FINITE-ELEMENT SOLUTIONS FOR LAMINAR FLOW IN SINUSOIDAL CORRUGATED-PLATE CHANNELS

Jorge V. Pinheiro [(1)], Carla S. Fernandes [(2)], Ricardo P. Dias [(1), (3)], João M. Nóbrega [(4)], João M. Maia [(4)]

(1) Instituto Politécnico de Bragança, Escola Superior de Tecnologia e de Gestão, Departamento de Tecnologia Química e Biológica, Bragança, Portugal

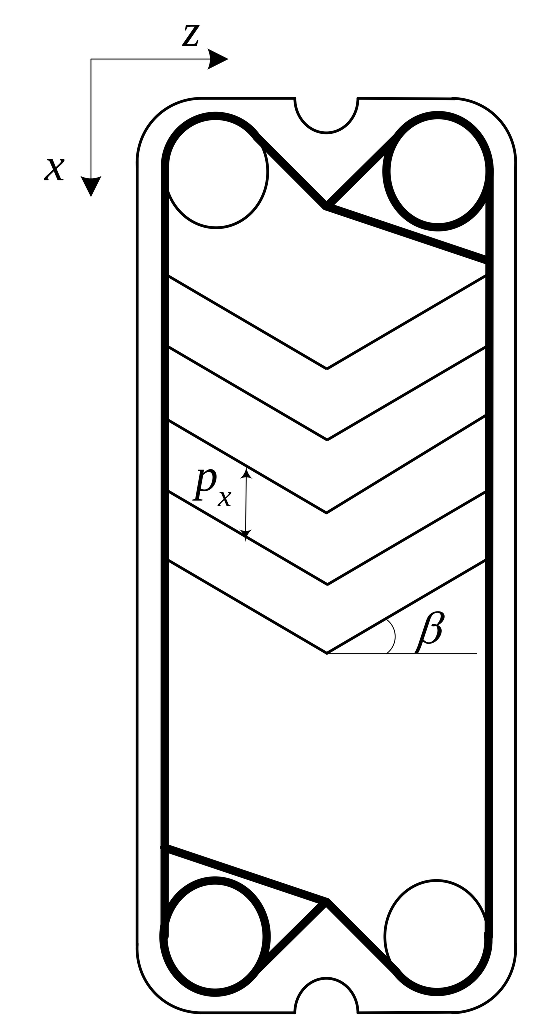
(2) Instituto Politécnico de Bragança, Escola Superior de Tecnologia e de Gestão, Departamento de Matemática, Bragança, Portugal

(3) Universidade do Porto, Faculdade de Engenharia, CEFT – Centro de Estudos de Fenómenos de Transporte, Porto, Portugal

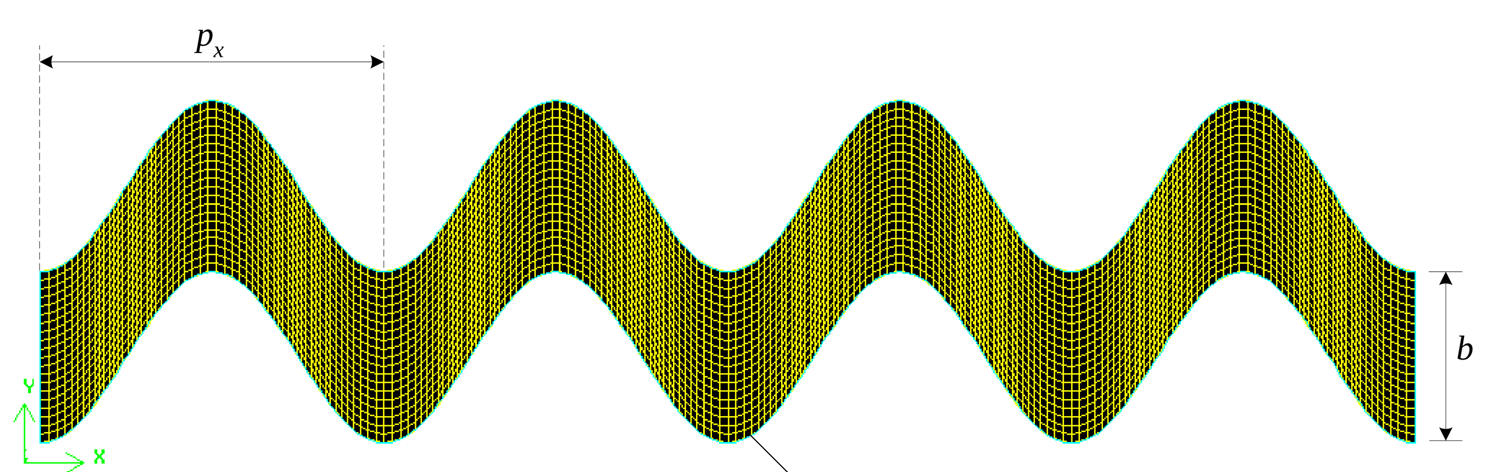
(4) Universidade do Minho, Departamento de Polímeros, IPC – Institute for Polymers and Composites, Guimarães, Portugal

INTRODUCTION

Analytical, numerical or experimental results for laminar flow in complex duct geometries are important for the design and application of compact heat exchangers. Chevron-type plate heat exchangers (PHEs) are commonly used in food, pharmaceutical, chemical processing, pulp and paper industry, offshore gas and oil applications, etc. In this work, fully developed laminar flows of Newtonian fluids in PHEs passages with a corrugation angle, β, of 0º, i.e., in sinusoidal wavy-plate channel, were numerically studied.



SINUSOIDAL WAVY-PLATE CHANNEL



$$y(x) = \frac{b}{2}\sin\left(\frac{2\pi}{p_x}\left(x - \frac{p_x}{4}\right)\right) + \frac{b}{2}$$

Plate width >> $b \Rightarrow$ 2D channels

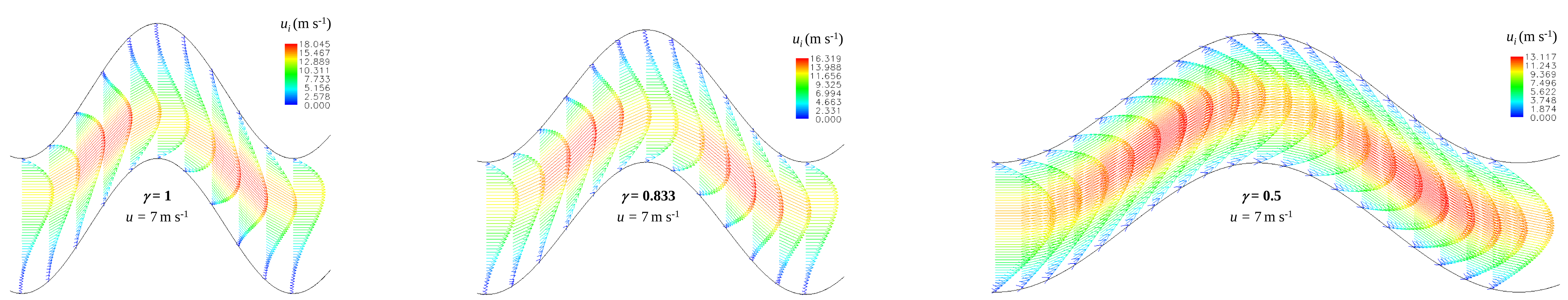
Hydraulic diameter: $D_H = 2b$

Channel aspect ratio: $\gamma = \frac{2b}{p_x}$

In the present work: D_H = 5 mm and $0 \le \gamma \le 1$

RESULTS

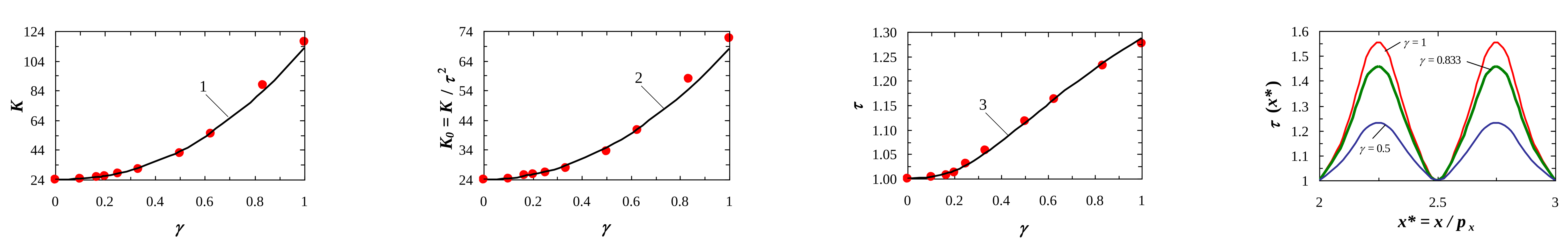
In the no-swirl flow regime, the surface geometry has no effect on the flow, and the fluid moves undisturbed through the passage, with no-recirculation, by simply adopting the wavy passage shape.



In the no-swirl flow regime, the Fanning friction factor, f, and the Reynolds number, **Re**, are related by the expression **f Re = K**, the coefficient K being related with the shape factor, K_0, and the tortuosity coefficient, τ.

$$\mathrm{Re} = \frac{\rho u D_H}{\eta} \qquad f = \frac{\Delta P D_H}{2L\rho u^2} \qquad \tau = \frac{u_i}{u} \qquad K = K_0 \tau^2$$

From the numerical calculations, it was possible to estimate the pressure drop in each of the consecutive modules (portion of the channel with length p_x) and, therefore, to compute the value of the coefficient K. Knowing the average interstitial velocity, u_i, the coefficient τ was determined. All the coefficients were modelled as functions of γ.



(1) $K = 24\left(1 + 3.6943\gamma^{2.2107}\right)$

(2) $K_0 = 24\left(1 + 1.8336\gamma^{2.0273}\right)$

(3) $\tau = \left(\frac{1 + 3.6943\gamma^{2.2107}}{1 + 1.8336\gamma^{2.0273}}\right)^{0.5}$

CONCLUDING REMARKS

In laminar regime, the hydraulic performance of PHEs can be easily modelled resorting to computer fluid dynamics techniques. Detailed information about the flow distribution can also be obtained.

The coefficient K and the average tortuosity coefficient increase with the increase of the channel aspect ratio, this dependence being also observed for the shape factor. The local value of τ reaches a minimum (τ =1) at the inlet, outlet and middle of each consecutive module; the maximums being achieved at ¼ and ¾ of the length of each consecutive module.

Simulations with power-law fluids are in progress, in order to establish a single friction curve equation (f Re = K) for the flow of Newtonian and distinct power-law fluids in PHEs with β = 0º and different channel aspect ratios ($0 \le \gamma \le 1$).

18th International Congress of Chemical and Process Engineering. August 24 - 28, 2008. Prague, Czech Republic