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From experimentation to modeling via an iterative and collaborative teaching approach in food and bioprocess engineering

Broyart Bertrand^a, Debacq Marie^{a,b}, Lachin Kevin^a, Pagliaro Samantha^a

^aUMR 782 SayFood AgroParisTech-INRAE, Campus Agro Paris-Saclay, 91120 Palaiseau, France,
^bCNAM, 3 rue de Conté, 75003 Paris, France

Introduction

The objective of the project is to propose an innovative educational module at the interface between experimentation and modeling. To clarify the link between these two modes of understanding reality, we want to propose a short module (6 h) concerning the analysis of the performance of heat exchangers. A first step of data acquisition would be carried out on small-scale heat exchangers (micro-pilot), leaving the students free to explore a large number of configurations and operating conditions for this type of device. These data would then allow us to develop a physical model (using open-source tools such as Python) describing the observed phenomena and allowing us to consider their extrapolation to a larger scale. A source of interest for the students for the module would be that they would generate themselves the data that they would model whereas, in the current curricula, experimentation and modeling are often approached in dissociated teachings.

General organisation of the educational module

STEP # 1 :

Data acquisition on micro-pilot by carrying out a series of experiments decided by the students

STEP # 4 :

Comparison of the extrapolated results with measurements made on pilot at larger scale

STEP # 3 :

Extrapolation to a larger scale by using the developed calculation code

STEP # 2 :

Modeling results by developing a Jupyter notebook (including Python code)

Step #2 and #3 : Modeling results using Nu, Re, Pr numbers and extrapolation at larger scale

Using Jupyter environment to create and share computational documents (using Python programming language) for :

- observation and basic statistical tests on raw data
- nondimensionalization of the problem by calculating dimensionless numbers of Nusselt, Reynolds and Prandtl to capitalize on experimental data and consider extrapolation at a larger scale
- determination of specific Nusselt number correlations

Text block: problem statement or answers given by students

Python code blocks : answers computed by students with numerical or graphical outputs

```

Entrée [2]:
1 from colorama import Fore
2 import numpy as np
3
4 rhoc=1000 #Density cold fluid, kg/m3
5 cpc=4180 #Specific heat cold fluid, J/kg/K
6 lamc=0.6 #Thermal conductivity cold fluid, W/m/K
7 muc=1e-3 #Dynamic viscosity cold fluid, Pa.s
8
9 mdotc=1 #Mass flow rate cold fluid, kg/s
10 Dint=3e-2 #Diameter internal tube, m
11
12 Sint=np.pi*Dint**2/4 #Section internal tube
13 print(Fore.RED + f"The area of the section of the internal tube is equal to {Sint:1.3e} m^2.")
14 print()
15 vc=(mdotc/rhoc)/Sint #Velocity cold fluid, m/s
16 Rec=rhoc*vc*Dint/muc #Reynolds number
17
18 print(Fore.RED + f"The velocity of the cold fluid in the internal tube is {vc:1.2f} m/s and the Reynolds number is {Rec:1.0f}")
19 print()
20
  
```

Example of Jupyter notebook interactive development environment

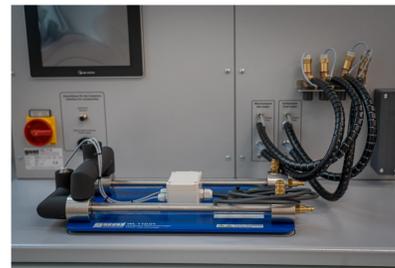
Step #1: Heat exchanger micro-pilot



Plate micro heat exchanger



Shell and tubes micro heat exchanger



Tubular micro heat exchanger

GUNT Hamburg
Equipment for experimental,
scientific and technical teaching
GSDE s.a.r.l.
181 Rue Franz Liszt
73000 Chambéry, France

Aim of the experiments: determining global heat transfer coefficient over as wide a range of operating conditions as possible

Experimental design thought by the students (the small size of micro-pilot allowing to reach quickly steady-state regime)

Operating conditions to be modified :

- mass flow rates of hot and cold fluid
- nature of cold fluid to cover a wide range of viscosity : water, glycerol aqueous solution, glucose solution...
- inlet temperature of cold fluid (to see how the modification of the thermophysical properties of this fluid with its temperature modifies the performance of the heat exchanger)
- nature of the heat exchange module : coaxial tubular heat exchanger, multitubular heat exchanger; plate heat exchanger

Step #4: Heat exchanger at larger scale

Aim : verify the validity of Nusselt number correlations determined in previous step and prediction of the efficiency of heat exchanger at larger scale



Conclusion

Through the development of this educational module located exactly at the interface between experimentation and modelling, the aim of the project is to awake students' critical thinking and creativity by insisting on the problems commonly encountered in this type of approach: link between the precision of the measurements obtained and the validity of the models, propagation of measurement uncertainties in the calculations, analysis of the sensitivity of the measured variables to the parameters of the models, sampling and repeatability problems. This project also allows the emergence of a solid collaborative dynamic created by the rapprochement of teachers, pedagogical engineers and the team in charge of the development of the technological hall, to carry out work together in a structured collective framework.

Contact

BROYART Bertrand
UMR 782 SayFood AgroParisTech-INRAE,
Campus Agro Paris-Saclay,
91120 Palaiseau, FRANCE
bertrand.broyart@agroparistech.fr