Development of Computational Flow Dynamics Code "MATIS-SC [*1]" for Steam Flow Calculation including Non-equilibrium Condensation

Background

About half of unscheduled shutdowns at power plants are caused by mechanical troubles. In those troubles, FIV(Flow Induced Vibration) occupies about 1/3, so the main subject is to clarify and remove the cause of FIV.

Vibration, noise and erosion caused by local supersonic steam flow may occur around a steam control valve, steam turbine and other plant structures in the steam piping like orifice. However, it is difficult to measure the state quantities of the complex 3D supersonic flow and understand the flow characteristics of them in detail only from experiments. Therefore, it is useful to combine experiments and CFD (Computational Fluid Dynamics) calculations for them, but there are few CFD codes that can be applied to a wide range of steam conditions and can calculate actual steam condensation accurately.

Objectives

Development of CFD code "MATIS-SC" which has following characteristics;

- Applicable to wide range of steam conditions including those in thermal and nuclear power plants
- Possible to calculate state quantities (pressure, temperature and so on) with a high degree of accuracy
- Possible to calculate not only equilibrium steam condensation [*2] but also non-equilibrium steam condensation [*3].

Principal Results

1. Model development for high accuracy and wide applicable range calculation

Existing models have both advantages and disadvantages (Table 1). Then, for "MATIS-SC", we combine their advantages and develop the new calculation model that can be applied to a wide range of steam conditions (Fig.1) and can calculate high accuracy non-equilibrium steam condensation.

2. Confirmation of "MATIS-SC"

As a confirmation of "MATIS-SC", we compared the calculation results with the results of the steam experiments of the nozzle flow (low-pressure (almost atmospheric pressure) condition, Binnie et al. [*4]) and it results in quantitative agreement (Fig.2). In addition, we compared the equilibrium and the non-equilibrium condensation calculation to check those differences. As a result, the equilibrium one can't reproduce the sudden changes of the pressure, wetness and velocity, while the non-equilibrium one can reproduce them and good agreement with the experiment (Fig.3).

Future Developments

- Confirmation of "MATIS-SC" in higher pressure condition by steam experiments
- Apply the code to the plant structures and clarify the phenomena to suggest measures based on the phenomena

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Reference

Ryo M, 2005/02, "Development of CFD Code "MATIS-SC" for Steam with Non-equilibrium Condensation", CRIEPI Report No. L04002 (Japanese only)

＊1：**M**ulti-dimensional **A**ccurately **T**ime **I**ntegration **S**imulation for **S**team with **C**ondensation
＊2：Equilibrium Condensation : Condensation phenomena that occurs along the saturated vapor line.
＊3：Non-equilibrium Condensation : Rapid condensation phenomena after it becomes below saturation temperature, not along the saturated vapor line. This causes sudden changes of state quantities. It occurs as actual phenomena.
＊4：Binnie, A.M., Green, M.A. et al., Proc. Roy. Soc., A, 181, plate 3, pp. 134-154, (1943)

Table 1 Model Comparison

Model	Steam Table Model	Equation of State Model	New Model (MATIS-SC)
Advantages	・High accuracy calculation of State Quantities (∼(10^{-7})) ・Applicable to wide range of steam condition	・Possible to calculate non-equilibrium condensation	・Possible to calculate non-equilibrium condensation ・High accuracy calculation of State Quantities (∼(10^{-7})) ・Applicable to wide range of steam conditions
Disadvantages	・Impossible to calculate non-equilibrium condensation	・Low accuracy calculation of State Quantities (∼(10^{-1}))	

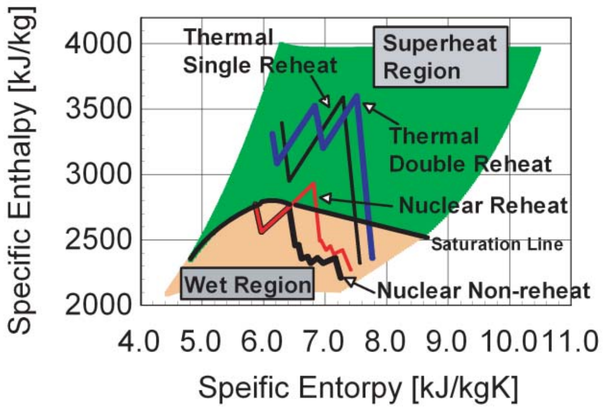

Fig.1 Steam Condition of Steam Turbine and Coverage of "MATIS-SC"

Applicable range of "MATIS-SC" is covered with the steamconditions in thermal and nuclear power plants.

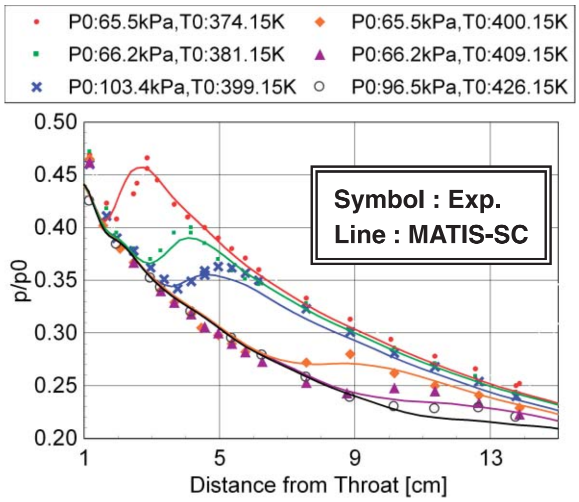

Fig.2 Static Pressure Comparison between MATIS-SC and Exp.[*4]
(P0 : Inlet Pressure, T0 : Inlet Temperature)

CFD results agree well with the experiments.

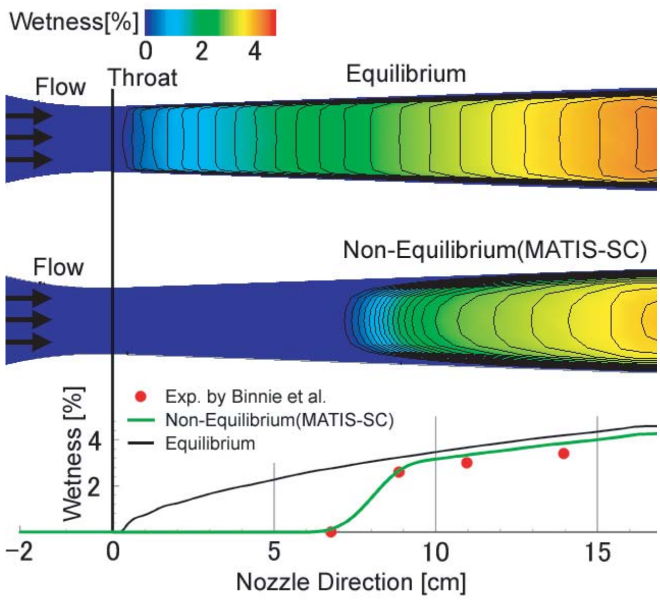

Fig.3 Flow Visualization Figures (Upper, Middle) and Wetness Distribution along Flow Direction (Lower)
(P0 : 65.5kPa, T0 : 400.15K)

"MATIS-SC" can reproduce the sudden changes of pressure, wetness and velocity, and has good agreement with the experiment.