Eddy current effect of quadrupole and CR dipole magnet beam chambers

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In order to keep the stable particle operation, beam chamber needs to have the high-quality vacuum state and thermal stability from external influence. The time-dependent magnetic field produces the secondary effects of heating and stray magnetic field, which can disturb the quality of the inside vacuum and the magnetic field. We present here the numerical simulation results for the recent issues related to the vacuum beam chambers of SIS100 quadrupole magnets and the current ripple effect of CR dipole magnet for the field stability optimization.

QP Star shaped beam chamber

The rib distance of the star-shaped beam chamber for quadrupole (QP) magnet has been changed from 17 mm to 7 mm. More number of ribs increase mechanical stability and the heat conduction between cooling pipe and beam chamber surface. The opposite effect is that it reduces electric resistance on the beam chamber which can be a cause of increasing eddy current. Therefore, we need to confirm the results of this design modification. The eddy loss depends on magnetic field operation scenario and we consider the 2c and triangular cycle which have higher operation load compared to other scenarios. Considering the planned boundary and initial conditions, we could find the effect of changing rib distance. Compared to previous design, the 7 mm rib distance shows small increasement of heat loss and temperature. The magnitude of increments are ΔT = 0.17 K, ΔW = 0.3 W/m at 2c and ΔT = 0.23 K, ΔW = 0.7 W/m at triangular cycle. These opposite effects are compensated and not considerably high.

Jump QP beam chamber

Jump QP has an operation scenario with ramping rate of 1600 T/s. It is the ramping rate of the integral field of the field gradient in QP magnet. After considering the real magnet dimensions, we found the ratio of 13.333 between the effective length and reference radius. With this dimensional ratio, we can interpret 1600 T/s to the value of 120 T/s at the reference radius and the corresponding maximum field is 300 G. Even though it is not extreme operation condition, this high ramping rate initiates us to confirm the effect of this operation. The simulation result shows that the time delay is $\sim 22.4\mu$s between driving current and magnetic field. Figure 1 shows the maximum temperature on the beam chamber as a function of time. Each cycle corresponds to the ramping cycles. Due to the short duty cycle with high field ramping rate, it has dynamic temperature variation. The conversed maximum temperature is estimated $\sim$ 7.5 K after infinite operation. The influence of Jump QP magnet operation on beam chamber is less than SIS100 main QP magnet.

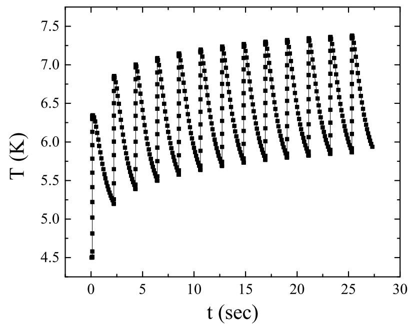

Figure 1: Maximum temperature on the beam chamber with respect to operation time.

CR dipole beam chamber

The magnet for the Collector Ring (CR) is designed to keep constantly accurate magnetic field. Therefore, the stability of the applied electric current is an important parameter for the field stability. The maximum tolerance of field variation is $\Delta B_{max}/B_0 \cong 10^{-6}$. The reported maximum current ripple is $\Delta I_{max}/I_0 \cong 10^{-4}$ considering all magnet circuits. Based on these parameters, we simulate the frequency dependence of the magnetic field from 10 Hz to 10 kHz. The maximum normalized field variation is found to be $\sim 6.3 \times 10^{-5}$ at 10 Hz. This value shows exponential decay with increasing the ripple frequency. Through the simulation procedure, we found that the reason of this field shielding effect was the secondary magnetic field by eddy current in the beam chamber. The field tolerance less than 10^{-6} have been found around 2 kHz and 5.5 kHz in the middle of magnet and the beam space inside the beam chamber, respectively.

References

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