Seminar Course for PhD Students

Title: Numerical Analysis and Geometrical Investigation of Compact Heat Exchangers

Abstract:

Compact heat exchangers are devices that allowed the achievement of high heat transfer rates per unit volume, leading to wide applications in automotive and naval industries. Recently, due to the manufacturing cost reduction, these heat exchangers have been applied to domestic refrigeration condensers and other compact systems as electronic packages. Consequently, the investigation of internal and external convective flows has been of chief importance to improve the comprehension of the physical behavior and obtain recommendations about the design of compact heat exchangers. Several studies have been developed investigating convective flows under different flow regimes (laminar and turbulent), the driven mechanism of the convective heat transfer flows (forced and mixed convection), and under phase change conditions (boiling and condensing). Another important aspect, regardless of the conditions of convective flow, is concerned with the influence of design over the performance of the devices subjected to convective heat transfer. Moreover, heat transfer is a profitable area to comprehend several fundamental aspects of flow systems design. Various works in the heat transfer realm have been used in the literature to demonstrate how shape and structure in several finite-size flow systems (trees, rivers, animal shapes, social dynamics) can be predicted by an universal physical principle of maximization of access to the internal currents (Constructal Law of Design and Evolution). In this sense, the present course makes a general overview about the contributions developed into the cooperation between research groups of FURG and Bologna Universities into the geometrical investigation of cavities, channels and external flows. Moreover, fundamentals about the modeling of laminar and turbulent convection flows, as well as, phase change and two-phase flows are presented. Fundamentals about the application of constructal design for geometrical investigation of various engineering problems and its analogy with natural flow systems is also reported. To summarize, a step-by-step simulation of forced convection flow in channels with heated blocks is performed.

Chronogram of the Seminar:

Lecture 1 – Introduction – November 27th (Monday) – 10 a.m. – 12 p.m.

Overview of the state-of-the-art heat transfer problems applied to compact heat exchangers developed by the Federal University of Rio Grande (FURG) constructal theory group in partnership with Bologna University.

The following topics will be reported in this lecture:

1.1. Presentation of the Visiting Professor and the main research activities

1.2. Geometrical investigation of fins and blocks inserted in cavities subjected to forced and mixed convective flows

1.3. Geometrical investigation in laminar and turbulent flows over cylinders and bluff bodies

1.4. Geometrical investigation of fins and blocks inserted in surfaces of channels applied in compact heat exchangers subjected to forced convective laminar and turbulent flows

1.5. Geometrical investigation of phase change flows (boiling in cavities with corrugated surfaces, boiling in corrugated channels, and boiling in channels with isothermal blocks).

Lecture 2 – Fundamentals of Numerical Approach in Laminar Convective Flows – November 29th (Wednesday) – 10 a.m. – 12 p.m.

2.1. Mathematical and numerical modeling of forced and mixed convective laminar flows

2.2. Modeling of two-phase boiling flows in heat transfer problems using a mixture model

2.3. Modeling of two-phase boiling flows in heat transfer problems using volume of fluid model

2.4. Boundary and initial conditions commonly used in convection heat transfer problems

2.5. Numerical procedures commonly used in convection heat transfer problems (grid independence, verification/validation).

Lecture 3 – Fundamentals of Numerical Approach in Turbulent Convective Flows – December 1st (Friday) – 10 a.m. – 12 p.m.

3.1. Fundamentals of turbulent flows (characteristics of turbulence, multiplicity of scales, Kolmogorov cascade of energy, structures of turbulence in different flow basins)

3.2. Numerical approach of turbulence (Direct Numerical Simulation, Large Eddy Simulations, and Reynolds-Averaged Navier Stokes)

3.3. The closure problem and RANS modeling (one, two equations and shear stress transport)

3.4. Large Eddy Simulation modeling (spatial filtering approach and subgrid models)

3.5. Boundary conditions in turbulent flows and spatial discretization in the near wall region.

Lecture 4 – Fundamentals of Geometrical Investigation with Constructal Design in Heat Transfer Problems – December 4th (Monday) – 10 a.m. – 12 p.m.

4.1. Constructal design used for the geometrical investigation of pre-defined shapes in flow systems

4.2. Constructal design associated with an exhaustive search for geometrical optimization (benchmark solution)

4.3. Constructal design associated with computational intelligence for geometrical optimization of complex configurations with several degrees of freedom (example of cavities intruded into heat generating solid walls)

4.4. Evolutionary design for construction of flow systems from elementary configuration and using pre-defined shapes

4.5. Evolutionary design applied to finned channels of heat exchangers (memory technique and exhaustive search).

Lecture 5 –Constructal Design Applied to Several Engineering Problems – December 6th (Wednesday) – 10 a.m. – 12 p.m.

5.1. Constructal design applied for geometrical investigation of wave and wind energy

5.2. Constructal design applied for geometrical investigation of the resin infusion process

5.3. Constructal design applied for geometrical investigation of earth-air heat exchangers and solar chimney devices

5.4. Constructal design applied for geometrical investigation in solid mechanics ("flow of stresses").

Lecture 6 – Application of the Numerical Approach for Convection Heat Transfer – December 11th (Monday) – 10 a.m. – 12 p.m.

6.1. Definition of forced convection laminar flow in the channel to be simulated using the finite volume method;

6.2. Construction of the computational domain and spatial discretization in the channel flow problem;

6.3. Numerical simulation of the study case with the finite volume method (definition of materials, boundary conditions, numerical procedures);

6.4. Post-processing of the numerical simulation.

Kind Regards,

Prof. Elizaldo Domingues dos Santos (DSc.)
Mechanical Engineering - Associate Professor III - School of Engineering
Universidade Federal do Rio Grande (FURG)
Italia Avenue, km 8, ZIP code 96201-390 Rio Grande (Brazil)
Scholarship in Research Productivity – 1D (CNPq - Brazil)
Tel: +55 53 9 9970.2391
e-mail: elizaldosantos@furg.br