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## Code coupling for the Tube Support Plate clogging in steam generators

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**Abstract.** A numerical platform for the secondary circuit of a nuclear power plant, with a focus on the modelisation of effects combining thermal-hydraulics and chemistry, is the background of this research. The aim of this study is to take into account the precipitate or deposit in the thermal-hydraulic code TrioCFD[1] from an accurate chemical modelisation. The effects of the precipitates are modelled in TrioCFD by a friction term and a turbulence contribution in the momentum equation, as well as by a thermal effect in the energy equation.

**Keywords:** Computational Fluid Dynamics, Chemical Transport, Multi-physics Coupling, Steam Generators, TSP Clogging.

### 1. Introduction

Digital Twins (DTs) have gained interest for industrials in particular for the nuclear power plants. Creating a digital twin for the secondary circuit requires a strong thermal-hydraulic and chemistry coupling to deal with corrosion, clogging and fouling. Since chemical transport calculations cannot predict accurately the interfaces that appear between precipitates and flow, the chemical deposit is treated like a porous media in the thermal-hydraulic calculation. We show how the developments undertaken in TrioCFD take this issue into account. The thermal-hydraulic calculation after the transition zone between the porous media and the fluid is the main interest in this study and we present numerical results illustrating the effects of the precipitate.

### 2. Clogging in steam generators

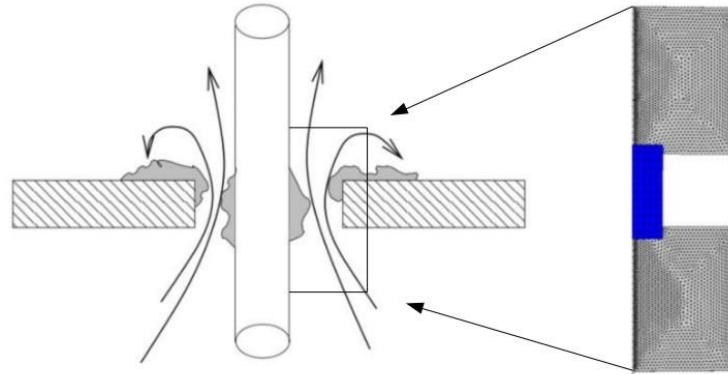
The Tube Support Plate (TSP) clogging is driven by thermochemistry, transport and deposition/erosion effects and influences the thermal-hydraulic problem. This application is the starting point of our study with a single phase-flow of water in two dimensions. The thermal-hydraulic code is TrioCFD and, for the present test, the chemistry problem is calculated by SCORPIO [2] with a single chemical equation that models deposition. The RANS equations are used for the turbulent flow with a  $k$ - $\epsilon$  model. SCORPIO and TrioCFD are based on the TRUST platform [3]; this platform allows us to use the ICoCo API [3] and the MEDCoupling [3] library for the data exchanges and the supervisor between the two codes.

### 2.1. Problem description and meshes

Under boiling condition, the potential contributing factors to clogging of TSP could be the centrifugal settling, the gravitational settling, the flashing in low pressure zone and the impaction on the bottom surface [4]. The meshes for the two codes are presented in Figure 1.

For performance reasons, the mesh for the chemical part is much coarser than the underlying fluid mesh.

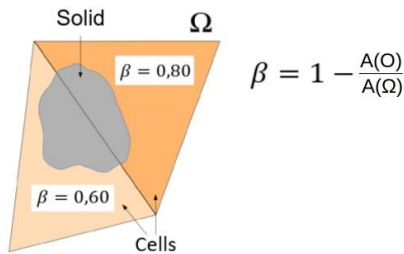
The chemical calculation needs the temperature field and the velocity field. After the chemical calculation, the porosity field is sent to the thermal-hydraulic calculation. The chemistry is supposed to be neither endo- nor exothermic.



**Figure 1.** Thermal-hydraulic description of the clogging [5] and meshes used in this study, in blue the chemical one and in black the thermal-hydraulic one.

### 3. Equations and mathematics

In the thermal-hydraulic solver, the presence of the solid precipitate is described by a porosity field defined as a volume fraction in each mesh cell (Figure 2).



**Figure 2.** The porosity field is defined as the scalar field of the non-occupied fraction of a volume  $\Omega$  for a solid  $O$ .

In TrioCFD, the momentum equation is discretized at the faces  $\sigma$  of the mesh and incorporates a friction term  $S_f$  approached on the face  $\sigma$  between two cells  $\Omega_1$  and  $\Omega_2$  by:

$$S_f \approx -\rho\beta_\sigma(1 - \beta_\sigma) \frac{l(\sigma)}{A(\Omega_1)+A(\Omega_2)} C_f \|\vec{V}_\sigma\| \vec{V}_\sigma. \quad (1)$$

In this equation,  $\beta_\sigma$  is a face interpolation of the cell-based porosity field,  $\rho$  is the density of the fluid,  $l(\sigma)$  is the length of the face,  $A(\Omega_i)$  is the area of  $\Omega_i$ , while  $C_f$  is the friction coefficient given by a correlation used for porous media and  $\vec{V}_\sigma$  is the velocity at the face.

The thermal contribution linked to the porous media is described in TrioCFD by the following additional heat flux:

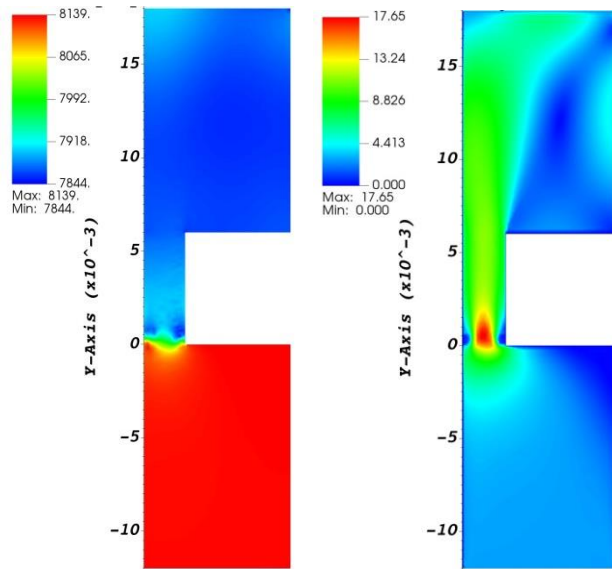
$$q_e = \left[ \frac{1}{\lambda_m \left( \frac{\beta}{\lambda_e} + \frac{1-\beta}{\lambda_m} \right)} - 1 \right] \times \frac{(1-\beta)\lambda_e}{\beta} \times \nabla T, \quad (2)$$

where  $T$  is the temperature,  $\lambda_e$  the thermal conductivity of the fluid and  $\lambda_m$  the thermal conductivity of the deposit.

#### 4. Results

The first results obtained with these new contributions are depicted on Figure 3. The pressure field is on the left and the velocity field is on the right. The effect of the deposit produced by the chemical calculation is observed on both fields.

The last part of this study will describe the term used to take into account the influence of the deposit on the turbulence term.



**Figure 3.** Thermal-hydraulic results with pressure (left) and velocity (right) fields.

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