Computational simulation of the natural circulation in an experimental test section of a pool type research reactor

F. R. T., Nascimento, C. A. S., Lima Junior, A. F. S., Oliveira , R. R. W., Affonso, J. L. H., Faccini, M. L., Moreira
e-mail: rogerio.tdn@gmail.com , faccini@ien.gov.br

SETER / IEN

Keywords: computational simulation, research reactor, natural circulation.

The present work presents a computational simulation of the natural circulation developing in an experimental test section of a pool type research reactor, [1]. The test section has been designed using a reduced scale in height 1:4.7 in relation to a pool type 30 MW research reactor prototype. It comprises a cylindrical vessel, which is opened to atmosphere, and representing the reactor pool; a natural circulation pipe, a lower plenum, and a heater containing electrical resistors which represents the fuel elements, with a chimney positioned on the top of the resistor assembly. Figure 1 shows a schematic of the test section. In the computational simulation, it was used a commercial CFD software, without any turbulence model. Besides, a model was used to simulate the test section where a laminar heat flow and a Newtonian incompressible fluid were assumed, and the equations of the mass conservation (1), momentum (2) and energy (3) were solved by the finite element method:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \mathbf{u}) = 0 \qquad (1)$$

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho \mathbf{u}.\nabla \mathbf{u} = -\nabla P + \nabla.(\mu(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)) - \\ -\frac{2}{3}\mu((\nabla.\mathbf{u})\mathbf{I}) + \mathbf{F} \qquad (2)$$

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u}.\nabla T = \nabla.(k\nabla T) + Q \qquad (3)$$

where ρ is the fluid density, $\mathbf{u}$ is the velocity, P is the pressure, $\mathbf{F}$ is the volume force vector , μ is the fluid dynamic viscosity, C_p is the specific heat capacity at constant pressure, T is the absolute temperature, k is the thermal conductivity, and Q is the heat source. In Figure 2, it is shown the average velocity profile (a) and the temperature profile on a plane YZ.

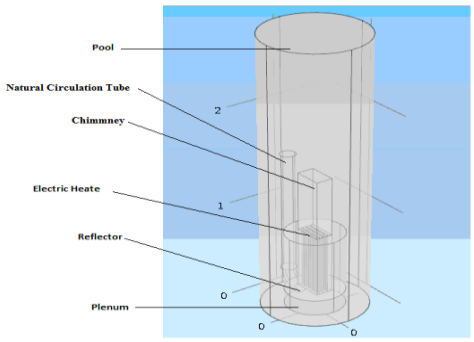
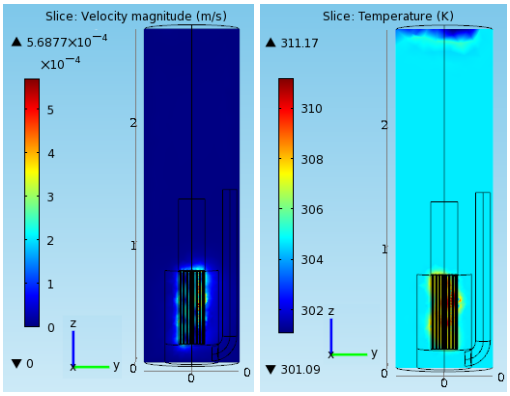


Figure 1. Schematic of the Test Section.



(a) (b)

Figure 2. Average velocity (a) and temperature (b) profiles on the plane YZ.

In Table 1 are presented the Grashof, Reynolds, and Richardson numbers calculated in order to evaluate the natural circulation in the proposed test section. The great difference between the results indicated that the flow is governed by natural convection in those regions.

Table 1 - Dimensionless numbers for test section.

Number	Core inlet	Chimney outlet
Grashof (Gr)	2634.11	7477.49
Reynolds (Re)	0.122	2.377×10^{-4}
Richardson (Ri)	176975.9	3.143×10^{11}

References

[1] NASCIMENTO, F. R. T. et. al. Computational simulation of the natural circulation in an experimental test section of a pool type research reactor. In: INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE - ENFIR: meeting on nuclear reactor physics and thermal hydraulics, 19., São Paulo. Anais… Rio de Janeiro: ABEN, 2015. Não paginado.