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Investigation of Spray Characteristics in TOSQAN-101 Experiment Using OpenFOAM CFD Simulation

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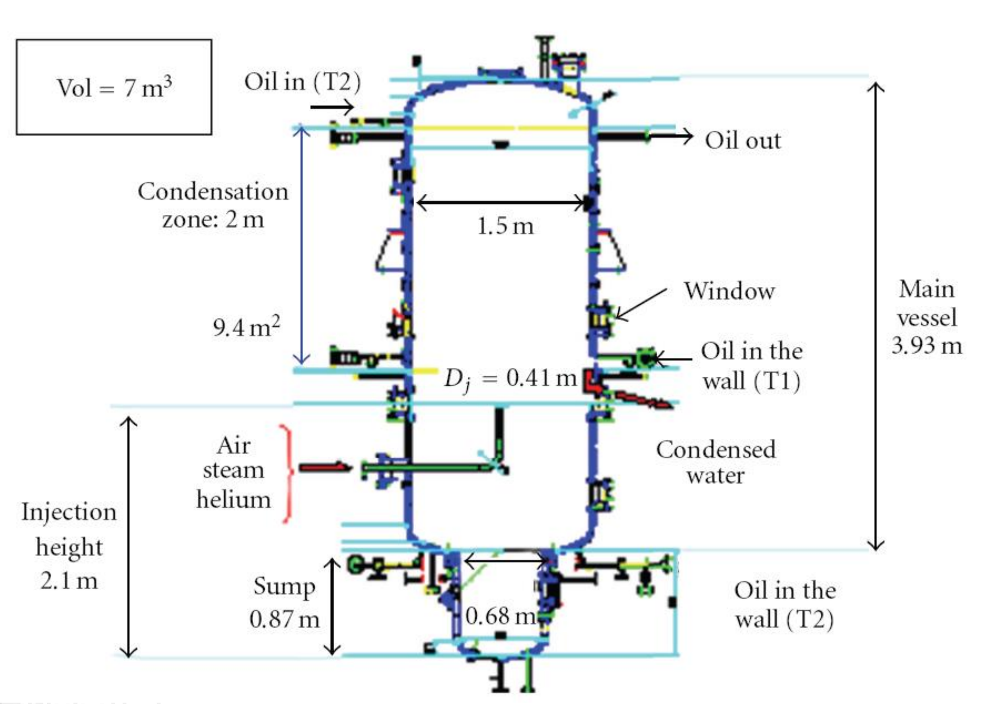
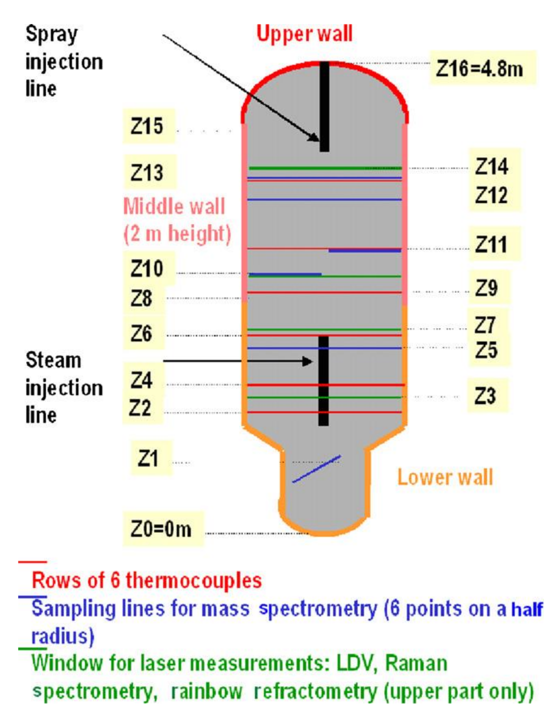
1. Introduction

- **Backgrounds**
  - Containment spray
    - When the reactor core is damaged, the containment building becomes heated and pressurized by steam emitted from RCS
    - **The spray** is used to cool and depressurize the containment building
    - However, **re-pressurization** due to free volume decrease and **increase of H_2 concentration** due to steam condensation
  - TOSQAN-101 experiment
    - TOSQAN-101 experiment : Examined influence of spray in reducing steam partial pressure in air-steam mixture, conducted by IRSN



The geometry of TOSQAN vessel



Measurement points of TOSQAN vessel

- **Objectives**
  - To **analyze TH behavior and spray characteristics** of the TOSQAN-101 experiment using CFD
  - In OpenFOAM-v2112 environment, used **Euler-Eulerian** framework

2. Computational Methods

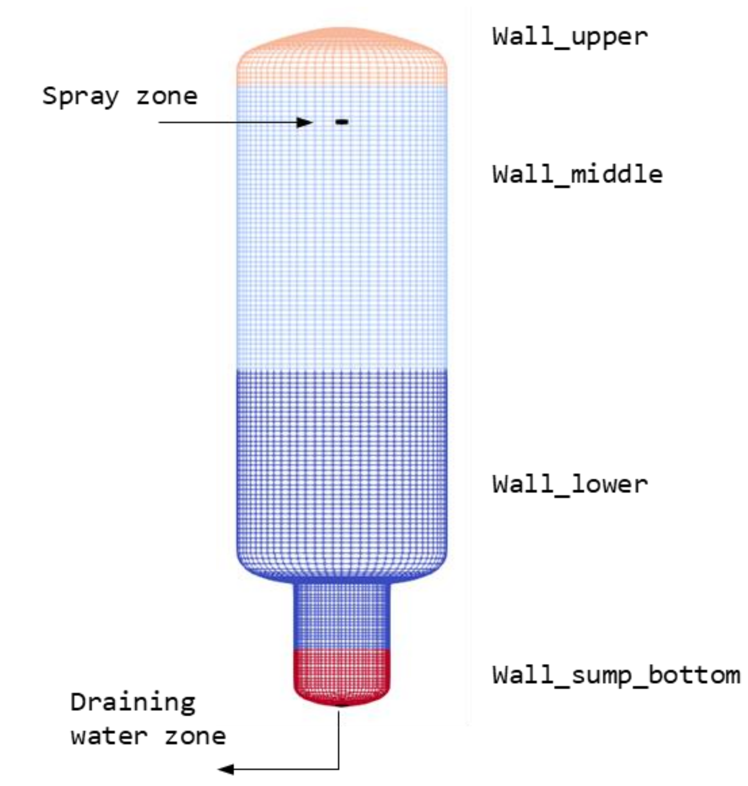
- **Mesh system**
  - **223,056 cells**, mostly hexahedrons
  - Wall boundaries are divided to reflect temperature data that varies with height
- **Numerical solver**
  - reactingTwoPhaseEulerFoam
    - **Euler-Eulerian two-phase flow solver** that can consider multiple species
- **Interfacial momentum transfer**
  - Drag force : Schiller-Naumann
  - Turbulent dispersion force : Custom model
    - To simulate spreading of spray
    - Turbulent dispersion coefficient is modeled as **a function of distance from the origin of spray injection and the spraying angle**

Wall temperature boundary condition

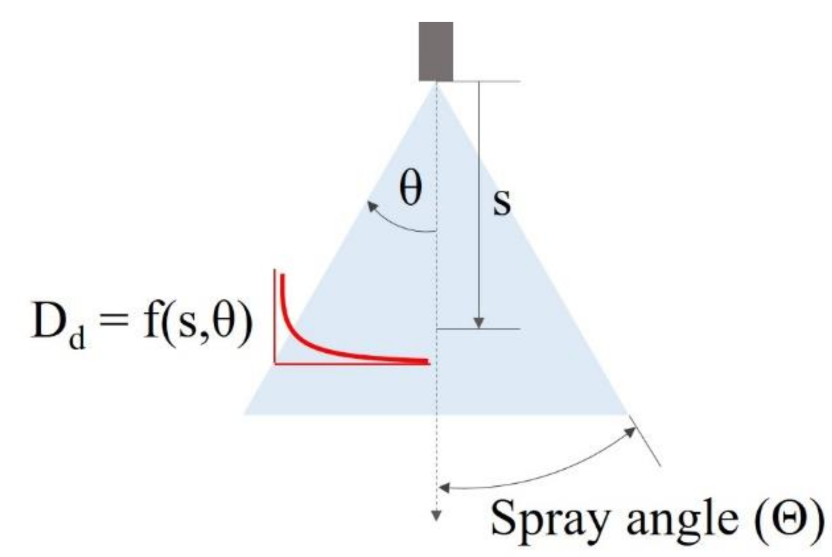
Time [s]	Upper [°C]	Middle [°C]	Lower [°C]
0	121.8	122.3	121.7
50	121.4	121.6	121.3
200	120.8	120.4	120.3
700	120.3	120.0	119.4
1000 ~	119.3	120.1	115.4

Boundary conditions for spray

Spray flow rate [g/s]		29.96
Spray angle [°]		55
Spray injection height [m]		4.13
Droplet size [μm]		200
Vertical droplet velocity [m/s]		10
Droplet injection temperature [°C]	At t = 0 s	119.1
	At t = 120 s	22.1
	From t = 1000 s	27.7
C_{td} value by distance from origin of injection	0 m	1×10^5
	0.5 m	5×10^5
	1.5 m	10^6
	3 m	0



Mesh system of TOSQAN vessel



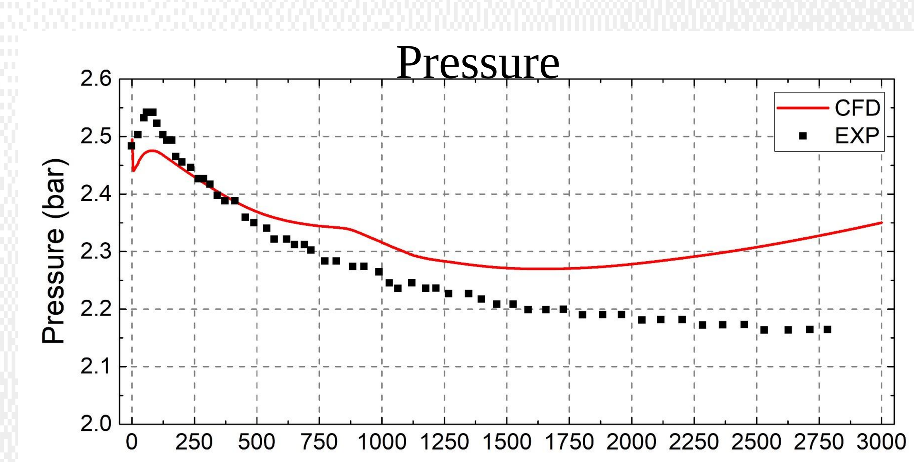
$$M_d^{td} = -D_d \times \nabla \alpha_d \quad (1)$$

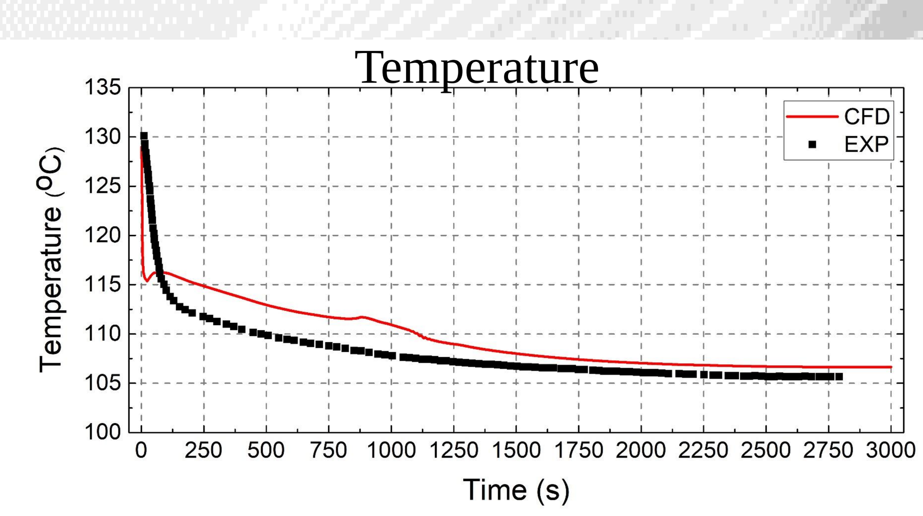
$$D_d = C_{td} \times \left(\frac{\theta}{\Theta}\right)^n \quad (2)$$

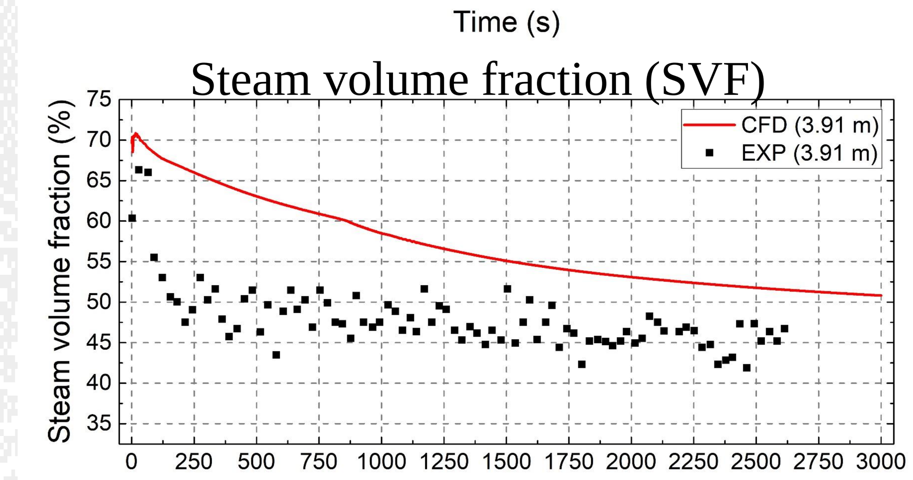
Expression of turbulent dispersion coefficient model

3. Results and Conclusions

- At the beginning of the experiment, the steam volume fraction (**SVF**) **was decreased rapidly near the injector → Condensation has occurred**
- In CFD, the SVF increased slightly and then decreased gradually → **Condensation is not predicted properly**
- The slope of pressure decrease in the experiment and CFD is also different, and after 1500 s in CFD results, pressure increase again
- It is judged that there was a problem in calculating the composition at the interface between phases in **predicting the condensation of steam**
- The spray model and saturation pressure models that influence the composition at the interface between phases will be reviewed.







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