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# Calculations for Standard Hydraulics and Heat Transfer Problem in Subassembly Model Cooled by Liquid Metal

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## 1. Introduction

The standard problem aims to analyze thermal and hydraulic characteristics in the model pin bundle under nonuniform geometrical and thermal conditions with square arrangement of pins. There is a spacer grid in the bundle with variable power zones. The problem intends also to estimate the reliability and accuracy of codes used for thermal hydraulic analysis [1].

In particular, the problem seeks to investigate the following measured and calculated variables: coolant temperature in channels under nonuniform geometrical and thermal conditions in the bundle, temperature of the external surface of the central measuring pin over perimeter along the heating section under nonuniform geometrical and thermal conditions in the bundle, and the coolant velocity in the cells of the bundle around the measuring pin simulator.

## 2. Problem Description

The model subassembly of the BREST-type reactor core is a pin bundle of square arrangement [2]. In this bundle there are two zones differing in the pin diameters and heat generation. The model pin bundle contains one spacer grid. A eutectic alloy sodium-potassium (22% Na + 78% K) is used to cool the heated rods. The pin simulators are spaced by the bottom and top centering grids and by a transverse spacer grid.

Table 1 presents the geometrical characteristics of the model bundle. Among the twenty-five pin simulators there is a measuring pin at the center of the bundle.

Table 1. Geometrical characteristics of the model bundle

| Parameters | Zones in bundle | |
|---|---|---|
| Outer diameter of pin simulators [mm] | 14 | 12 |
| Number of pin simulators | 15 | 10 |
| Pitch-to-diameter ratio of pin simulators | 1.25 | 1.46 |
| Length of pin simulators [mm] | 1014 | |
| Distance from initial point of heating (from the bottom grid) in which spacer grid is located [mm] | 372 (400) | |
| Size of square wrapper inner side [mm] | 4.86 | 4.35 |

The measuring pin simulator is made rotary in a stuffing box. On the surface of the measuring pin simulator twelve micro thermocouples are located in longitudinal grooves and placed with an azimuthal step of 30°. The measuring simulator is made of steel 20. The pin simulators are heated by the spirals from nichrome wire providing constant heat flux over height and perimeter of the simulator. Current suppliers are located in the bottom collector.

## 3. Results and Discussion

### *3.1 Subchannel Analysis*

This study inquires about the liquid metal coolant behavior along the subchannels and whether the given flux profiles and geometrical arrangement of fuel rods yield reasonable flow distribution in subchannels during nominal operation using the subchannel analysis code MATRA. The lumped parameter code is based on the subchannel approach for calculating the enthalpy and flow distribution in fuel assemblies for both steady state and transient conditions [3]. MATRA improves on the predictive capabilities with a reasonable computing time resorting to mixture equations tied with approximate numerical models. This approach comprises separating the core flow area into several subchannels, and further dividing the subchannels into discrete control volumes.

One can then determine distribution of thermal and hydraulic parameters such as flow rate, pressure, and enthalpies of the reactor coolant by combining sets of conservation equations for mass, energy or enthalpy, and axial and transverse momentums with constitutive equations in the subchannel. A fully three-dimensional physical situation can be represented by connecting the channels in a three-dimensional array, which simplifies the governing equations and reduces the computing time [4].

### *3.2 Geometric Consideration*

The subassembly consists of twenty-five pin simulators in square array located in the square wrapper. There exist two zones with different pitch-to-diameter ratios $p/d_1$= 1.25 and $p/d_2$= 1.46 ($d_1$= 14 mm and $d_2$= 12 mm) and with different heat fluxes.

A transverse spacer grid is located from the initial point of heat production at 372 mm. Rehme reported that the pressure loss by grid spacers can be estimated as [5]

$$\Delta P_s = C_v \left( \frac{A_s}{A_v} \right)^2 \frac{1}{2} \rho V^2 = K \frac{1}{2} \rho V^2 \qquad (1)$$

where $C_v$ is the modified drag coefficient, $A_s$ the projected frontal area of the grid spacer, $A_v$ the unrestricted flow area away from the grid spacer, $\rho$ the density of fluid, $V$ the average bundle flow velocity, and $K$ the loss coefficient of the grid spacer. The drag coefficient $C_v$ turns out to be a function of the average bundle Reynolds number $Re$.

Rehme's data indicated that for square arrays $C_v$= 9.5 at $Re$= $10^4$, and $C_v$= 6.5 at $Re$= $10^5$. One can then calculate the loss coefficient of the grid spacer. Table 2 lists the geometrical characteristics and calculated loss coefficient for the spacer grid [6].

Table 2. Geometrical characteristics of the spacer grid

| | | | |
|---|---|---|---|
| Pitch-to-diameter ratio | 1.25 | 1.34 | 1.46 |
| Loss coefficient | 4.864 | 4.637 | 4.358 |

*3.3 Input Conditions*

The experiments were performed in five different thermal conditions, varying pin assembly power ration and inlet coolant temperature.

The inlet temperature was varied from 56 to 63℃, while the inlet velocity was fixed at 2.6 m/s. The Pin power ratio $P_{15}/P_{10}$ was changed from 1.35 to 2 between the zones. Thermophysical properties were practically the same amongst the five test conditions.

*3.4 Coolant Temperature*

Tests were performed to get the coolant temperature distribution at the top of subchannel. The subchannel analysis was performed on the same geometric and thermal hydraulic conditions with MATRA.

The test revealed interesting results that regardless of the power ratio the temperature rise was always higher on the side where fifteen pins with $d_2$= 12 mm were located.

On the other hand, the code result showed that the higher coolant temperature rise occurred on the side where higher pin power was supplied, as shown in Figs. 1 and 2.

According to the experiment, the temperature rise was strongly dependent upon the geometry of the pin simulator. In contrast to the experimental results, the MATRA calculational results were mainly dependent upon the thermal conditions.

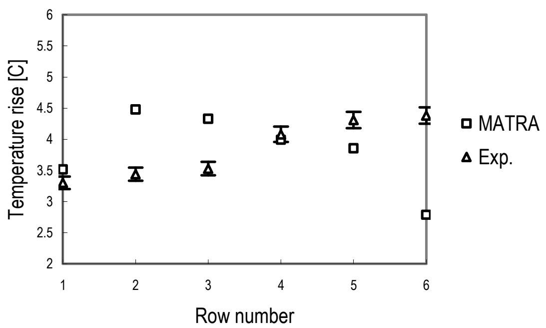


Figure 1. Coolant temperature rise for power ratio of 2:1.35

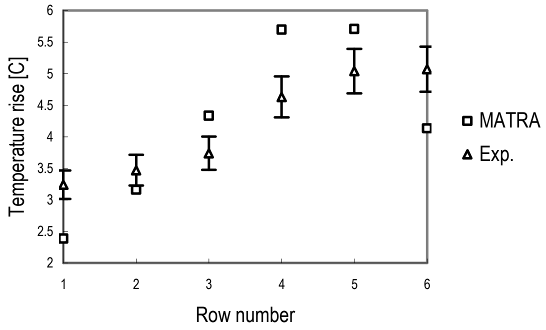


Figure 2. Coolant temperature rise for power ratio of 1.35:2

## 4. Conclusion

Comparison between the BREST experimental and MATRA results revealed that MATRA (alpha mode 4) requires modifications in the transverse momentum equation and pressure drop correlations, and for the inclination angle of the grid spacer. More analytical efforts are being poured to analyze the coolant twisting effect of the spacer grid in the model subassembly.

## NOMENCLATURE

$C_v$ Modified drag coefficient
$K$ Loss coefficient of grid spacer
$Re$ Reynolds Number

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