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CFX Simulation of High Temperature Thermal-Chemical Experiment: CS28-2

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1. Introduction

The CS28-2 experiment [1,2] is one of the experiments for the simulation of high-temperature steam cooling condition in a full scale horizontal fuel channel with 28 fuel element simulators (FES). Previously, as a part of CFD simulation of the CS28-2 experiment, we performed the benchmark test on the calculation of a radiation heat transfer [3] and steady state calculation [4] during a low power phase using a CFX-10 code [5]. In the present work, the transient simulation by CFX-10 is performed and its results are compared with the experimental data.

2. Overview of the CS28-2 Experiment

2.1 Test Section

The test section is shown in Fig. 1. The test section consists of the electrically heated 28-element bundle, pressure tube, gap annulus, and calandria tube. The 28-element bundle consists of three rings and they were eccentrically located inside the pressure tube.

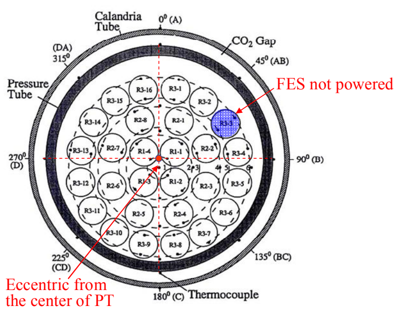

Figure 1. Cross sectional view of the CS28-2 test section.

2.2 Test Procedures

The procedure of the CS28-2 experiment consists of a low power phase (steady-state condition) and a high power phase (transient condition). The FES power connections were set up in three distinct rings and the normalized pin powers were 1.111, 0.894 and 0.775, for the outer, middle and inner FES rings, respectively. Electric power to the FES bundle was increased from 10 to 130 kW to start a high power phase at time=530 sec (Fig. 2). The bundle power increased to a maximum of 147 kW prior to shutting off electric power to the bundle at time=884.5 sec. Electric power returned to zero when the FES temperatures reached 1700℃ to study the energy released from the exothermic Zircaloy/steam reaction.

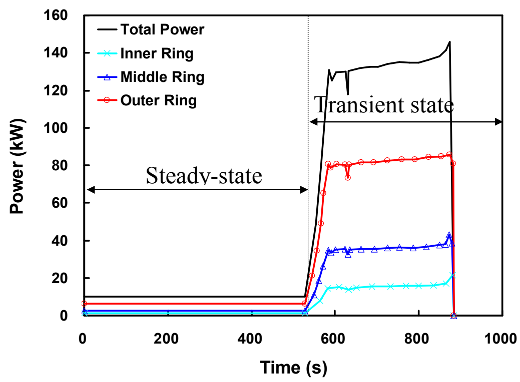

Figure 2. Electric power to the FES bundle

3. CFX-10 Modeling

3.1 Zircaloy/Steam Oxidation

From the reaction rate constants of the Urbanic and Heidrick [6], reaction heat generation and hydrogen production rate are calculated by a user FORTRAN subroutine. The procedures of using a user FORTRAN in a CFX-10 calculation are shown in Fig. 3.

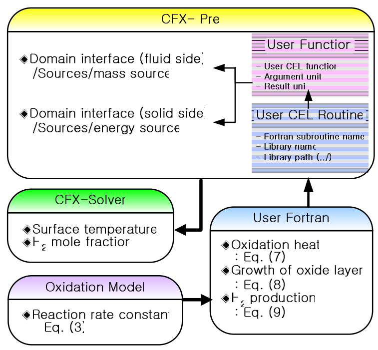

Figure 3. Oxidation model implemented in the CFX-10

3.2 Setting of Domain and Grid

The fluid domains consist of the super-heated steam in the pressure tube and the CO_2 gas in the annulus between the pressure tube and calandria tube. Fig. 4 shows the results of the grid generation with a refined mesh density near the wall boundaries. The number of the elements used is 764,901.

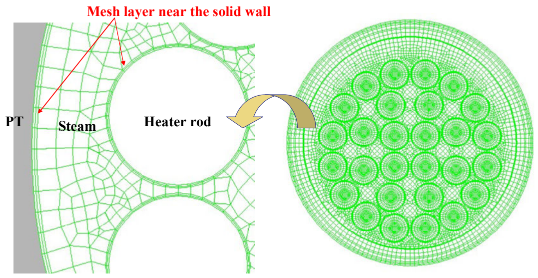

Figure 4. Grid of CS28-2 test section

4. Calculation Results

4.1 Temperature Prediction

The CFX-10 predictions of temperatures at various measurement points are compared with the experimental results in Figs. 5 and 6. The temperature predictions at axial location of 1575 mm from inlet of test section (Fig. 6) are well agreement with the experimental data. The temperature measurements at other locations show some difference from the CFX predictions, but the overall trend is well reproduced.

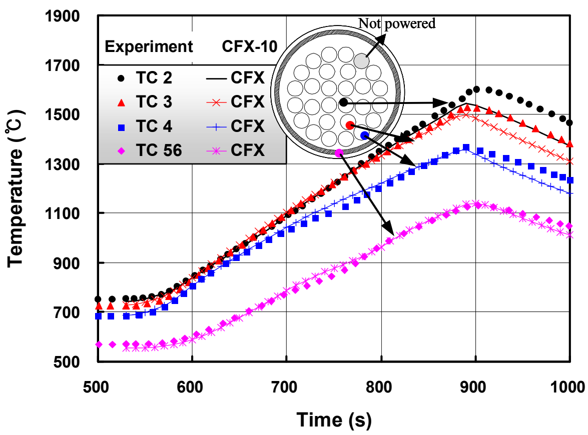

Figure 5. Temperature transient at 225 mm from inlet

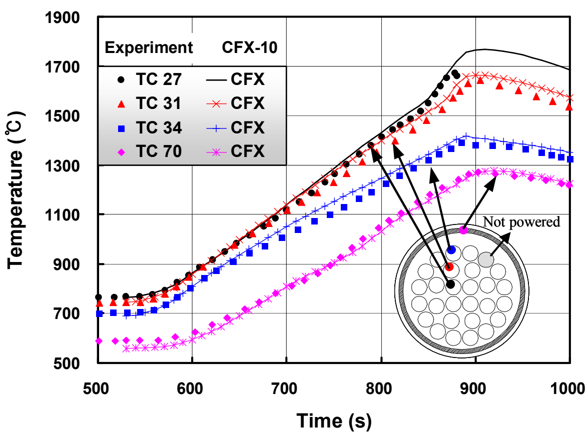

Figure 6. Temperature transient at 1575 mm from inlet

4.2 Hydrogen Production

Fig. 7 shows the comparison of simulated and measured hydrogen production. The results obtained with the Urbanic-Heidrick correlation agreed well with measured values regarding the total amount of hydrogen produced, although the beginning of hydrogen production is earlier than the measurement. However, a systematic over-prediction of hydrogen is predicted when using the Baker-Just correlation over all range of time.

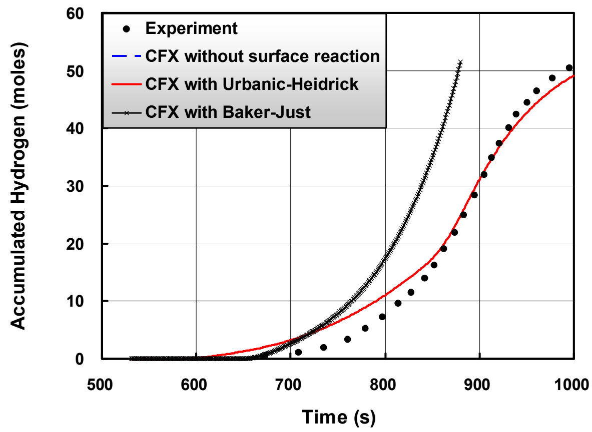

Figure 7. Cumulative hydrogen production

5. Conclusion

It is concluded that application of the proper oxidation model to CFX-10 is essential for simulation of the CS28-2 experiment and the CFX-10 with Urbanic-Heidrick oxidation model successfully predicts the temperature transient and the hydrogen production in the CS28-2 experiment.

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