Intergraded and Coupled Analysis of Reflood Using Fuel Simulator (ICARUS) Thermal loss analysis

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1. Introduction

The safety criteria and licensing problems of nuclear power plants are changing due to the application of design extended conditions (DEC) and high burn up fuel safety issues. This requires multiple physical coupling safety analysis. One of the activities related to multi-physical coupled safety analysis is a development of coupled safety analysis code system for the thermal hydraulic safety analysis code and thermal mechanical safety analysis code. Currently, there is not enough experimental data to verify the combined safety code system. Therefore, thermal hydraulics and thermal mechanics are needed to evaluate new safety criteria. An experimental facility called ICARUS (Intergraded and coupled analysis of reflood Using Fuel Simulator) was developed for multi-physics coupled phenomena during loss of coolant accident (LOCA) ant KAERI (Korea Atomic Energy Research Institute) [1]

ICARUS facilities can simulate deformation of fuel cladding under LOCA and reabsorption conditions. The system measures temperature, Pressure and Cladding geometry in real time during transient experiments. This study compared and analyzed heat loss measured at ICARUS Facilities and heat loss through CFD calculation.

2. Methods and Results

The conceptual system consists of the boiler, pipe and super heater. The steam line of the pipe is connected to Test Section. And the two phase mixture generated by boiling in the boiler is an inlet condition. MARS_KS version 1.5 has been utilized for the thermal hydraulic calculation.

Primary steam is produced in a boiler. Boiled steam passes through the pipe, passes through the super heater, and becomes an inlet of the Test Section. Steam generation and heater thermal power are calculated by MARS_KS and with the generated inlet conditions, STAR CCM+ performs heat transfer analysis.

The primary side flow value inputs mass flow data calculated by MARS_KS. The Secondary coolant flows into the water jacket. The above water jacket is to protect the O-ring of the flange fixing the heater rod. It is installed in the upper and lower pars of the Test Section.

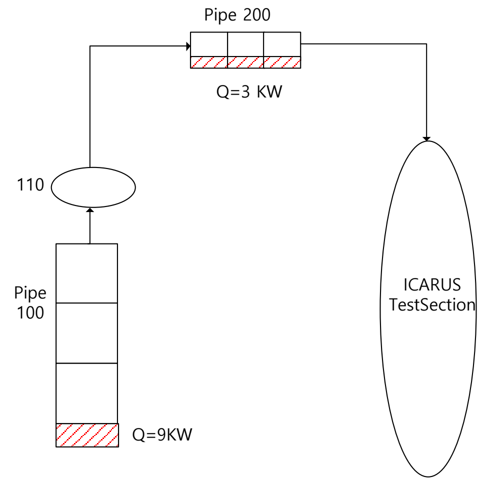

Fig. 1. MARS model for steam supply system

The existing thermal loss test results are shown in Table I. The wall temperature was measured while increasing the output of the heater rod. It was increased in a total of four ranges. When the heater output was applied and the wall temperature stabilized, data was acquired for 20 minutes.

Table I. Measurement of heat loss

Total Power(w)	Heating Rod	Wall Temperature	Room Temperature
273.0	227	123	33
591.1	414	213	35
1128.7	550	319	31
2293.6	741	508	35

It is a method of calculating the amount of heat loss. First, the Test Section is heated. When the power of the heater rod is increased, some are heated and some are discharged to the atmosphere due to heat loss.

$$Q_{total} = Q_{heatup} + Qloss$$

In a steady state, all power of the heater rod is discharged to the atmosphere.

$$Q_{total} = \cancel{Q_{heatup}} + Qloss \text{ , at } Q_{heatup} = 0$$

Compare the above test results with the CFD analysis results. It also analyzes the relationship between the outer wall temperature and the heating rod Power.

3. Results

The MARSA_KS result is input to the primary side as a flow rate value. The flow rate of steam is 0.5 g/s Figure.2 shows a total of four heater rod temperatures. The temperature of the wall varies depending on the temperature of each heater rod.

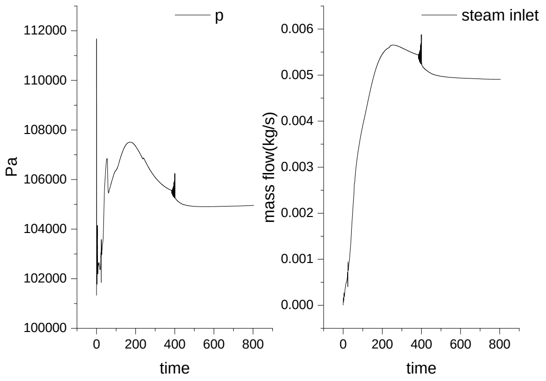

Fig. 2. MARS_KS result

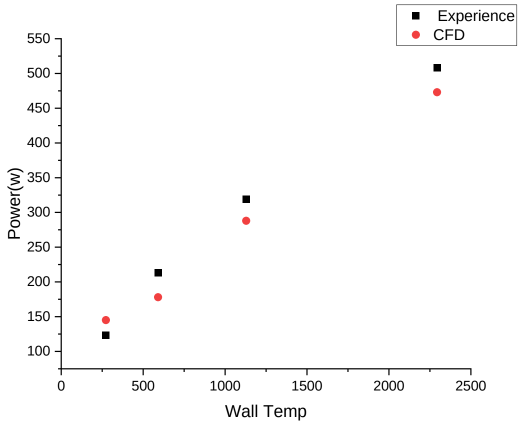

Fig. 3. Experimental value and CFD result value

The temperature distribution of the ICARUS Test Section was analyzed. Steam is supplied to the primary side and cooling water is supplied to the secondary side. The upper and lower Test Sections have lower temperatures than the center. This is because the heater rod power flanges are affected by cooling due to water jackets.

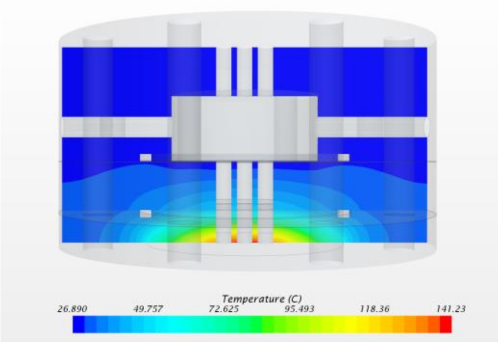

Fig. 4. Water jacket O-ring Temperature at 508℃

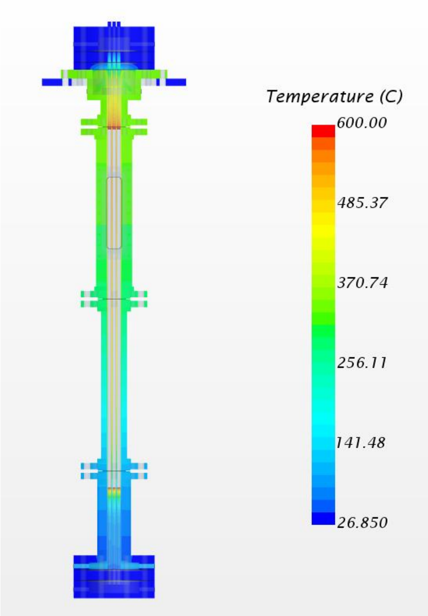

Fig. 5. Temperature distribution heater rod at 508℃

In the experiment, the heater rod temperature and the wall temperature ware measured according to the heater power. In the CFD calculation, the wall temperature was calculated using the heater rod temperature. The results are shown in Fig. 3 some reasons for the difference between experimental data and CFD results are speculated. The first is the insulation condition. In the experiment, a ceramic wool insulating agent was used, but the flange visualization window was not insulated. On the other hand, in the CFD calculation, it was calculated as a thermal insulation In accordance with the above experimental conditions, the ceramic wool insulation value can be input and calculated by inputting an external convection condition. Second, it requires several tuning operations. In this paper, the trend of experimental and CFD results was studied and the overall heat loss value was estimated.

REFERENCES

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