Core Thermal Hydraulic Characteristics of Open Pool Type Research Reactors

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1. Introduction

KAERI (Korea Atomic Energy Research Institute) is currently designing an integrated thermal hydraulic experimental loop for studying single and two-phase flow characteristics in research reactor core cooling channel. In particular, the facility aims to produce thermal hydraulic experimental data on narrow rectangular cooling channel in open pool type research reactors with plate type fuels. The design activity must be preceded by determining range of thermal hydraulic operating conditions of test section. In this study, based upon open literatures, the core thermal hydraulic conditions of open pool type research reactors with medium thermal powers (≥5 MW) have been compiled and their characteristics are analyzed[1].

2. Methods and Results

In this chapter, compiled thermal hydraulic conditions of research reactor cores are summarized and their characteristics are discussed.

2.1 Summary of Core Thermal Hydraulic Designs

From various open literatures, the core thermal hydraulic operating conditions of various reactor cores were collected. Table I lists the design variable values of selected research reactors[2-19]. Some of the data are uncertain due to limited resources. These parts (values with underlines) were evaluated based upon first principle calculations with conservation laws, or referencing similar design concepts. Therefore, the presented values on the table are used only for analyzing and comparing overall characteristics, but not for precise engineering calculations. The compiled table shows that the research reactors have similar inlet temperature ranges (35~40 ^{o}C). However, they have widely scattered distributions of inlet pressures (1.5~5.6 bar), coolant velocities (2.5~11.5 m/s), and heat fluxes (158~940 kW/m^2). At glance, relationship of each design variable is hard to understand, some of which are analyzed in the following sections.

Figure 1 shows distribution of core inlet/outlet subcooling. In overall, relatively higher subcooling is observed in reactors with core coolant flowing upward. This can be expressed as following, as seen in Fig. 2, for cores with upward coolant flow, it is possible to maintain higher core inlet pressure by pump head. In contrasts for cores with downward coolant flow, the pressure at the core inlet is determined by merely hydrostatic pressure head from pool water, and it is difficult to further increase the pressure.

Figure 3 compares core inlet coolant velocities for various research reactors. It is seen that for some reactors such as ETRR-2 and RGS-GAS, the coolant velocity is maintained at lower level when compared with other similar powered research reactors. The nominal coolant velocity is usually determined by heat transfer characteristics of the core. Therefore, comparing coolant velocities to fuel heat fluxes may be more intuitive than just looking at their core power levels. Figure 4 shows the ratio of fuel heat fluxes versus coolant mass fluxes. The results shows that the variables have proportional relationship in overall.

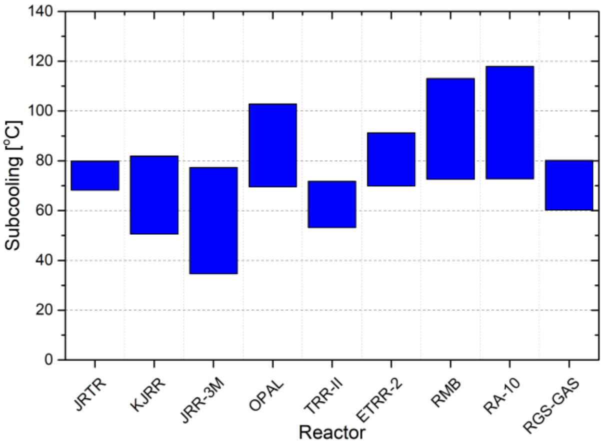

Fig. 1. Reactor-wise distribution of core inlet/outlet subcooling.

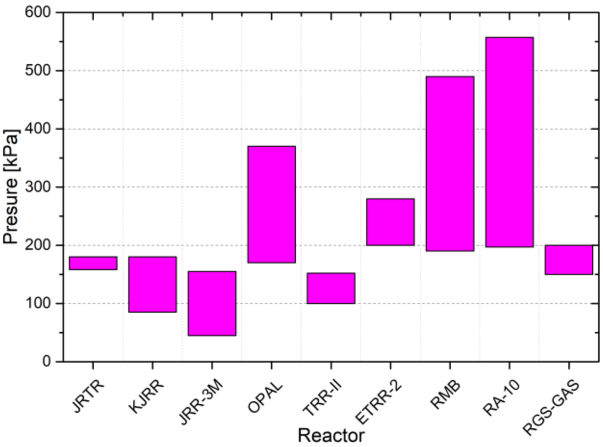

Fig. 2. Reactor-wise distribution of core inlet/outlet pressure.

Table I: Core thermal hydraulic design variables of medium and higher power research reactors

	Research Reactor								
Parameter	JRTR	KJRR	JRR-3M	OPAL	TRR-II	ETRR-2	RMB	RA-10	RGS-GAS
Q_{core} [MW]	5	15	20	20	20	22	30	30	30
T_{in} [^oC]	37	35	35	38	40	40	38	38	40
P_{in} [kPa]	180	180	155	*370*	152	280	*490*	*557*	199.7
dP_{core} [kPa]	22	95	110	*200*	*52*	80	300	360	50
V_{ch} [m/s]	2.5	6	6.2	8.2	6.24	4.7	9.4	11.5	3.8
Direction	Down	Down	Down	Up	Up	Up	Up	Up	Up
No. FAs	18	22	26/6	16	25/6	29	23	19	40/8
No. Plates/FA	21	21	19/15	21	21/17	19	21	21	21/15
t_{ch} [mm]	2.35	2.35	2.28/2.38	2.45	2.58	2.7	2.45	*2.45*	2.55
W_{ch} [mm]	66.6	66.6	66.6/54.0	70.5	71.5	70	70.5	*70.5*	67.1
W_{meat} [mm]	62.1	62	62/49	65	67.3	64	65	*65*	62.75
L_{meat} [mm]	640	600	750	615	600	800	615	*615*	600
q_{avg} [kw/m^2]	158	414.6	380.2	720	409	*370.4*	*738*	940	*394.3*
F_Q[-]	*≤3.0*	*≤3.0*	3.112	*≤3.0*	3.829	*3.16*	*≤3.0*	3.3	*5.62*

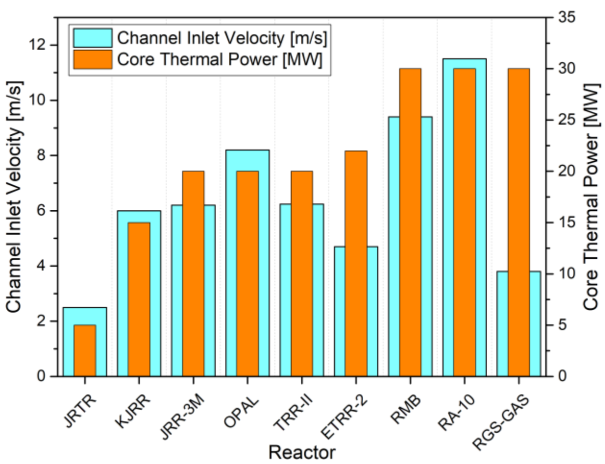

Fig. 3. Core coolant velocity and power level for various research reactors.

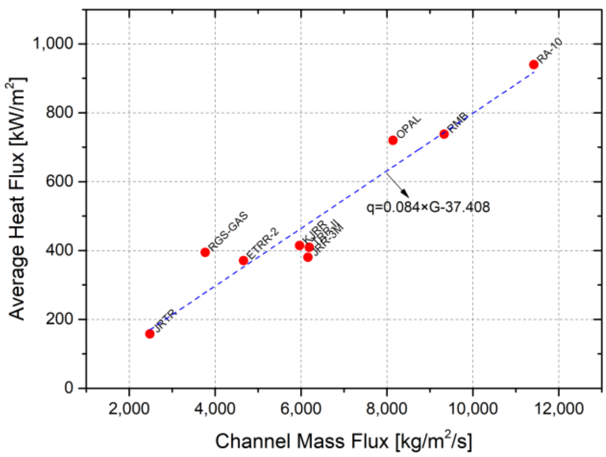

Fig. 4. Core coolant mass flux vs. fuel heat flux for various research reactors.

3. Conclusions

In this study, various core thermal hydraulic design values of open pool type research reactors are investigated to analyze their characteristics and inter-relationships. The study showes that their core subcooling and pressure conditions are related to each other when coolant flow direction is accounted for. It is also seen that the core power density (heat flux) is almost linearly proportional to coolant velocity (mass flux). The deviations from linearity seem natural considering each reactor cores' design differences such as coolant channel geometries, presence of in-core reflectors and irradiation components. The data and insights obtained from the study will be utilized to yield required performance specifications for the test section of the test loop under design.

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