Department of Applied Nuclear Technology

Key words Thermal hydraulics, Gas-Liquid Two phase flow, Computational Fluid Dynamics(CFD), Critical Heat Flux, Nuclear reactor safety, Nuclear fuel design,ATF,SMR

Doctor of Engineering / Professor

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Education

Department of Engineering, Faculty of Electric Engineering II, Kyoto University
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Professional Background

Nuclear Fuel Industries,Ltd. Kumatori Works. General manager of Fuel Engineering Development, General manager of Environmental Safety

Consultations, Lectures, and Collaborative Research Themes

Technical consultant and analysis of thermal hydraulic phenomena, Design of thermal hydraulic equipment, Nuclear Reactor Safety Evaluation

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Main research themes and their characteristics

「Numerical analysis study of droplet behavior in mist flow and annular mist flow」

Annular mist flow and mist flow are gas-liquid two-phase flow regimes that greatly affect the thermal limits, safety, and reliability of the reactor core under loss of coolant accident and severe accident. Empirical correlations based on many experiments have been proposed for droplet behavior in these cases in the past, but they are all limited to the range of experimental conditions. A droplet behavior prediction method that can be used under a wide variety of accident conditions has not been established. Therefore, we aimed to develop a general-purpose droplet behavior prediction method that does not rely on experiments, using computational fluid dynamics analysis, for droplet turbulent diffusion and droplet deposition phenomena, which are fundamental phenomena in droplet behavior. In addition to the mist flow, in order to analyze the annular mist flow necessary for thermal limit evaluation, we developed a numerical analysis model for the annular mist flow that takes into account the generation of droplets from the liquid film. The liquid film flow rate calculation was made possible with high accuracy. And now, we are working on droplet behavior analysis and annular spray flow analysis using the open source 3D fluid analysis code “OpenFOAM” so that we can analyze the annular mist flow in the reactor core system. Figure 1 shows the results of unsteady three-dimensional droplet behavior analysis in a circular pipe spray flow. Fig. 2 shows the results of analysis of how a droplet in a circular pipe deposits on the pipe wall and the liquid film grows downstream. In the future, we plan to conduct a three-dimensional unsteady analysis of the annular mist flow considering the complex shape of the actual nuclear fuel assembly, and work on a more realistic thermal-hydraulic analysis of the reactor.

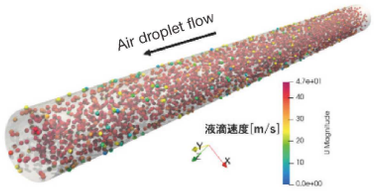

Fig1. 3D mist flow CFD analysis

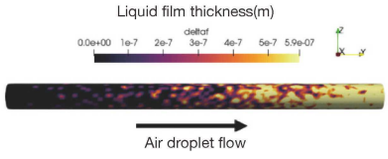

Fig2. Annular Spray Flow Analysis Considering Adhesion of Droplets to Tube Wall

「Small Modular Reactor (SMR) fuel applicability study」

In recent years, research and development of SMR has been promoted in various countries. Compared to conventional light water reactors, the SMR is a nuclear reactor that is smaller, has lower output, and has improved intrinsic and passive safety such as "self-stopping" and "self-cooling". Overseas, it is expected to be used as a power source and heat source in remote areas without power grids. On the other hand, in Japan, there is no need as a power source for remote areas because the power grid is spread all over the country. However, the combination with photovoltaic power generation is attractive SMR use. When considering this combination, the daily load operation of the nuclear reactor must be assumed. Since the load applied to the nuclear fuel fluctuates when the output is changed, it is necessary to confirm that the fatigue fracture of the nuclear fuel does not occur. Figure 3 shows the daily load fluctuation of the reactor and the accompanying stress fluctuation of the nuclear fuel cladding at the end of the life of nuclear fuel. It is shown that the stress fluctuation due to the power fluctuation occurs due to the contact between the fuel pellet and the metal cladding. As a result of the fatigue evaluation, it was confirmed that the stress fluctuation does not cause fatigue failure.

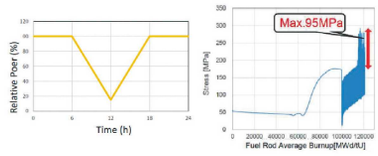

Fig.3 Nuclear fuel stress evaluation in daily load operation SMR

Major academic publications

K.Matsuura,I.Kataoka,K.Mishima
“Post-Dryout Heat Transfer Analysis Model with Droplet Lagrangian Simulation” JSME International Journal SeriesB, Vol.49, No.2.(2006)

K.Matsuura, I.Kataoka, A.Serizawa
“Annular Dispersed Flow Analysis Model by Lagrangian Method and Liquid Film Cell Model” The 10th International Topical Meeting on Nuclear Reactor Thermal Hydraulic (NURETH-10) (2003)