DEVELOPMENT OF THE COLLIMATOR SYSTEM FOR THE 3GEV RAPID CYCLING SYNCHROTRON

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Abstract

In order to localize the beam loss in the restricted area, the beam collimation system is prepared in the 3GeV Rapid Cycling Synchrotron (RCS) of the Japan Proton Accelerator Complex (J-PARC) Project. The amount of the localized beam loss on the one collimator is estimated about 1.2kW, and that loss generates a large quantity of the secondary radiations. So the beam collimator must be designed that it is covered with enough shielding.

We calculated the radiation dose of the collimator and decided necessary shielding thickness. This result indicated that the residual dose rate at the outside surface of the shielding was mostly under 1mSv/h. We developed the remote cramp system and rad-hard components in order to reduce the radiation exposure during maintenance of the collimator. And also we coated The Titanium Nitride (TiN) film on the inside surface of the vacuum chamber in order to reduce the secondary electron emission from the collimator and the chamber surface. Now we investigate the possibility of another coating.

INTRODUCTION

Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK) have been going ahead with the Japan Proton Accelerator Complex (J-PARC) Project. The accelerator complex consists of a 181MeV linac, a 3GeV rapid cycling synchrotron (RCS), and a 50GeV synchrotron Main Ring [MR] at first stage[1]. The RCS ring accelerates a proton beam up to 3GeV and supplies it to the MR and the neutron production target. The RCS ring aims to generate a high power proton beam of 1MW at the repetition rate of 25 Hz.

We must keep the beam loss at an order of 1W/m for hands-on maintenance. The beam collimation system of RCS is prepared to localize the beam loss in the restricted area and to keep another area an order of 1W/m. The amount of the localized beam loss on the one collimator is estimated about 1.2kW[2], and that loss generates a large quantity of the secondary radiation.

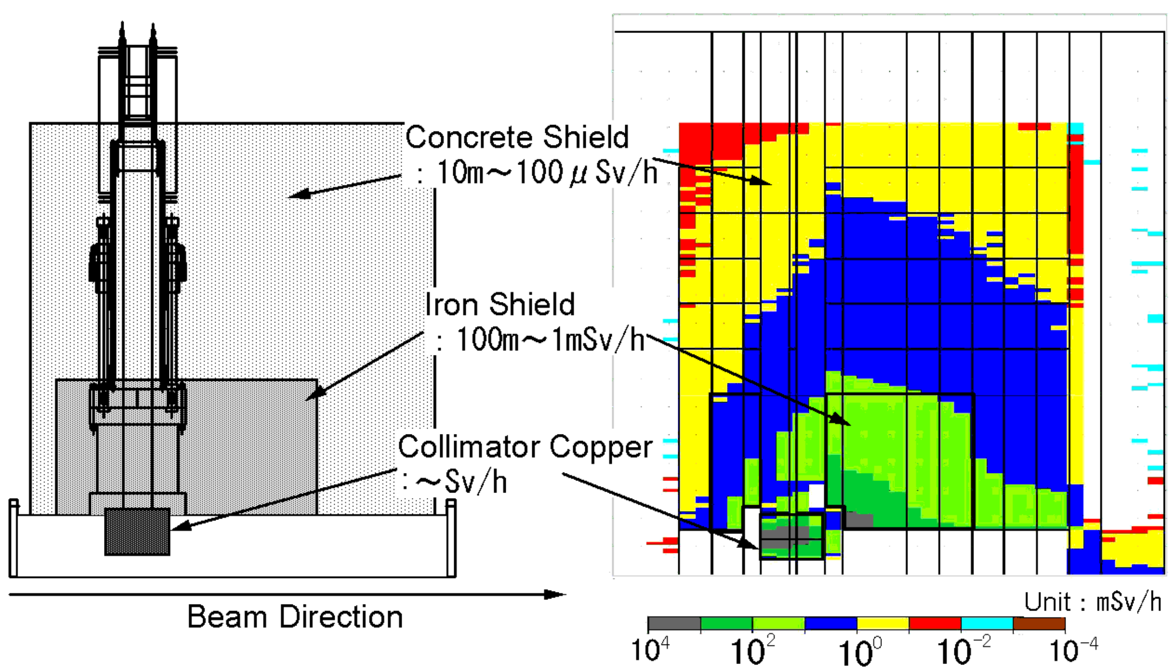

Figure 1: Estimation of the Residual Dose.

This is the side cross section of collimator shield. Residual dose rate [mSv/h] is distinguished by colors. The collimator is drawn a dark green and grey and it means there are over 1mSv/h residual dose. The surface of the outer concrete shield is almost yellow and it means there are under 1mSv/h residual dose.

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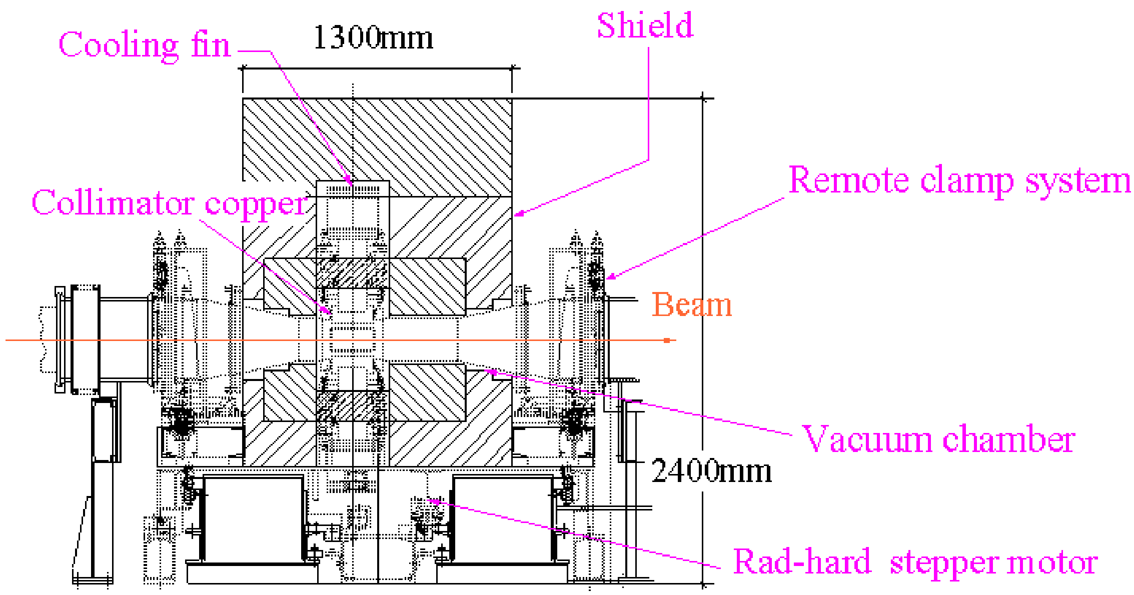

Figure 2: Schematic of J-PARC RCS collimator.

In order to develop the RCS collimator system, at first we calculated the radiation dose of the collimator and decided necessary shield thickness by using the MARS code[3]. Next we developed the remote cramp system and rad-hard components in order to reduce the radiation exposure during maintenance of the collimator. And also we coated the Titanium Nitride (TiN) film on the inside surface of the vacuum chamber and the collimator copper block in order to reduce the secondary electron emission from the collimator and the chamber surface.

RADIATION ESTIMATION

The estimation of the radiation dose and the radiation shielding design of collimator were carried out by the MARS code. From the simulation result of the STRUCT code, the maximum loss power was estimated about 1.2kW on the one collimator. To reduce the radiation dose from the collimator, we made the following model : the collimator vacuum chamber was covered with the 350mm iron inner shield and the 800mm concrete outer shield. The MARS calculation result is shown in Fig 1. This result expresses the residual dose distribution of the collimator and its shielding after 1 month operation / 1day cooling. In this result, the collimator copper block is activated over 1Sv/h, but the surface of the outer concrete shield is activated mostly under 1mSv/h and this value is almost same as the residual dose rate of the 1W/m region. The personal dose by the collimator can suppress by this shielding. The radiation dose of whole RCS tunnel was calculated by Nakao et al[4].

REMOTE CLAMP SYSTEM AND RAD-HARD COMPONENTS

In order to reduce the opportunity of maintenance, we investigated the radiation hardness of several components that would be used to the collimator. And we developed the remote cramp system and the rad-hard stepper motor.

We performed the gamma-ray irradiation experiment of the collimator components. We used the Co-60 gamma-ray source in the Takasaki Establishment at JAERI for these experiments. For the results of the irradiation experiment, we changed the cooling system into the thermal conductivity of the support arm from the heat pipe system. Fig.3 shows the result of the ANSYS simulation. The simulation result shows that the collimator temperature can be kept under 150 degrees centigrade.The detail of these experiments are presented in this conference[5].

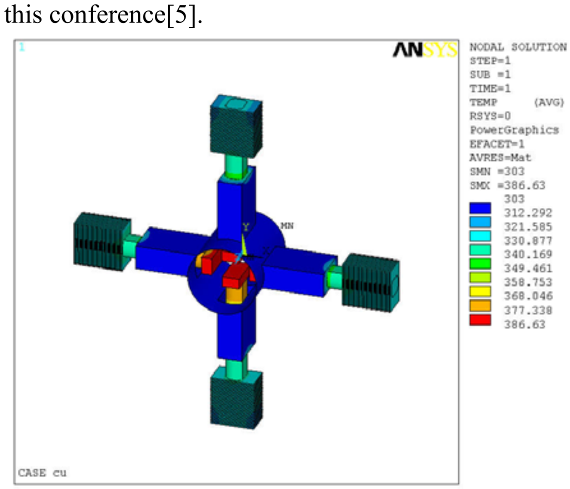

Figure 3: ANSYS calculation result.

And especially we developed the stepper motor which had high durability over 70MGy absorbed dose.

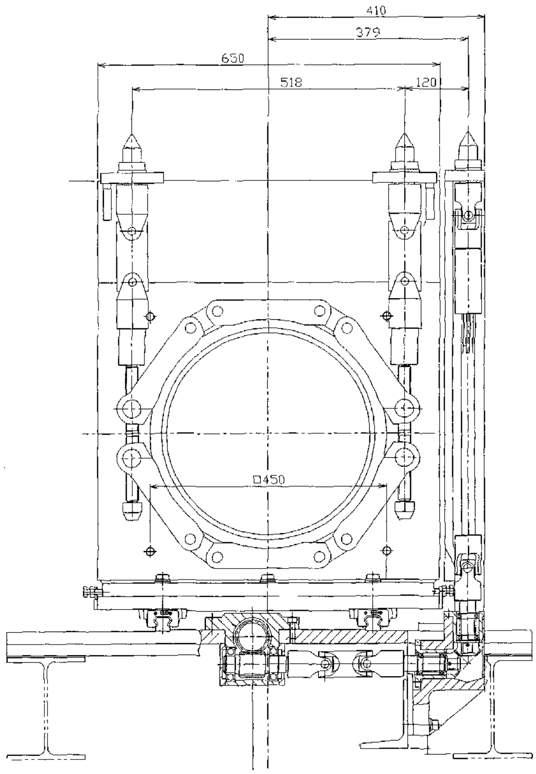

Figure 4: Schematic of the remote clamp system

The schematic of the remote clamp system is shown in Fig.4. By using the remote clamp system, the collimator vacuum chamber can be removed only by turning the screws far from the collimator. The quick-coupling clamp can be opened by turning two screws which are connected with the clamp, and another screw separate the flange of collimator chamber and the flange of other accelerator component. Test of the first production is ongoing.

SURFACE COATING

Since the radiation from the collimators will become the source of the secondary electrons, there is a possibility of bringing about the beam instability by those secondary electron clouds[6]. In order to reduce these undesirable electron emission, the Titanium Nitride (TiN) is coated on the inside surface of the chamber and the collimator copper block. We measured the secondary electron yield (SEY) from the TiN film with various condition[7]. We also investigated the Diamond Like Carbon (DLC) film to search the possibility of another coating. From the results of these studies, the DLC film is more stable than the TiN film with oxygen/water vapour and the electron beam bombardment. And the SEY of the DLC film is smaller than the SEY of the TiN film. We will investigate more detail of the DLC and another Carbon film.

CONCLUSIONS

- We designed the collimator system of J-PARC RCS.
- We decided the enough radiation shielding of the RCS collimator and estimated the residual dose. The surface of the outer concrete shield is activated under 1mSv/h and this value is almost same as the dose level of the 1W/m region.
- We developed the remote cramp system and rad-hard components in order to reduce the radiation exposure during maintenance. Especially we developed the stepper motor which had high durability over 70MGy absorbed dose.
- The Titanium Nitride is coated on the inside surface of the chamber and the collimator. We further investigate the Diamond Like Carbon coating to search the possibility of another coating.

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