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Comparison of Different Safety Injection Tank Models in MARS-KS

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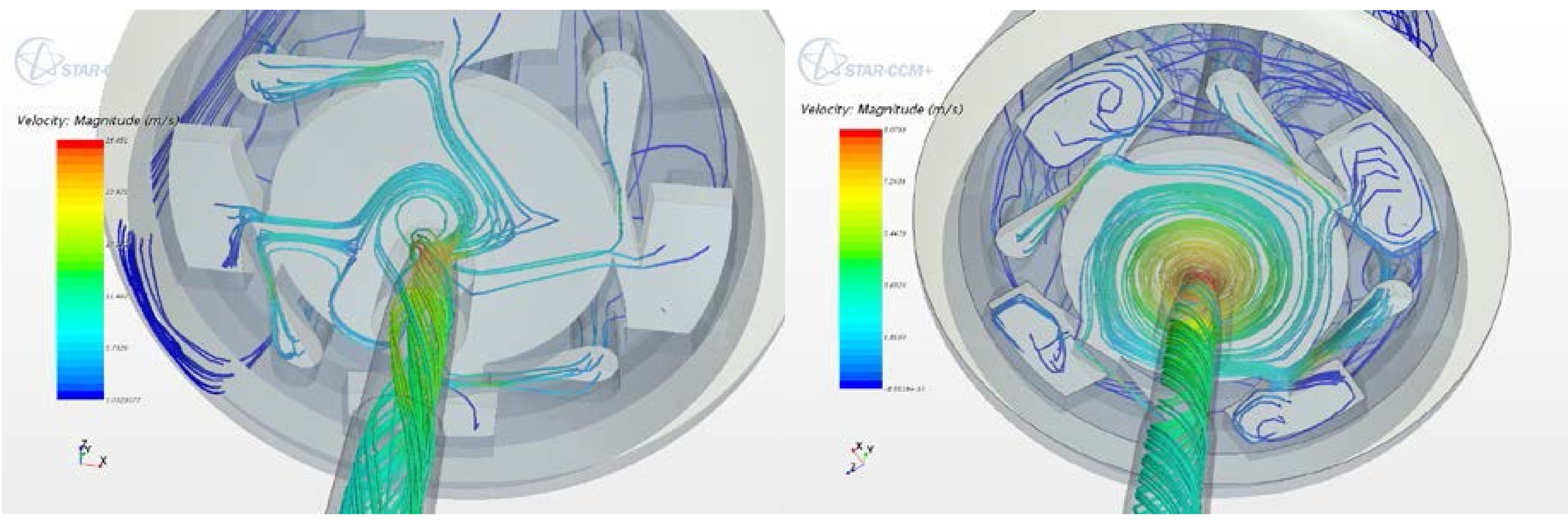
Introduction

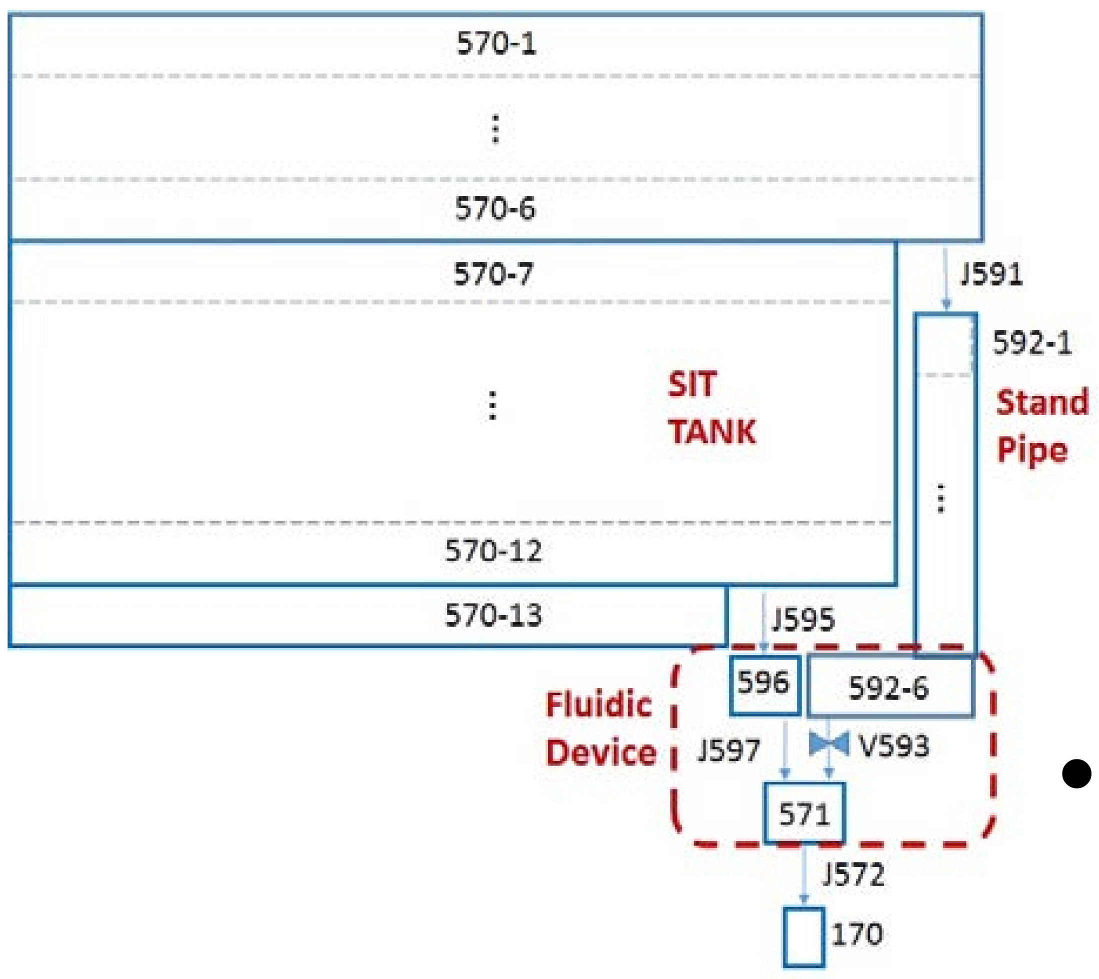
- The Advanced Power Reactor (APR) 1400 has an emergency core cooling system (ECCS).
- One of the most important components in the ECCS is the safety injection tank (SIT).
- Inside the SIT, a fluidic device (FD) is installed, which passively controls the mass flow of the safety injection of the coolant, eliminating the need for low-pressure safety injection pumps.
- As passive safety mechanisms are emphasized nowadays, it has become more important to model the SITs more realistically.
- During the high flow mode, water level is higher than the standpipe height. Hence, water flows into the vortex chamber of the FD from two ports, the supply port and the control port. Water from the two different nozzles collide and flows into the discharge pipe directly.
- During the low flow mode, water level is lower than the standpipe height, therefore, water can only flow into the vortex chamber through the control port. Therefore, the flow is directed to a tangential angle of the vortex chamber generating a vortex, resulting in a lower water flowrate supplied to the reactor core.



Streamlines within the FD during high flow (left) and low flow (right)

MARS-KS Modeling

- 1D system codes, such as MARS-KS, have used single or double k-factors to control the mass flow of SITs. However, in the real case, the k-factor and mass flow may be not a constant. Moreover, as the water level drops, nitrogen may be entrained into the discharge pipe and then into the core. This may affect the core cooling capability and threaten the fuel integrity during LOCA situations.
- Accumulator models need two different valves with two different pressure loss coefficients to simulate the different mass flows. In addition, the implementation of fluidic device introduced nitrogen entrainment into the system, which cannot be simulated with the accumulator model.
- Therefore another model was developed using pipe and junction components. The nodalization is shown in the figure below. The new pipe model includes a standpipe and a fluidic device. In addition, a valve is situated where the flow from the supply port meets with that of the control port. It cuts off excessive nitrogen entrainment through the standpipe once the standpipe is emptied. Previous studies show that such modeling makes pressure and mass flow prediction much more accurate. Unlike the accumulator model, the pressure loss coefficient is given in two different places (V593 J597).



Nodalization of the SIT pipe model

- This study focuses on modeling the pressure loss coefficient of the supply port and control port more accurately. The pressure loss coefficients were tuned in components J597 and V593. Three different models were used for comparison using different methods to determine the pressure loss coefficients.
- The first model (SIT_A) uses pressure loss coefficients based on CFD calculations. K597 and K593 were calculated to be 10 and 45 respectively.
- The second model (SIT_B) uses experiment data to find a constant for the pressure loss coefficient. The test data came from Shin-Kori Unit 3 SIT cold function test. K597 and K593 were found to be 24.5 and 500 respectively.
- The third model (SIT_C) uses the built-in function for the pressure loss coefficient based on the Reynolds number using eqn. (1). Testing the model with different sample sets, we were able to compare the results with the test data to find the set that gives the closest result with those of the experiment. The set is shown in Table I.

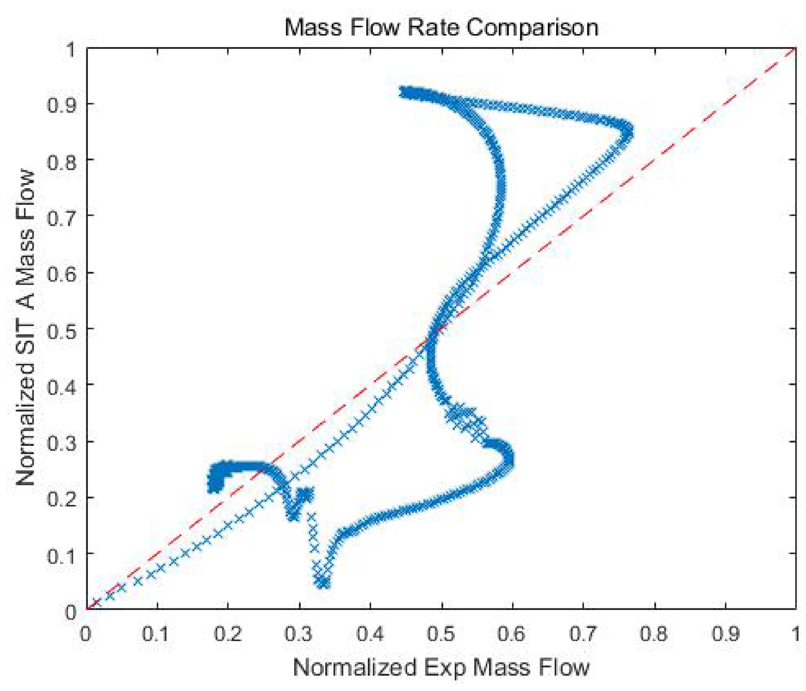
$$K = C_1 + C_2 \times Re^{-C_3} \quad (1)$$

Table I: Value of each variable for pressure loss coefficient function

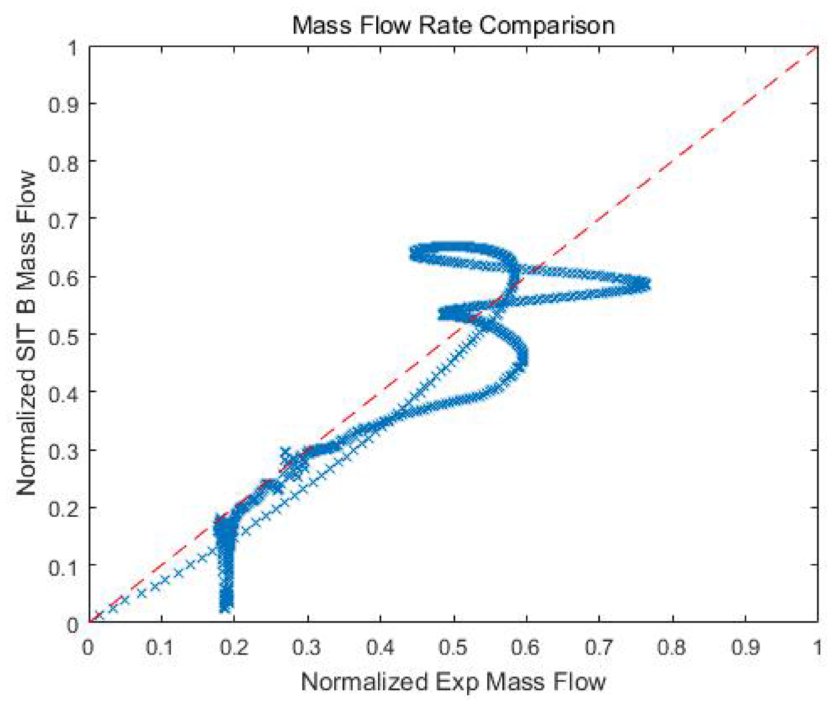
	Supply Port	Control Port
C_1	36	18
C_2	7.42 E11	8.32 E11
C_3	1.75	2.56

Results

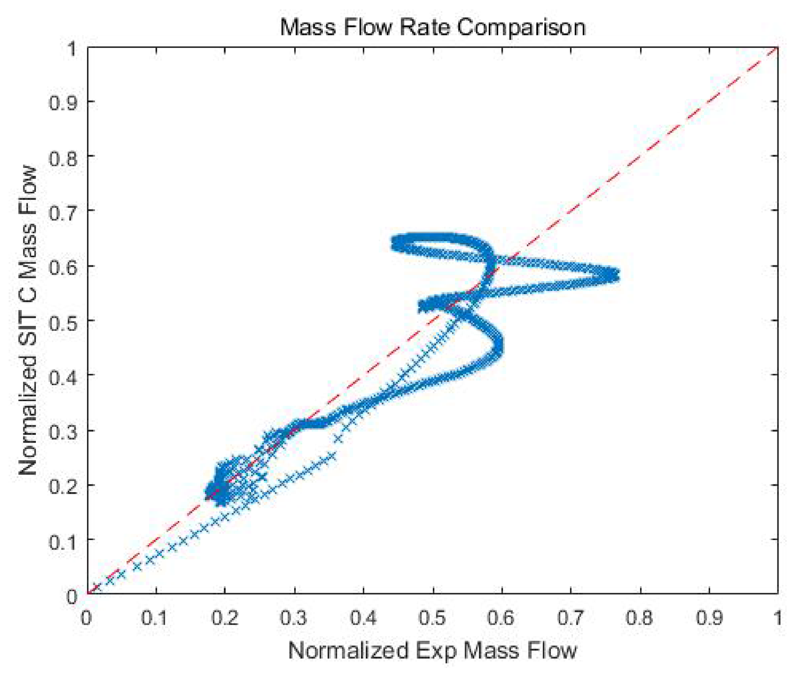
- We can plot the mass flow rate from each model and compare it with the results from the experiment. The graphs below show the calculated mass flow rate plotted against the experimental data.



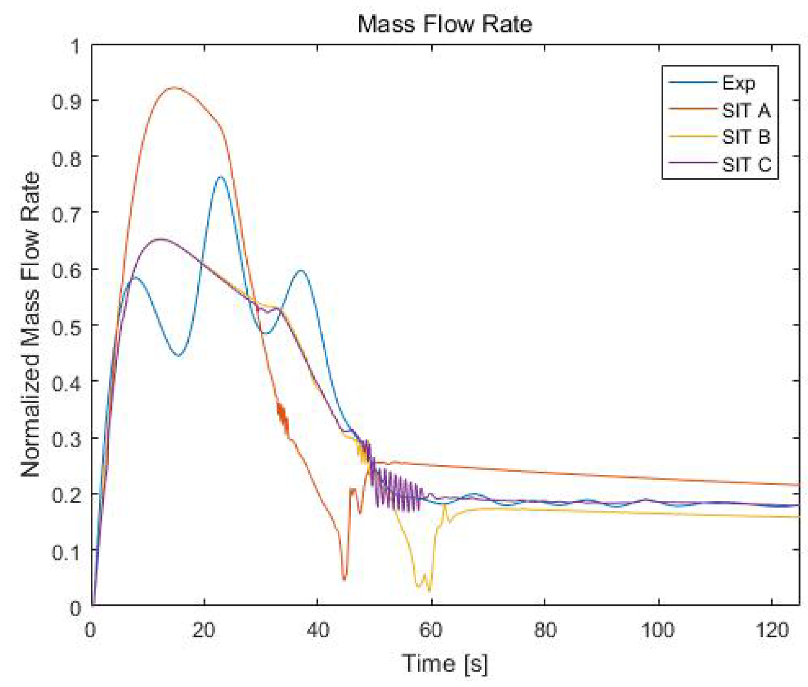
Mass Flow Rate of model SIT_A and experiment



Mass Flow Rate of model SIT_B and experiment



Mass Flow Rate of model SIT_C and experiment



Comparison of Mass Flow Rate of different models

- We can quantify the deviation from the experimental value using the R^2 value.
- We can define eq. (2) and (3), which can be used to define R^2 by eq. (4).
- Table II shows the R^2 value for each case. The closer the number is to 1, the closer it is to the experimental result.
- Just as we anticipated, SIT_C model is closest to the test data and is the most suitable for modeling the SIT tank.

$$SS_{res} = \sum_i (y_i - f_i)^2 \quad (2)$$

$$SS_{tot} = \sum_i (y_i - \bar{y})^2 \quad (3)$$

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}} \quad (4)$$

Table II: R^2 value of each model

Model	SIT_A	SIT_B	SIT_C
R^2	0.5596	0.8628	0.8671

Conclusions

- Several models of the SIT were compared to find the most suitable one for a system analysis.
- Among the three models compared, SIT_C model showed the best performance.
- The SIT_B model showed very close performance but had some deviation from the experiment data during the transition from the high flow to the low flow.
- Thus, in future modeling of the SIT with FD, K-factor as a function of Reynolds number is recommended to be used for the calculation of the related accident.