LACANES benchmarking of thermal hydraulic loop models for LBE integral test loop

Phase-I: isothermal steady state forced convection

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1. Introduction

As highly promising coolant for new generation nuclear reactors, liquid lead-bismuth eutectic (LBE) has been extensively investigated in worldwide. With high expectation about this advanced coolant, a multi-national systematic study on LBE was proposed in 2007, which covers benchmarking of thermal hydraulic prediction models for Lead-Alloy Cooled Advanced Nuclear Energy System (LACANES). To produce experimental data for LACANES benchmarking, thermal-hydraulic tests were conducted by using a twelve-meter tall LBE integral test facility, named as HELIOS (Heavy Eutectic liquid metal Loop for Integral test of Operability and Safety of PEACER) which has been constructed in 2005 at the Seoul National University in the Republic of Korea.

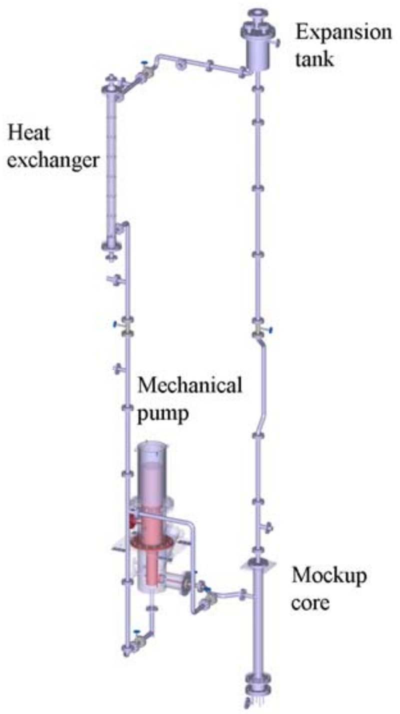

Fig. 1. HELIOS picture located in the NUTRECK, Seoul National University

2. Methods and Results

In this section methodologies of LACANSE benchmarking and its currently results are described.

2.1 Method of LACANSE benchmarking Phase-I

Low mass flow rate, 3.27kg/s, and high mass flow rate, 13.57kg/s, were considered in the forced convection case (phase-I). For the suggested cases, the pressure loss coefficients for all components were predicted by nine participants. All participants used internal correlations embedded in thermal hydraulic system codes or specific handbook correlations to calculate pressure losses. Computational Fluid Dynamics (CFD) simulations were also carried out to predict pressure loss in the most significant component, a core. All predictions of pressure loss were based on Eq. (1). Pressure loss coefficients were determined by combining of friction loss coefficient (f) and form loss coefficient (K).

$$\Delta P = \frac{1}{2}\rho V^2 (f\frac{L}{D} + K) \quad (1)$$

Then, predictions were compared with the measured data. From comparison and discussion between predictions and the measured data, best practice guidelines for the prediction method of a pressure loss were established.

2.2 Results

Fig.2. shows the accumulated pressure losses versus the accumulated length of the forced convection flow path, predicted by the nine organizations-participants. The accumulated pressure losses start from the core inlet and go through the main components of the HELIOS loop. Declinations at a distance of 3 meters are due to pressure loss of the core region and at 9-10 meters are due to pressure loss of the orifice region. At a distance of about 25 meters, the accumulated pressure losses are compensated by head supplied by a mechanical pump. This graph also shows the lines of these two calibrated results, along with the indications of the measured data. Calibrated results have shown good agreement with the measured data in the combined region.

CFD simulations were made for the all components of HELIOS, using CFX® and Star-CD®. Excellent comparisons between CFD simulations and the measured data for all components shed lights for the good guidelines for prediction of pressure losses, everywhere measured data are not available. Fig.3. shows the comparison between measured data and CFD prediction. All predictions by CFD simulation are located within ±15% error band. Following sections show the results of CFD estimations and comparison of CFD estimations with measured data for the core region, the orifice region, and the gate valve region.

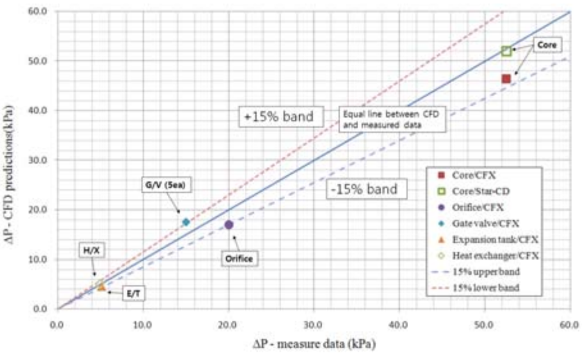

Fig. 3. Comparison between measured data (X axis) and CFD prediction (Y axis) with ±15% error band

3. Conclusions

Through the LACANES benchmarking phase-I, best practice guidelines for pressure losses prediction are established. Experimental test are conducted to obtain the pressure loss in the core, the gate valve, the orifice, the heat exchanger region, and the expansion tank region. Predictions are also performed by participants with correlations from handbooks. Furthermore, to improve the prediction for the complicated geometry and to solve the uncertainty of prediction from correlations, CFD simulations for all components are conducted. LACANES benchmarking phase-II which covers prediction of natural circulation behaviour will be conducted during 2010.

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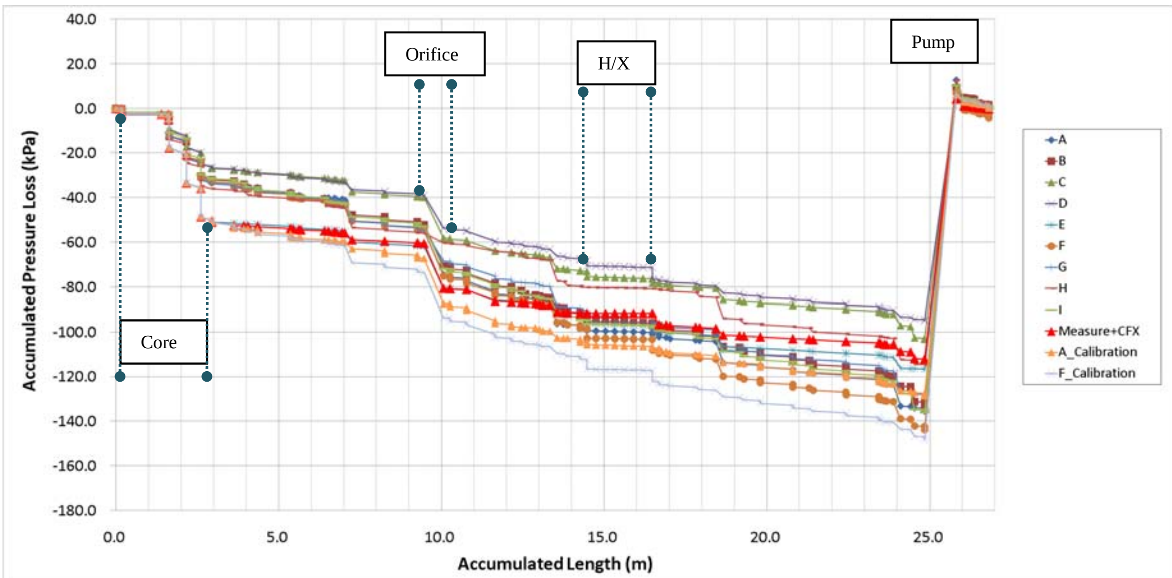

Fig. 2. Accumulated length versus pressure loss for participant predictions by using handbook correlation in high mass flow rate condition (13.57kg/s)