# CHF Performance of Hybrid Mixing Vane Grid

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## 1. Introduction

A new mixing vane design is being developed to enhance the Critical Heat Flux (CHF) for advanced spacer grid. It's called a Hybrid Mixing Vane. Mixing vane generally increases the CHF through promoting the turbulence level, increasing the thermal mixing between the subchannels, inducing a swirl flow within the subchannels and so on [1]. However, the CHF performance of the mixing vane is strongly depend on its design.

The main objective of the present work is to evaluate the CHF enhancement of the hybrid mixing vane grid. In order to measure the CHF data, 5X5 rod bundle experiments were conducted at FTHEL (Freon Thermal Hydraulic Experiment Loop) in KAERI. R-134a was used as a working fluid because of its low latent heat, low critical pressure and well-known properties. Two kinds of rod bundles were tested to compare the mixing vane effect on the CHF: one without mixing vane grids and the other with hybrid mixing vane grids. The test matrix covers sufficiently the PWR operating conditions in water equivalence.

## 2. Experimental Apparatus and Procedure

In the FTHEL facility working fluid is circulated by two non-seal canned motor pump connected in series through a flow-meter, a pre-heater, an inlet throttling valve, test section, a condenser and a cooler. 25 rods for the 5x5 rod bundle are electrically heated directly with a DC power. The wall temperatures are obtained from 68 thermocouples installed at the end of the 25 heater rods which have a uniform axial power shape. The radial power distribution is non-uniform. The parameters of the test section are listed in Table 1.

Table 1. Parameters of the 5x5 bundle test section

| Parameter | 5x5 Bundle |
|---|---|
| Total number of heated rods | 25 |
| Rod pitch (mm) | 12.85 |
| Rod diameter (mm) | 9.5 |
| Heated length (mm) | 2000 |
| Rod to wall gap (mm) | 3.0 |
| Corner radius (mm) | 3.0 |
| Flow area ($mm^2$) | 2695.8 |
| Axial power distribution | Uniform |
| Distance between spacer grids (mm) | 564 |
| Radial power distribution | |
| Peaking factor of inner 9 rods | 1.123 |
| Peaking factor of side 16 rods | 0.931 |

The Hybrid mixing vane grid has a set of vanes at every grid junction as shown in Figure 1[2]. It is composed of two types of vanes, called primary vanes and secondary vanes. The primary vane set is mainly to generate the cross flow between the subchannels. Meanwhile, the secondary vane set is to generate the swirl flow within the subchannels.

Each experiment was performed by maintaining the following system conditions as constant: inlet pressure, inlet temperature, and mass flow rate. The power to the test section is then increased until a temperature excursion is observed by one or more thermocouples, or the maximum temperature is 35 $^{o}$C greater than the saturation temperature. To estimate the heat loss and data reliability, heat balance tests were performed before and after each series of experiments and they showed that the heat losses were within 2%. The uncertainties of the main variables are 1.2% for the temperatures, 3% for the outlet pressure, and 0.3% for the mass flux. The experiments were performed in the ranges of inlet pressure of $P_{in}$ = 2000 ~ 3000 kPa, mass flux of G = 1000 ~ 3000 kg/m$^2$s, and inlet subcooling of $\Delta h_{in}$= 10~ 55 kJ/kg, which simulate the PWR operating conditions in water equivalence through the fluid-to-fluid modeling.

## 3. Results and Discussion

Generally, a critical heat flux is known, regardless of the existence of mixing vanes in space grid, to increase linearly with the inlet subcooling (expressed in terms of enthalpy, $\Delta h_{in}$), or to increases with the mass flux for the given inlet conditions [3]. Figure 2 shows typically the effect of the inlet subcooling on the CHF over the mass flux range of 1000 to 3000 kg/m$^2$s at the pressure of 3000 kPa. The relationship between the CHF vs. inlet subcooling is shown in a linear fashion for both the without and with mixing vane grids.

Figure 3 shows the CHF with the mass flux. At the

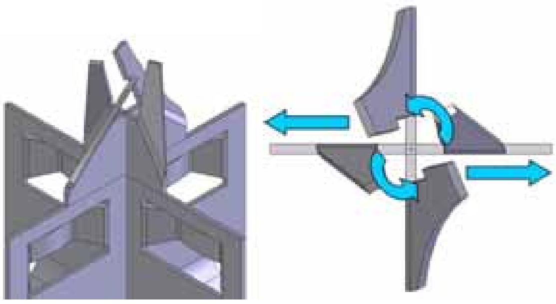

Fig. 1 Hybrid Mixing Vane Grid

mass flux of 1000 kg/m$^2$s the mixing vane effect turns out to be minor. But as the mass flux increases, the rate of the CHF increase is faster for the mixing vane grid than the without mixing grid. However, when the mass flow reaches roughly 2000 kg/m$^2$s, the differences of the CHFs between the two cases remain nearly constant.

To obtain the amount of CHF enhancement, a performance factor is defined as follows:

$$\left(\Delta q''_{MV} - \Delta q''_{NMV}\right)/\Delta q''_{NMV}$$

Figure 4 shows the CHF performances results along with the mass flux under the pressures of 2000, 2500, and 3000 kPa. It was revealed that the CHF enhancement gradually increases with the mass flux at the pressure of 2000 kPa. At the pressure of 2500 kPa, the CHF converges to a certain level over the mass flux of 2500 kg/m$^2$s. Finally, at the pressure of 3000 kPa the CHF has a peak near the mass flux of 1500 kg/m$^2$s and then it shows a slowing down. In summary, CHF enhancement is over 8%, at least, for the examined range and the average of the CHF enhancements for the whole data is 16.4%. It is an excellent result for the mixing vane.

## 4. Conclusion

Experimental investigation was carried out with 5x5 rod bundles at the FTHEL in KAERI to estimate the CHF performance of Hybrid Mixing Vane grid. From the results, the followings were observed:

- Around 1000 kg/m$^2$s the mixing vane effect is insignificant.
- As the pressure increases, the peak CHF enhancement reduces to lower mass flux.
- Near the PWR operating condition by a fluid-to-fluid modeling the CHF performance of the hybrid mixing vane grid is superior by about 16.4% than the without mixing vane grid.


### Acknowledgment

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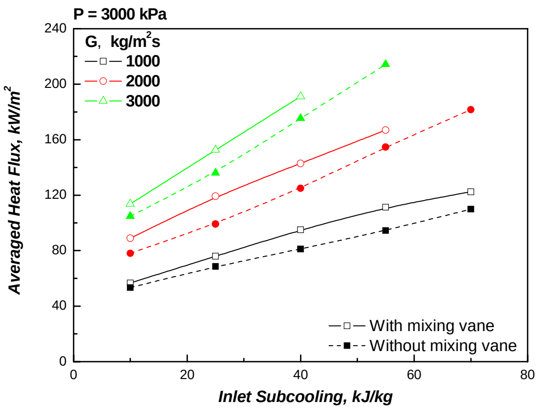


Fig. 2 Effect of inlet subcooling on CHF

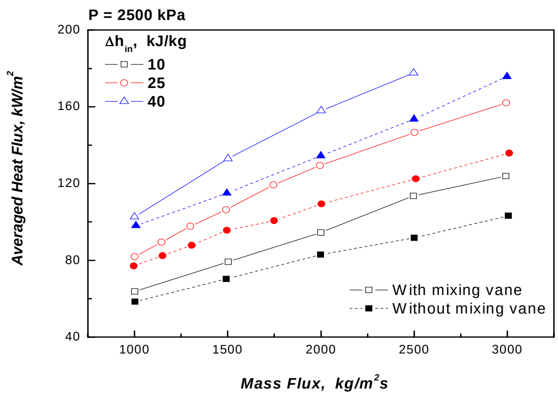


Fig. 3 Effect of mass flux on CHF

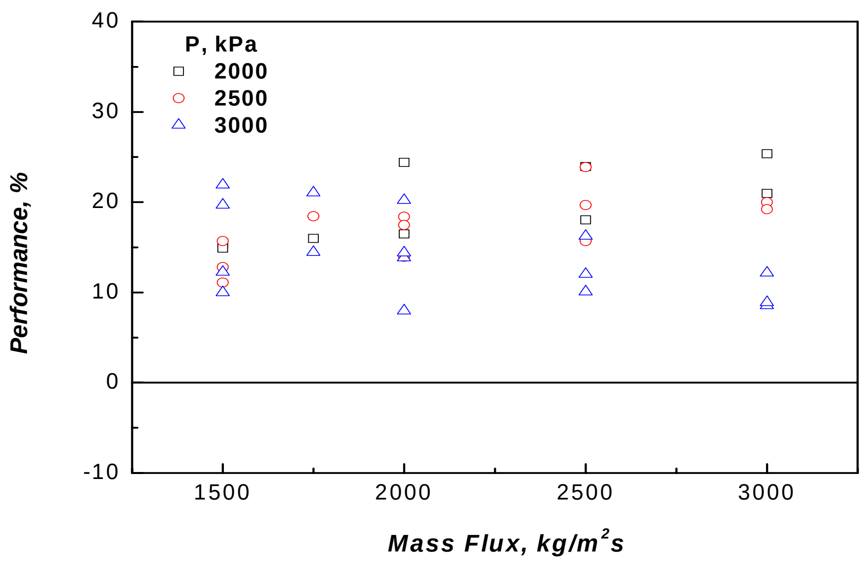


Fig. 4 CHF Performance of Hybrid Mixing Vane Grid