# Heat Load Analysis of the Fixed Mask

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## 1. Introduction

Fixed masks to be installed in the front ends are subject to have the most serious heat probrem in the SPring-8 beamlines. The incident beams would accidentally hit the mask surfaces, for example, due to the installation and source instabilities. Temperature analyses on the fixed masks were planned to be made on the undulator and wiggler beamlines.

## 2. Models for analysis

ANSYS ver.5.0 was used for thermal equilbrium analysis. Two types of three demensional mask structures were prepared for the cases of undulator and wiggler, accordingly, on the basis of the front end designs in 1994. ( See Figs. 1 and 2. ) Each structure had fin channels for water cooling, and the irradiated surface is inclined by 0.02 rad in respect to the beam axis to avoid the thermal damage. These masks were positioned at 20 m from the source point. In the analyses, the 1/4 models were employed, because there was little defference between the 1/2 and 1/4 models in preliminary calculations. The number of the calculated nodes were 10575 points for FMSK-Um and 10220 points for FMSK-Wm. The temperature dependence of the thermal conductivity upon the mask materials was considered, as of, 403 W/(m·°C) at 0 °C, 395 W/(m·°C) at 100 °C, and 381 W/(m·°C) at 300 °C for copper. The heat transfer coefficients were caluculated for the water velocities of 2.0, 3.0, and 6.0 m/s, using the phenomenological equations of the heat transfer coefficient of cylindrical channel[1], as shown in Tables 1 and 2 for the two models. These constants were applied uniformly on the channel surface as the averaged heat transfer coefficient. The power density of photons as emitted from the sources were caluculated as shown in Figs. 3 and 4.

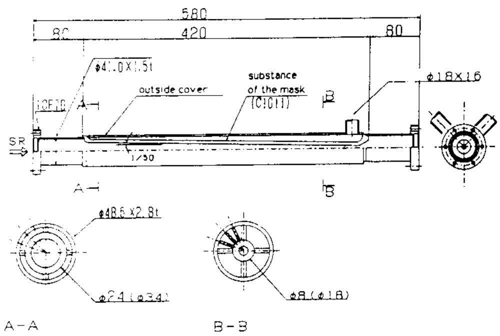


Fig.1 Design of FMSK-Um

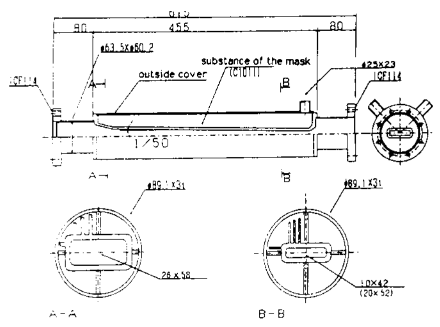


Fig.2 Design of FMSK-Wm

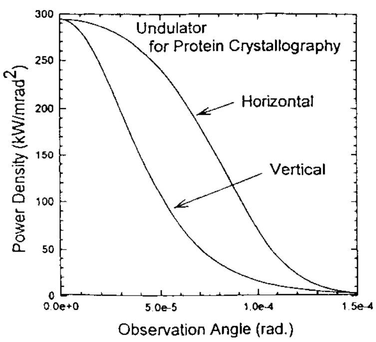


Fig.3 Power density of undulator

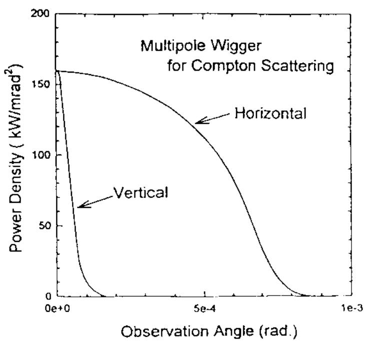


Fig.4 Power density of wiggler

## 3. Calculation in the accidental case

Heat load analyses were carried out in a most serious case. It was assumed that the whole beam accidentally hit the mask surface, giving high heat loads on the surface. In such a case, the maximum heat flux and the total power on the irradiated surface were estimated to be 14.7 MW/m$^2$ and 4.6 kW for undulator, and 8.0 MW/m$^2$ and 17.7 kW for wiggler respectively. The water temperature at the inlet was set to be 27 ·°C in all cases.

## 4. Results

( See Tables 1 and 2. )

Table 1 Calculated results of FMSK-Um

Max. heat flux = 14.7 [MW/m$^2$], total power = 4.6 [kW]

| | | | |
|---|---|---|---|
| water verocity [m/s] | 2.0 | 3.0 | 6.0 |
| Heat transfer coefficient [W/(m$^2$·°C)] | 10x10$^3$ | 15x10$^3$ | 28x10$^3$ |
| Max. temp. on irradiated surface [°C] | 150 | 142 | 131 |
| Max. temp. on channel surface [°C] | 86 | 76 | 64 |

Table 2 Calculated results of FMSK-Wm

Max. heat flux = 8 [MW/m$^2$], total power = 17.7 [kW]

| | | | |
|---|---|---|---|
| water verocity [m/s] | 2.0 | 3.0 | 6.0 |
| Heat transfer coefficient [W/(m$^2$·°C)] | 9.9x10$^3$ | 14x10$^3$ | 26x10$^3$ |
| Max. temp. on irradiated surface [°C] | 294 | 266 | 227 |
| Max. temp. on channel surface [°C] | 215 | 186 | 144 |

## 5. Discussion and Conclusion

We checked whether the caluculated temperature of the channel surface exceeds 150 ·°C, at which the water is almost saturated with a vapor pressure of 5 kg/cm$^2$. As seen in Table 2, FMSK-Wm is in danger of boiling. Considering the temperature dependence of the elongation percentage and the tensile strength, the maximum temperature rating of copper for usage can be estimated about 350 ·°C. The calculated maximum temperature on the irradiated surface is sufficiently low in comparison with this temperature, indicating that the copper can be used for the mask materials.

References

[1] JSME Data Book : Heat Transfer 4th Edition, JSME (1986).