

# Effect of Corrugation Angle on the Hydrodynamic Behaviour of Power-law Fluids During a Flow in Plate Heat Exchangers

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## Abstract

Hydrodynamic behaviour of a non-Newtonian fluid in PHEs channels with different corrugation angles was numerically studied and relations between Fanning friction factors and Reynolds number were developed, considering and discarding the effect of temperature on viscosity.

## Introduction

In laminar flows, Fanning friction factors are usually related with Reynolds number by the standard expression :

$$f = a \text{Re}^{-1}. \quad (1)$$

The flows on PHEs are more accurately described using 3D geometries on CFD simulations.

## Problem description

Numerical simulations of a non-Newtonian non-isothermal flow in a PHE were performed.

Thermo-rheological behaviour of the fluid was described by:

$$\eta(\dot{\gamma}, T) = K_c \dot{\gamma}^{n-1} \exp\left(\frac{E}{RT}\right) \quad (2)$$

Parameters of Eq.(2) are:  $n = 0.5$ ,  $K_c = 0.0499 \text{ Pa s}^{0.5}$  and  $E/R = 3065 \text{ K}$ .

Geometrical domain represents half of a channel of PHEs with  $\beta = 30^\circ$  and  $\beta = 60^\circ$ .

As boundary conditions it was imposed a linear heat flux along the plates and non-slip at the walls.

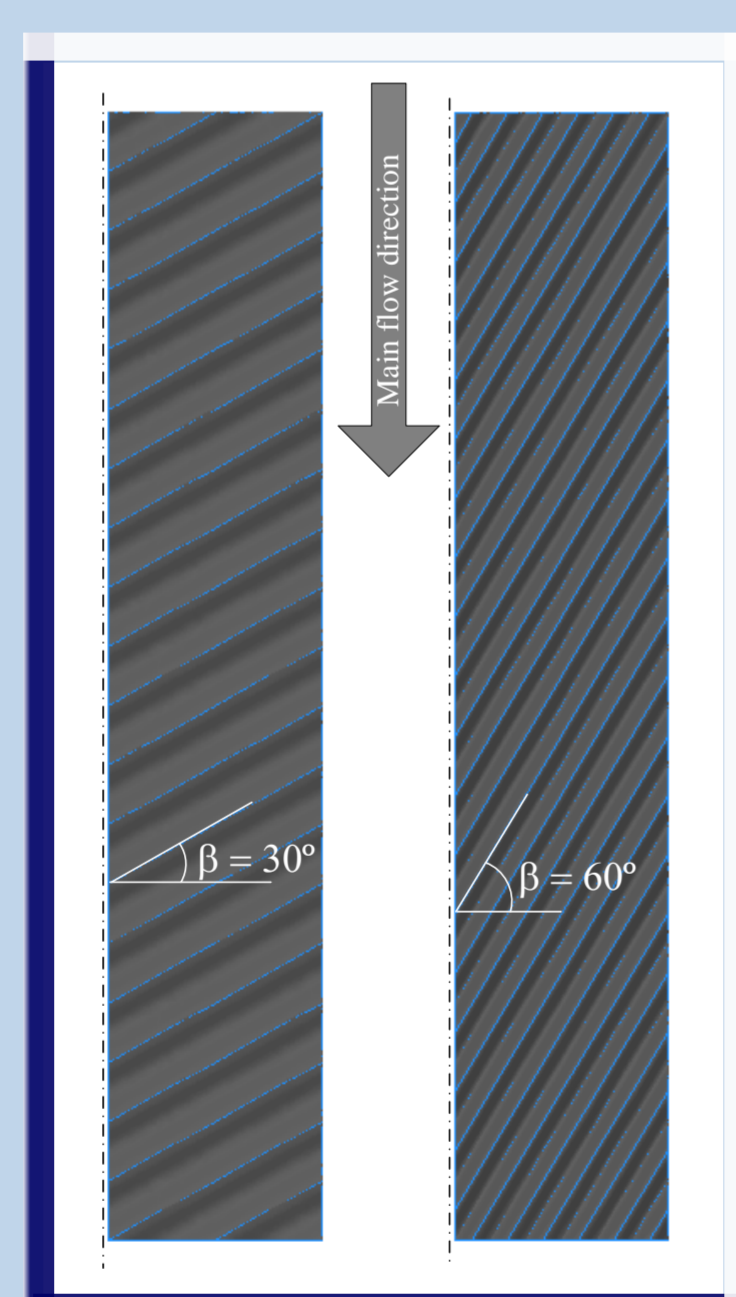


Fig. 1: View of half of a channel for  $\beta = 30^\circ$  and  $\beta = 60^\circ$ .

## Results and Discussion

In the development of  $f$ - $\text{Re}$  expressions the hydraulic diameter was defined as  $D_H = 2b$ , being  $b$  the inter-plates distance. Fluid viscosity was obtained from CFD calculations. Fanning friction factors were very well described by Eq. (1).

Tab. 1: Values of constant  $a$  for the power-law fluid.

$\beta$ (°)	$E/R$ (K)	$a$ (-)
30	3 065	32.121
	0	44.740
60	3 065	19.549
	0	38.394

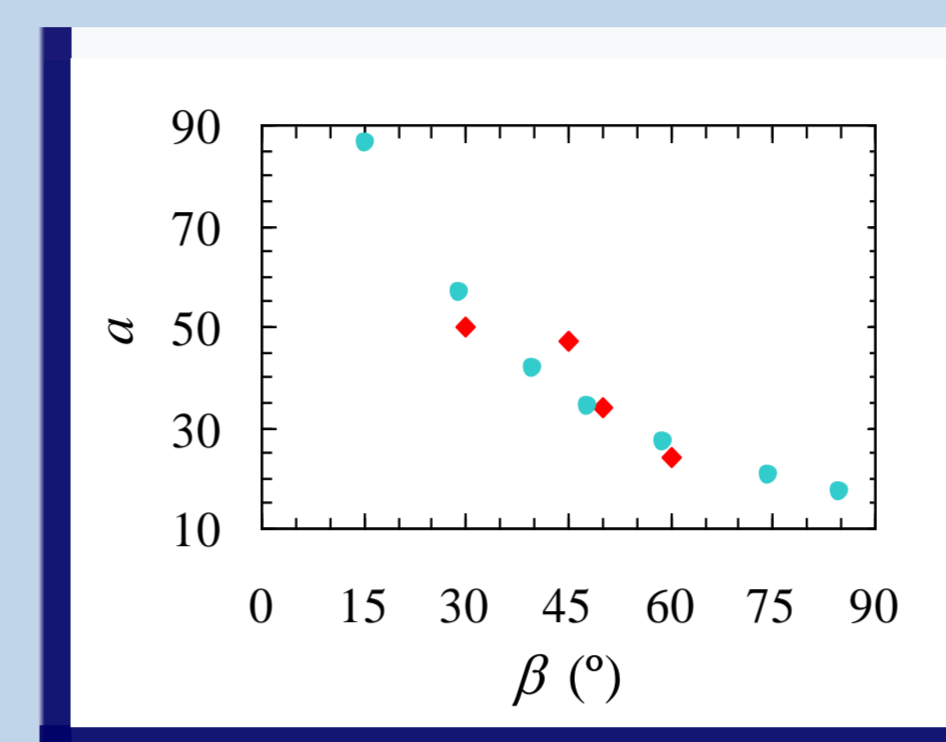


Fig. 2: Constant  $a$  for Newtonian fluids considering  $DH = 2b/\phi$ . (♦) Kakaç and Liu (2002); (●) CFD calculations.

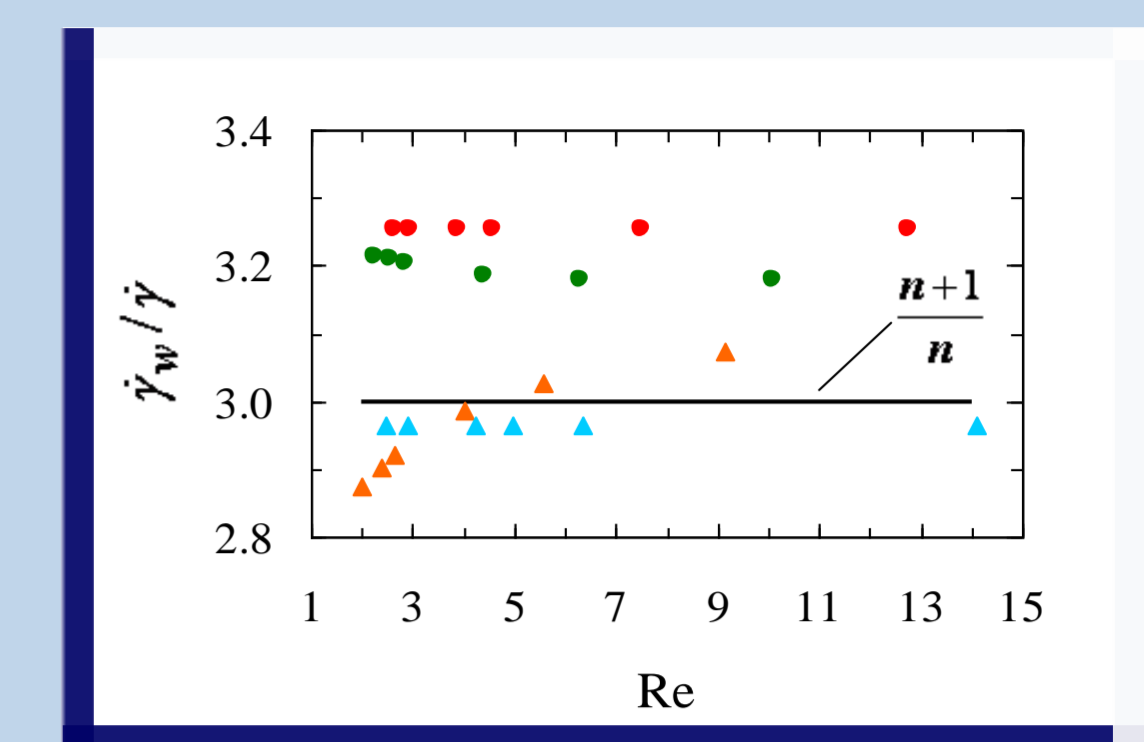


Fig. 3: Ratio between wall and bulk shear rate. (●)  $\beta = 30^\circ$  and  $E/R = 0 \text{ K}$ ; (●)  $\beta = 30^\circ$  and  $E/R = 3065 \text{ K}$ ; (▲)  $\beta = 60^\circ$  and  $E/R = 0 \text{ K}$ ; (▲)  $\beta = 60^\circ$  and  $E/R = 3065 \text{ K}$ .

Simulations with a Newtonian fluid were performed in order to compare the numerical results with literature data (Fig. 2) and a good agreement was found.

The ratio between wall and bulk shear rate (Fig. 3) approaches the ratio obtained for parallel plates,  $(n+1)/n$ . However, the shear rates developed on the PHEs are higher than the observed on parallel plates (Fig. 4).

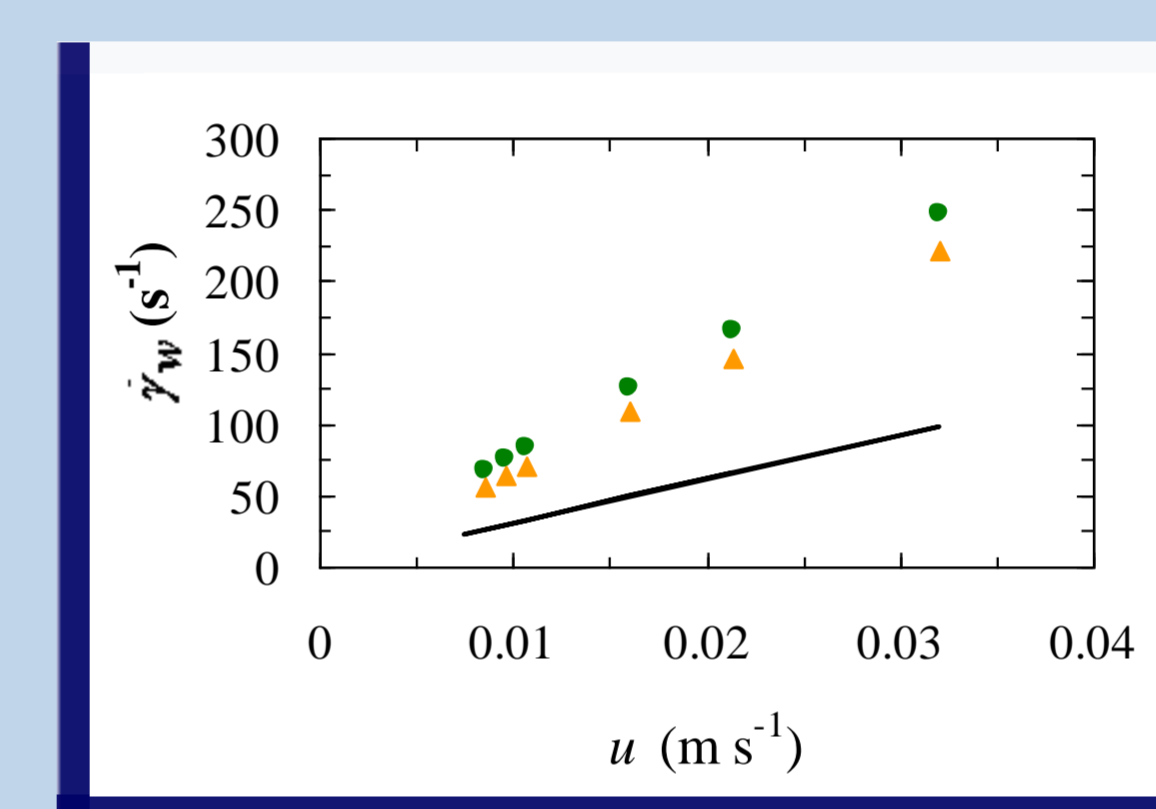


Fig. 4: Wall shear rate with  $E/R = 3065 \text{ K}$  for (●)  $\beta = 30^\circ$  and (▲)  $\beta = 60^\circ$ . Line represents parallel plates.

The influence of shear rate and temperature on the fluid viscosity can be observed on Fig. 5.

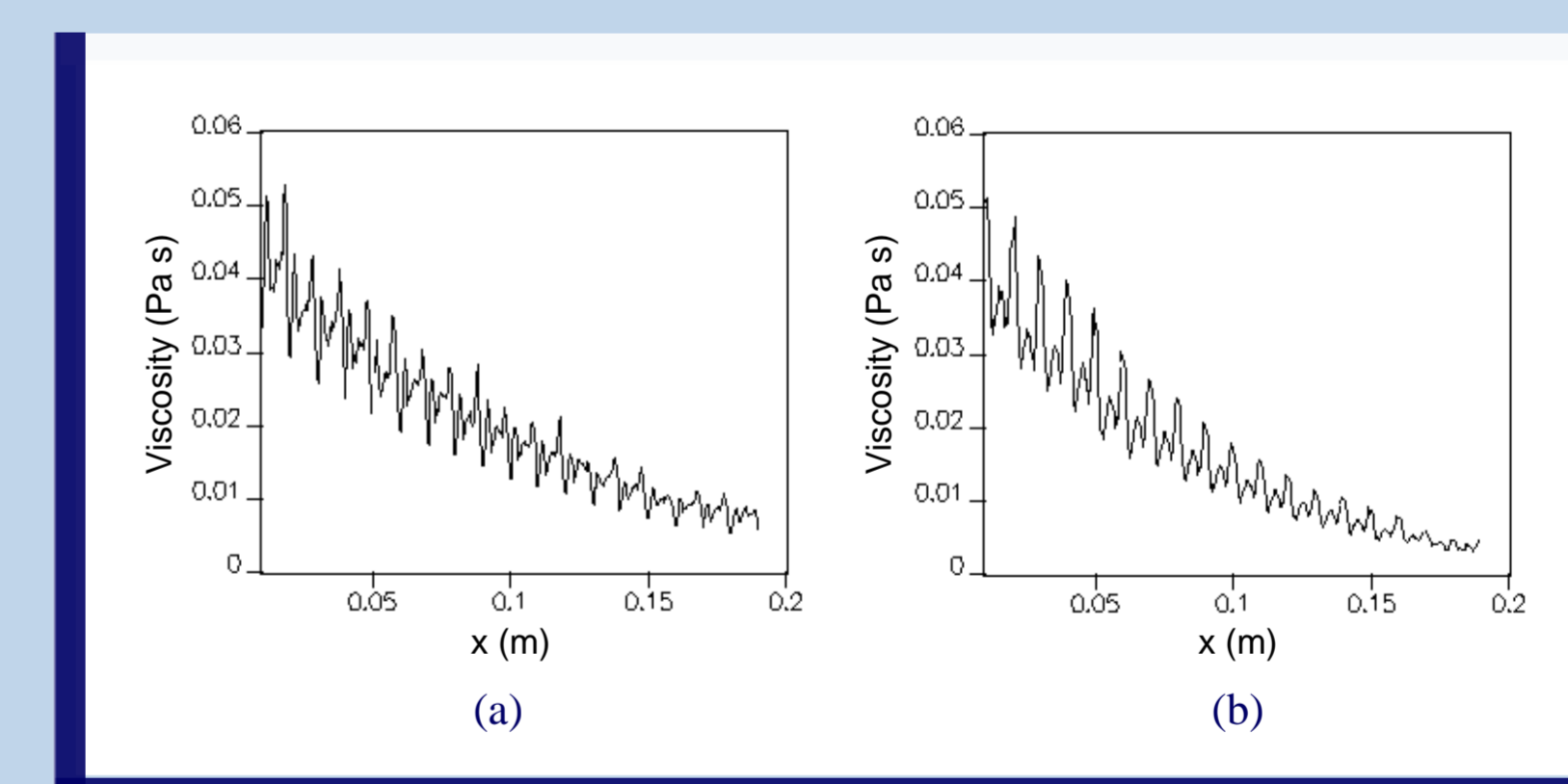


Fig. 5: Viscosity profiles along the PHEs channels and  $E/R = 3065 \text{ K}$  for (a)  $\beta = 30^\circ$  and (b)  $\beta = 60^\circ$ .

## Conclusions

The present analysis it's useful to understand the non-isothermal flows of power-law fluids on PHEs channels. For Newtonian fluids, a good agreement between CFD fanning friction factors and literature data was observed. On the different simulations with the power-law fluid the constant  $a$  was lower for a corrugation angle of  $60^\circ$ . The current work will be extended for turbulent flows.

## References

- Kakaç, S., and Liu, H., 2002. Heat exchangers selection, rating, and thermal design, 2nd ed., CRC Press, Boca Raton.
- Manglick, R. M., and Ding, J., 1997. Laminar flow heat transfer to viscous power-law fluids in double-sine ducts, *International Journal of Heat and Mass Transfer*, Vol. 40, No. 6, pp. 1379-1390.