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# Influence of flow topology on the heat transfer upstream a single plate-finned tube

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## Abstract

A numerical study of the influence of flow topology on the heat transfer upstream a single plate-finned tube is presented in this paper. Investigations have been carried out for three fin spacing E/D= 0.13, 0.2, 0.27 and different Reynolds number ReD, ranging from 1400 to 3840 using a computational fluid dynamic code. The results are compared with heat transfer visualization performed by infrared thermography system. It is shown that calculations reproduce correctly the heat transfer distribution and results are very close to the experimental data qualitatively. A strong dependence of the heat transfer on the flow structure is observed by increasing the fin-spacing and the Reynolds number.

*Keywords:* horseshoe vortex; heat transfer, *K-w sst* model, fin spacing, heat exchanger

## 1. Introduction

Finned-tube heat exchangers are widely used when heat is transferred between air and fluids in tubes. They are used extensively as both evaporators and condensers in air conditioning, refrigeration and dehumidifying equipment. Because of their extensive use and simple geometry, many research groups have examined their performances.

The flow structure in the finned-tube configuration can be fairly complex. Flow complexities are primarily attributable to the coexistence of the horseshoe vortex, a stagnant wake behind the tube and a developing flow along the fin near the leading edge. Several studies of finned-tube heat transfer problems have been carried out.

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These studies have provided us with useful information, revealing that the horseshoe vortex structure formed in the front of the tube is made of two main helical vortices on each side of the tube leading to high heat transfer rates and a recirculating flow pattern behind the tube. Saboya and Sparrow [1] use the naphthalene mass transfer method to measure the local heat transfer coefficients for one-row and two-rows plate-fin and tube heat exchangers for a fin-spacing equal to E/D=0.193. They report that the heat transfer rate is high on the forward part of the fins due to developing boundary layers as well as in the front of the tube due to a vortex system located there.

Romero-Mendez *et al* [2] study the effect of the fin-spacing over the overall heat transfer rate using flow visualization and numerical analysis, and report that the heat transfer can be enhanced by the increase of the fin-spacing at a fixed fluid velocity due to a more extended horseshoe vortex system. M.N.Bey [3], studied in detail the structure of the horseshoe vortex with the Particle Image Velocimetry system (PIV) in one single-row plate finned tube. He showed that the fin spacing and inlet flow velocity have a major influence on the horseshoe vortex structure formed at the tube-fin juncture. The number and size of horseshoe vortices increase as the fin spacing or the Reynolds number increases.

Our investigations, in the present paper, aim to the better understanding of the effect of flow topology on the heat transfer upstream single plate-finned tube. We propose a numerical study using RANS turbulence models. Results are compared to infrared thermography experimental data [4] in order to check the ability of CFD codes to produce accurate predictions of the flow and heat transfer characteristics.

**Nomenclature**

| | |
|---|---|
| $C_f$ | Skin friction coefficient |
| D | Tube Diameter, m |
| E | Fin-spacing, m |
| E/D | Dimensionless fin-spacing |
| H | Distance between the tube and the leading edge of the fin, m |
| h | Heat transfer coefficient, $W/m^2.K$ |
| $I_0$ | Turbulent intensity inlet, % |
| I | Turbulent intensity in computational domain, % |
| L | Fin length, m |
| Pt | Transversal tube pitch, m |
| $Re_D$ | Reynolds number : $Re_D=U_0D/\nu$ |
| $U_0$ | Velocity inlet, m/s |
| $\nu$ | Kinematics viscosity, $m^2/s$ |

## 2. Computational Domain and Boundary Conditions

### 2.1. Computational domain

Simulations are carried out in a fundamental model, consisting of a pair of parallel plates and a single circular tube passing perpendicularly through the plates. It represents an elementary part of the real plate-fins and tube heat exchanger (see *Figure 1-a*). A cartesian reference frame whose origin is at the center of the tube is defined on the lower fin. Assuming the symmetry conditions of the flow on the mid-plane of the tube (y=0) and mid-plane of the fin-spacing (z=E/2), the boundaries perpendicular and parallel to the fins are defined as symmetries. Thus, computations are made within the region from y = 0 to $P_T$ /2 (in y-direction) and from z = 0 to E/2 (in z-direction). In x-direction, two zones were respectively added forward and behind the finned-tube for, respectively, the flow development and flow tranquillizing downstream the heat exchanger (see *Figure 1-b*).