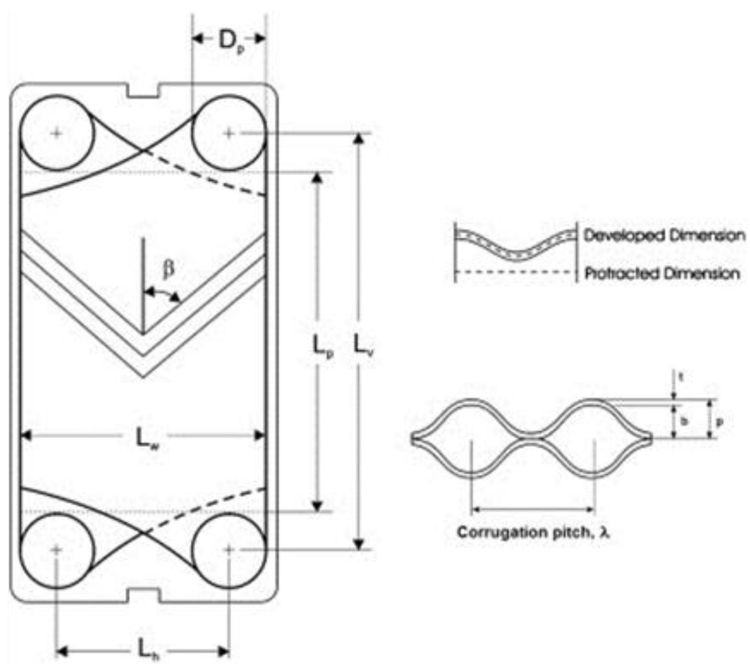
PHEX model - Methodology



PHEX model - Methodology

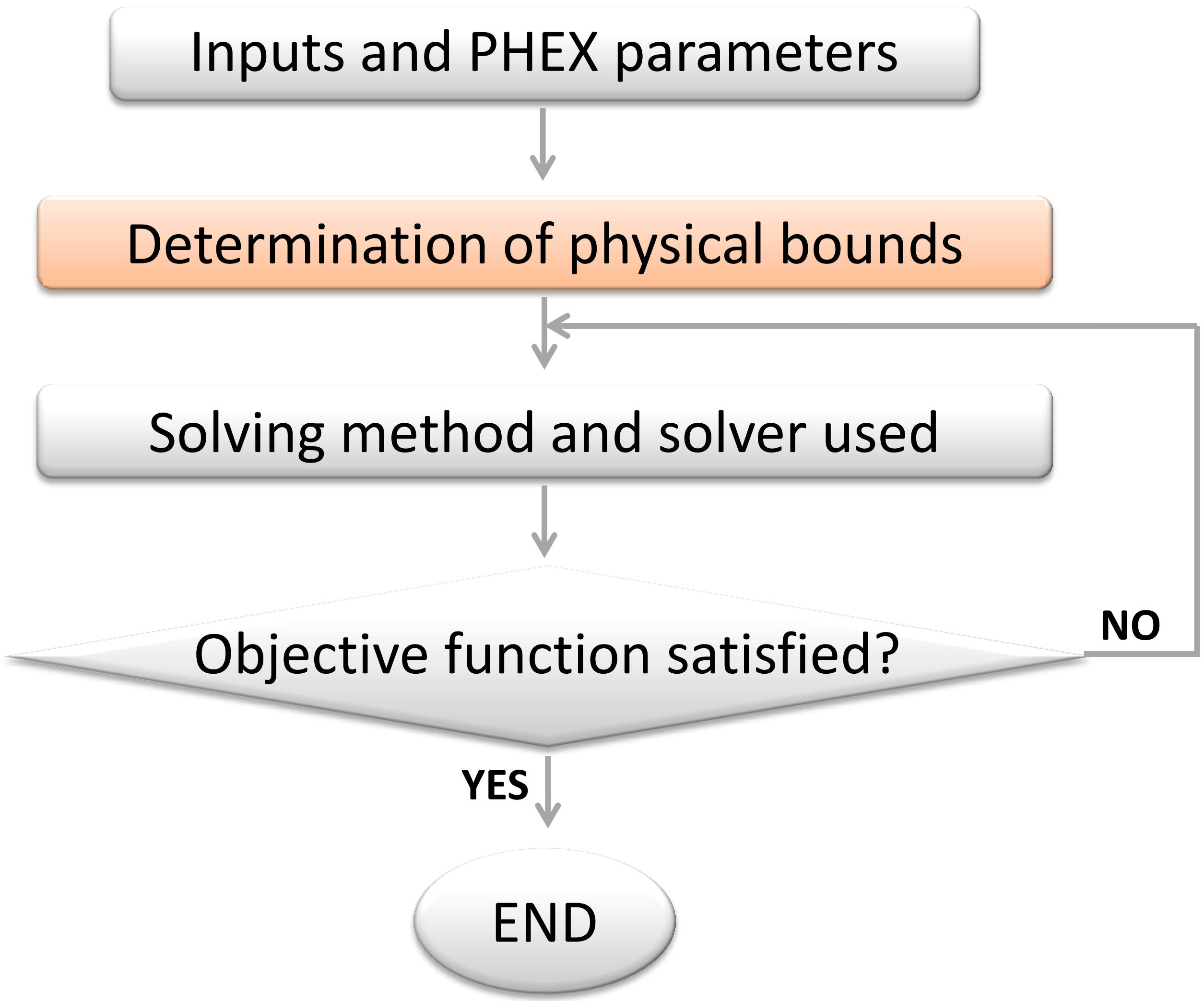
Inputs and PHEX parameters

- ❖ Inlet temperature on both sides
- ❖ Inlet pressure on both sides
- ❖ Mass flow rate on both sides



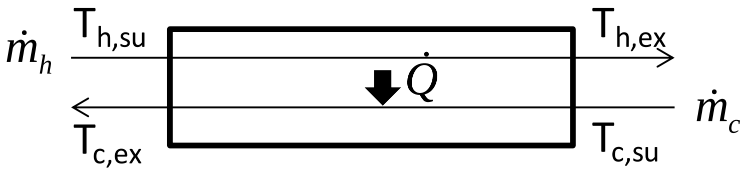
- ❖ Dimensions
- ❖ Number of plates
- ❖ Plates characteristics:
  - ✓ inclination angle,
  - ✓ conductivity,
  - ✓ amplitude,
  - ✓ wavelength.

PHEX model - Methodology



Determination of physical bounds

❖ Maximum heat transfer rate?



$$\dot{Q}_{\max} = \min\left[\dot{Q}_{\max,c} ; \dot{Q}_{\max,h}\right]$$

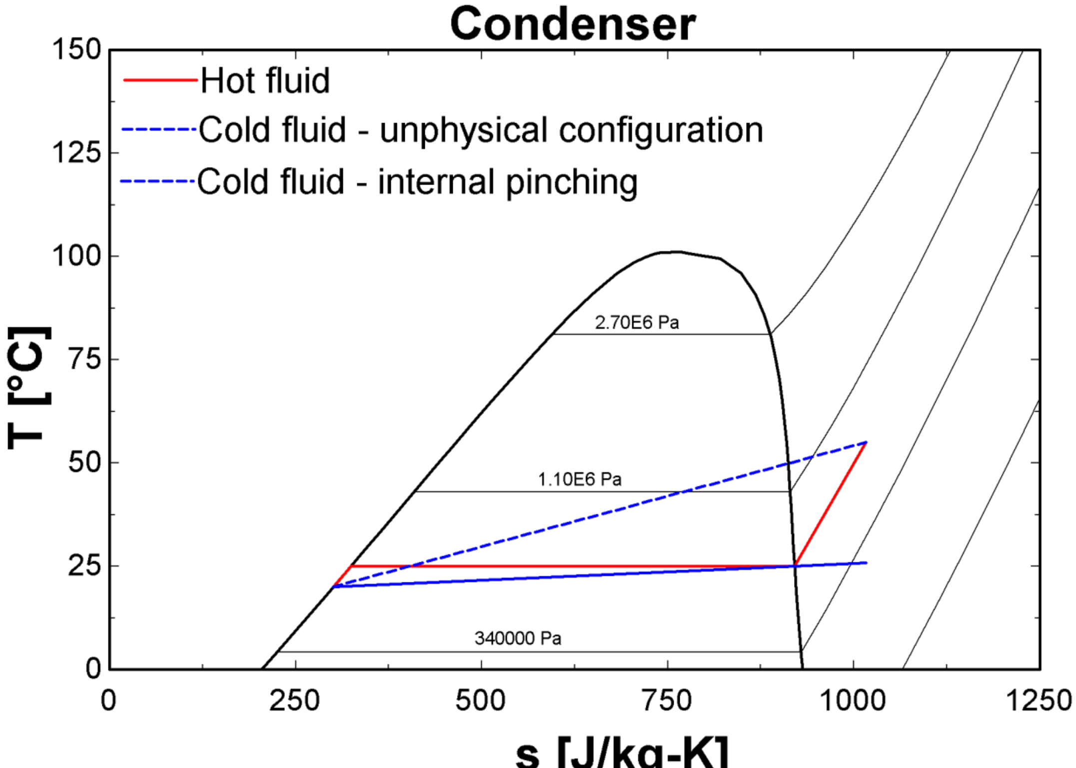
$$\dot{Q}_{\max,c} = \dot{m}_c\left[h(P = P_{c,ex}, T = T_{h,su}, \text{ fluid}_c) - h_{c,su}\right]$$

$$\dot{Q}_{\max,h} = \dot{m}_h\left[h_{h,su} - h(P = P_{h,ex}, T = T_{c,su}, \text{ fluid}_h)\right]$$

PHEX model - Methodology

Determination of physical bounds

❖ Internal pinching? The maximum heat transfer rate possible is decreased.



$$h_{pinch,c} = h(P = P_c, T = T_{dew,h}, fluid_c)$$

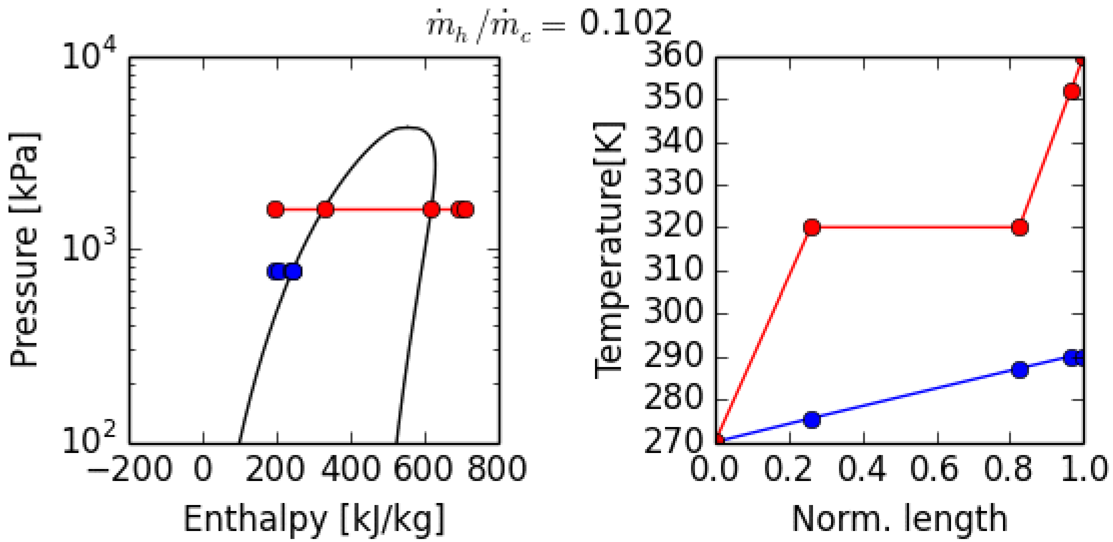
$$h_{pinch,h} = h(x = 1, T = T_{dew,h}, fluid_h)$$

$$\dot{Q}_{\max} = \dot{m}_c (h_{pinch,c} - h_{su,c}) + \dot{m}_h (h_{su,h} - h_{pinch,h})$$

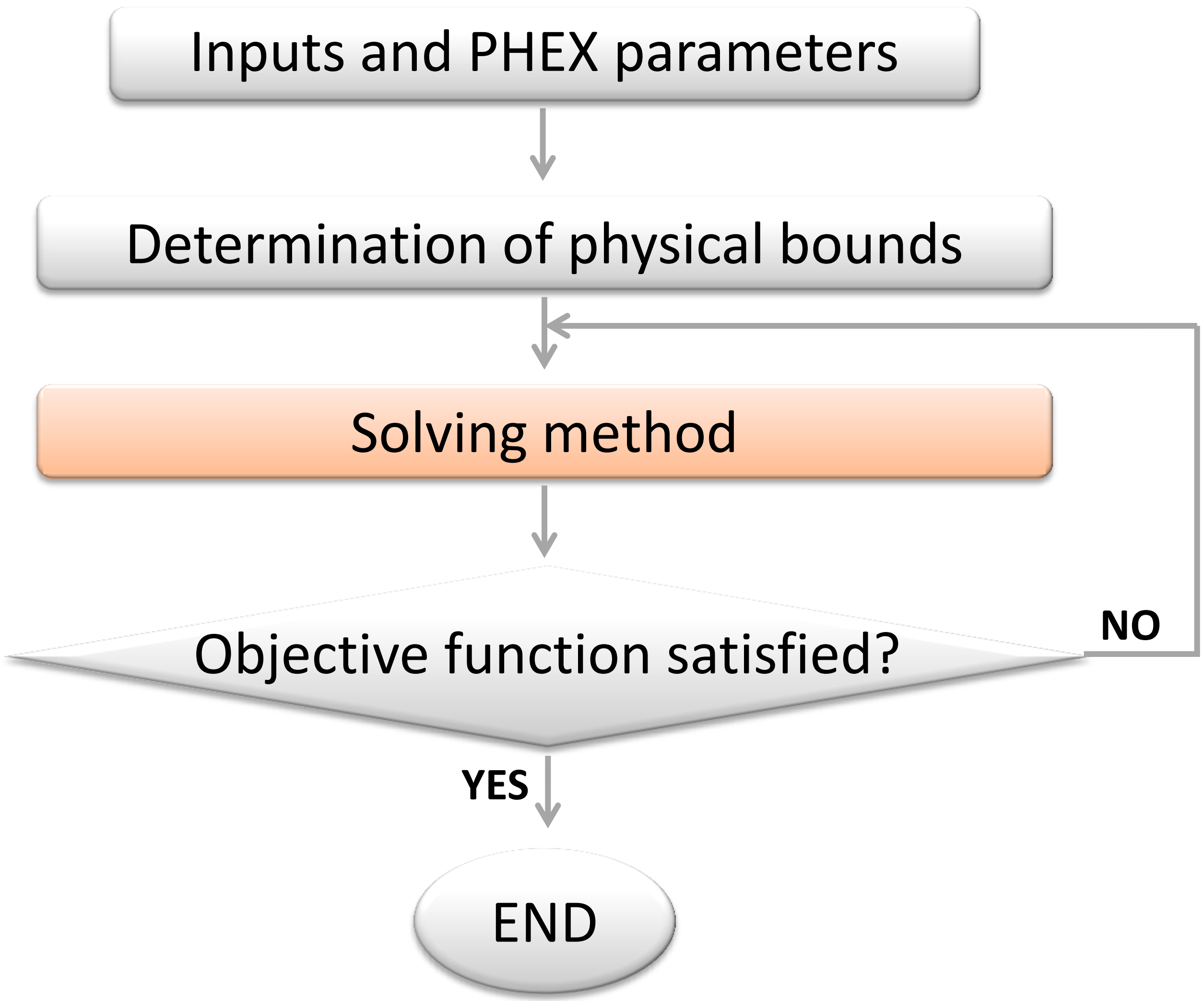
PHEX model - Methodology

Determination of physical bounds

❖ Combine to determine physical bounds for the heat transfer rate



PHEX model - Methodology



PHEX model - Methodology

Solving method and solver used

In each cell,

- Use LMTD method to determine required AU (AU_{req})

- Determine AU if the entire heat exchanger was devoted to this cell

$$\frac{1}{AU} = \frac{1}{\frac{1}{h_c A_c} + \frac{e}{kA} + \frac{1}{h_h A_h}}$$

- Compute the portion of heat exchanger actually devoted to it

$$w_k = \frac{AU_{req}}{AU}$$

PHEX model - Methodology

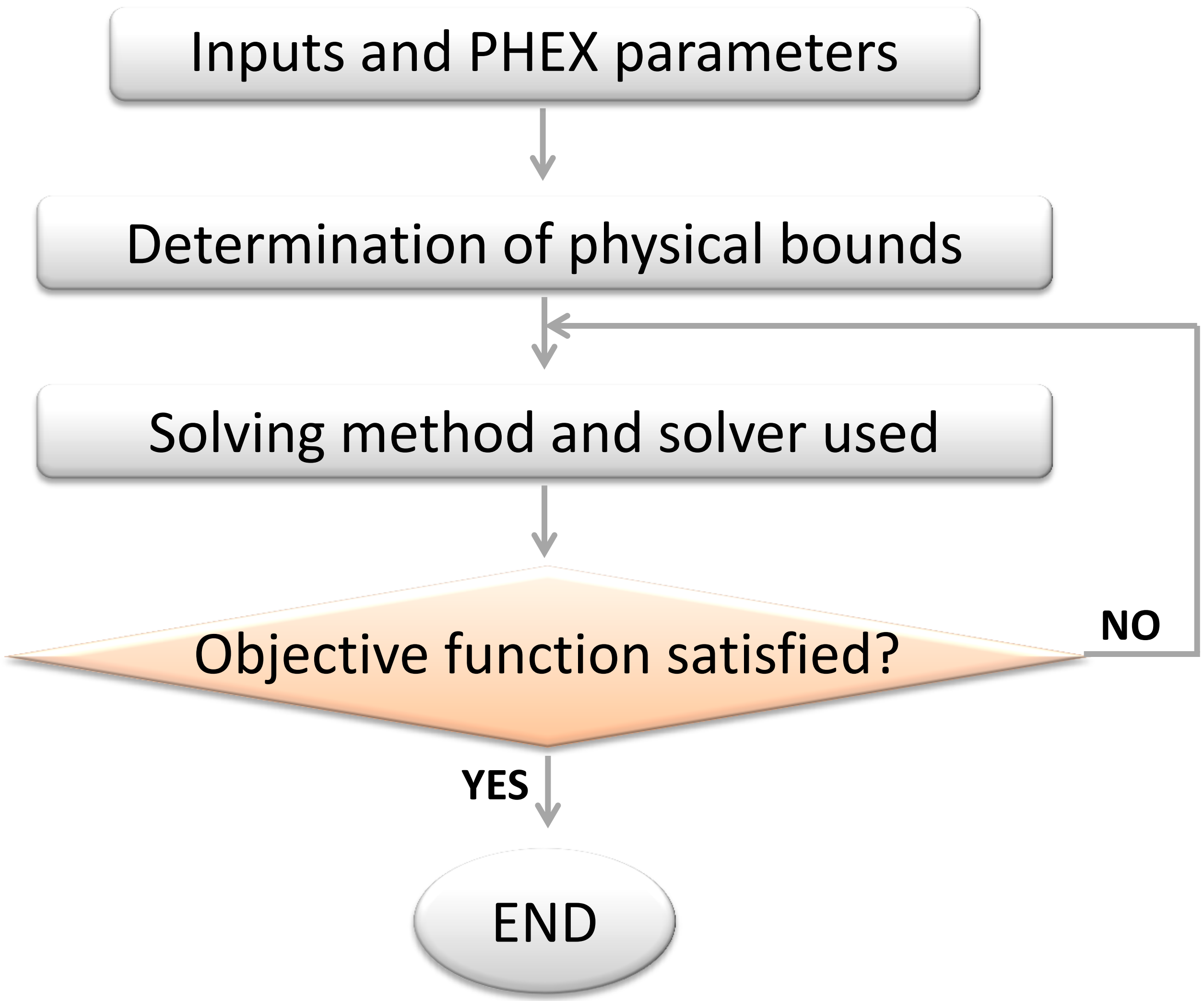
Solving method and solver used

Heat transfer coefficients from correlation

- Evaporation from Cooper pool boiling
- Single-Phase from Martin

Thermophysical properties from CoolProp (http://coolprop.sf.net) (open source, free, reference-grade)

PHEX model - Methodology



PHEX model - Methodology

Objective function satisfied?

The objective function is given by

$$\sum_k w_k = 1$$

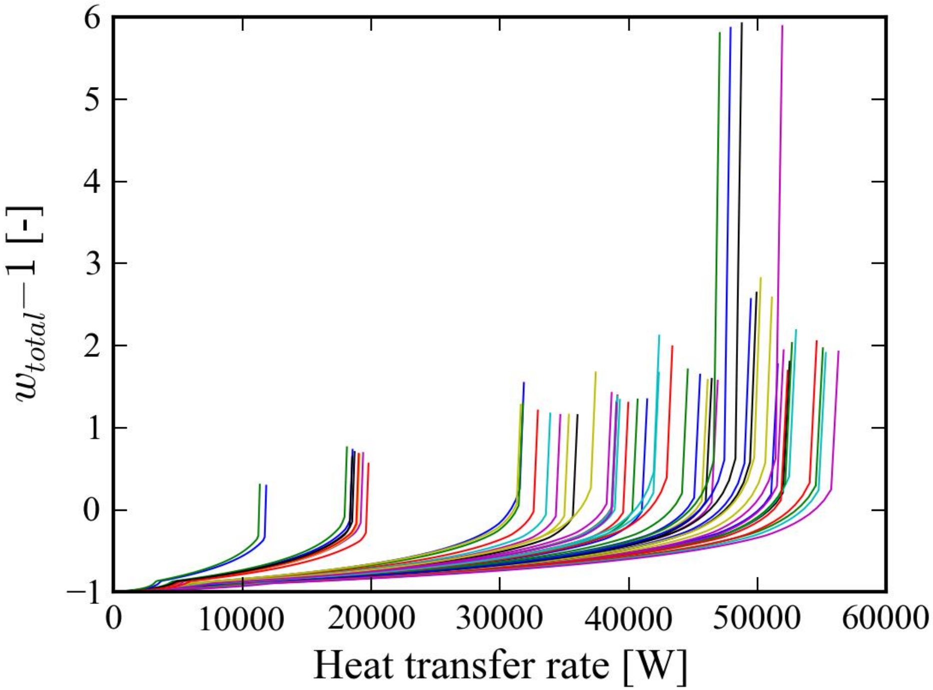
and the actual heat transfer rate is computed by an iterative process. It is varied between 0 and Q_{max} until the size of the heat exchanger determined at each iteration verifies this relation.

PHEX model - Methodology

Objective function satisfied?

BRENT SOLVER

✓Solution guaranteed so long as the objective function is continuous and the bounds bracket the solution.

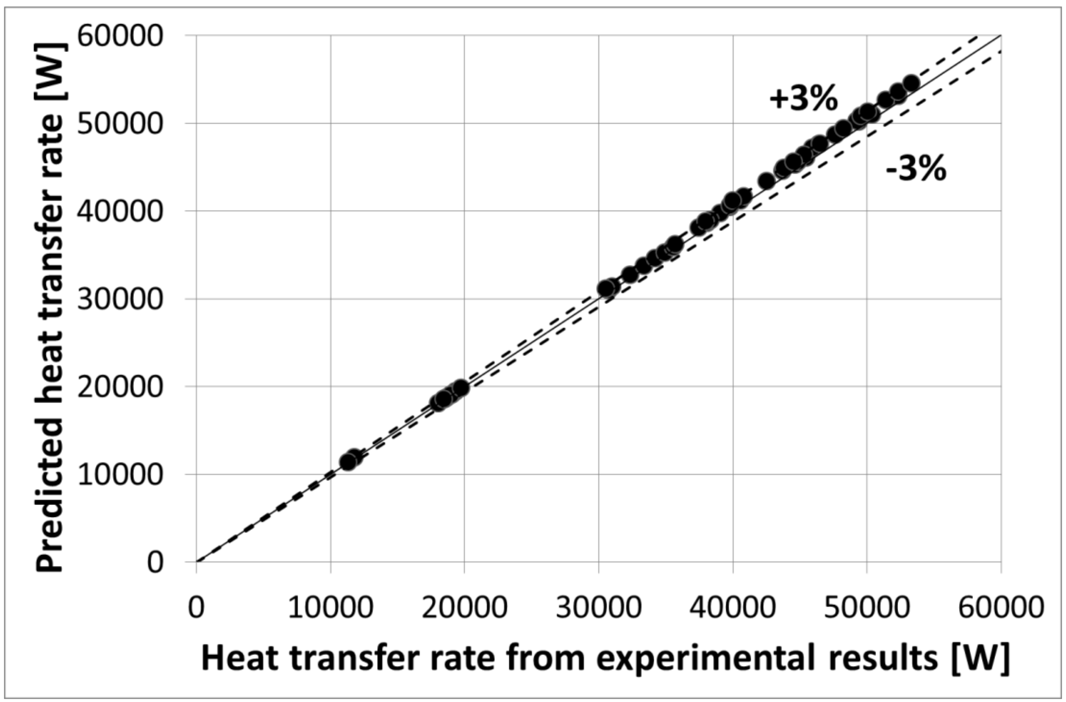


✓Quadratic interpolation and bisection method.

✓Increased efficiency to solve highly non-linear objective functions behavior.

Validation

- Validation under way...
- So far, tested for a dataset from experimental data carried out with R134a

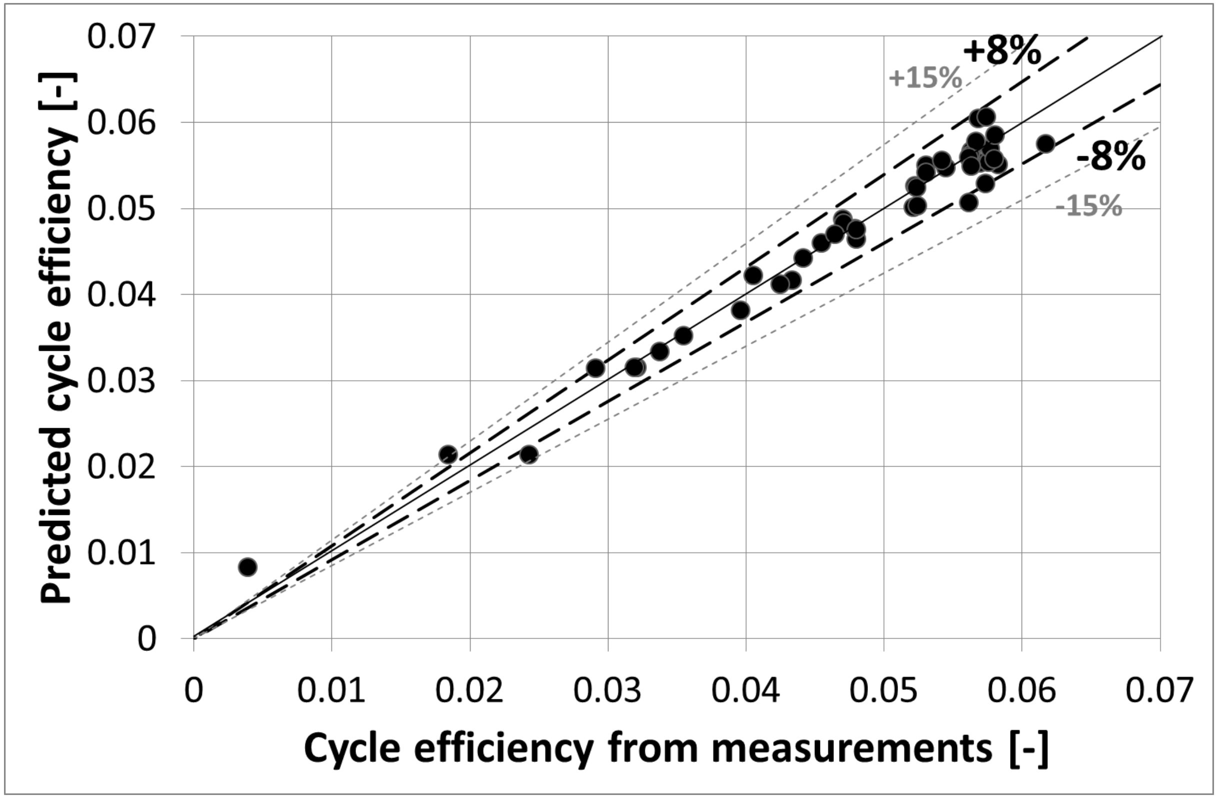


✓ Good agreement found for heat transfer rate and outlet temperature prediction

But points characterized by pinch points ranging between 2 and 12 K and a **high efficiency**.

Application to ORCs

- 4 components ORC test stand with plate heat exchangers for **condenser** and **evaporator**



Conclusions

Thank You!!

Any Questions