A CFD Simulation of a 1/5-Scale Steam Generator Simulator

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1. Introduction

A 1/5-scale steam generator simulator was developed for core flow test of SMART [1,2]. Its overall layout is illustrated in Fig.1. To simulate a pressure drop induced by a helical tube of steam generator, an orifice is installed in the lower part of the 1/5-scale steam generator simulator. The axial flowrate is measured by a venturi flow. The SG bypass fraction is ignored because it is quite a few amount compared with the total flow amount.

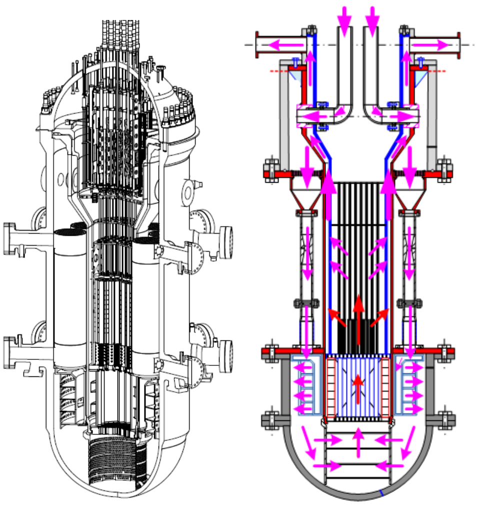


Fig.1 Overall layout of SMART and SCOP

2. Modeling & Scaling Methodology

2.1 Steam Generator Simulator

The SG simulator is designed by 1/5 linear scale method [3]. The flow ratio is 1/125. To evaluate the pressure drop, a parametric study is performed with various orifice sizes.

2.2 Numerical Model

A commercial CFD code of CFX version 11 is applied for this simulation. The continuity, momentum equation and k-e turbulent model are applied. The steady-state numerical solution is applied in the pressure drop simulation. The number of mesh is about 120. The tetra mesh is shifted to the wall layer as shown in Fig.2. The boundary condition is illustrated in Fig. 3.

Boundary condition

Inlet (mass flow rate) : 14.2 kg/s
Outlet (pressure) : 0 Pa

Water Properties

Density : 983.2 kg/m^3
Viscosity : 4.67e-4 Pa-s

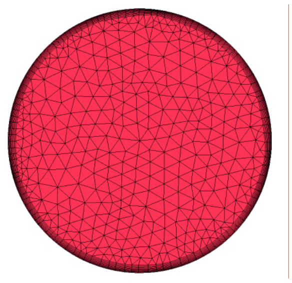


Fig. 2 Wall layer

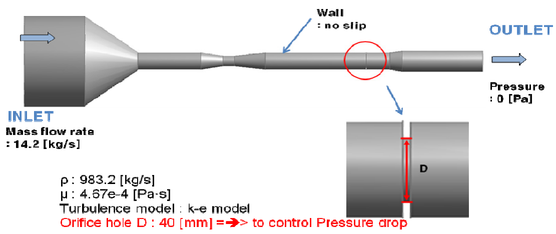


Fig. 3 Boundary Condition

The pressure drop is calculated at three points as shown in Fig.4..

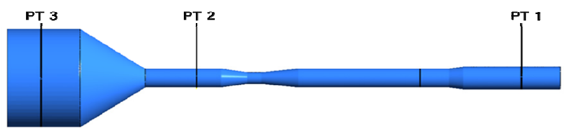


Fig. 4 Pressure estimation point

3. Results and Discussion

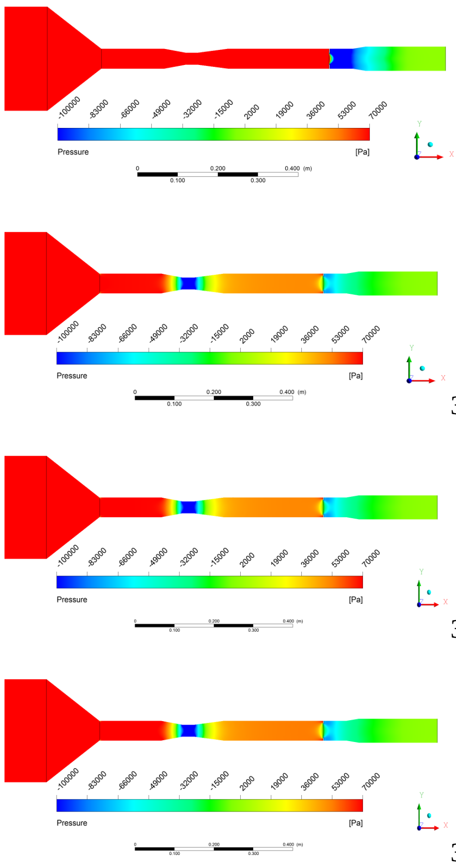
The pressure and the internal flow distribution are demonstrated in Fig.5 and 6. As increasing the orifice diameter, the pressure difference and velocity is decreased.

The working condition of the test facility is about 100°C and 0.1 MPa whereas operating condition of SMART is 323°C and 15 MPa. The different temperature causes a different density which is $960m^3/kg$ at 100°C and $670m^3/kg$ at 323°C. The ratio of water density is about 1.4 times greater than that of SMART330. Therefore, the ratio of pressure drop is increased by the density ratio. The design value of pressure drop in SMART is about 50 KPa. To compensate the scaling distortion, the scaled pressure drop is set to 70KPa.

Table 1 Diameter and pressure.

No	D(mm)	PT3-PT1	PT2-PT1	P3	P2	P1
1	40	73310	44020	70630	41350	-2519
2	30	314800	285500	313300	284000	-1665
3	38.5	88014	58731	85362	56081	-2512
4	38	94107	64830	91482	62206	-2497
5	37.5	100747	71464	98139	68856	-2493
6	37.4	101671	72382	99104	69817	-2459
7	37.3	103307	74016	100769	71479	-2432

The results of the parametric study are summarized in Table1. The total pressure drop of the 1/5-scale SG simulator appears about 70 kPa for the diameter of 40mm. It reveals that the minimum diameter of the inner orifice of the SG simulator should be over 40mm.



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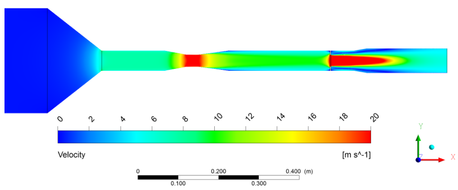
37.5

38

38.5

Fig.5 Pressure distribution with diameters



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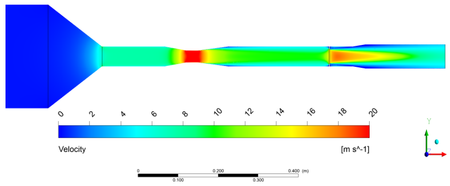

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Fig.6 Velocity distribution

4. Conclusion

The 1/5-scale steam generator simulator is developed. To simulate the pressure drop and the velocity distribution, the 1/5-scale SG simulator was estimated by a steady-state solution. The parametric study for orifice size was carried out under the condition of the linear scaling method. The Reynolds number and the Euler number are conserved at the order of $1E^4$ and 1/20~1/40. The orifice size for the 1/5-scale SG simulator is estimated about 40mm. The orifice size will be determined by a cold water calibration test.

REFERENCES

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