Conceptual Design Study of a Ferrite Loaded RF Cavity for a PEFP RCS 1GeV Operation

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1. Introduction

A RCS (Rapid Cycling Synchrotron) is studied with a 100MeV proton injector, which the proton engineering frontier project (PEFP) is developing. For the initial stage, the maximum extraction energy 1GeV, repetition rate 15Hz, maximum beam power 60kW can be supplied for many high power applications such as a spallation neutron source using a fast extraction system. The main parameters are shown in Table 1.

Table I: Main Parameters for Initial 1GeV Operation

Beam Power	60kW
Injection Energy	100MeV
Extraction Energy	1GeV
# of Protons per pulse	2.5E13
Circumference	224.16m
Repetition Rate	15Hz
Revolution Frequency	0.58 ~ 1.17MHz

2. Conceptual Design Study of RF Cavity

For rf cavities in synchrotrons, there are two materials, ferrite and magnetic alloy. The most conventional rf cavity for RCS is a ferrite loaded cavity, which is more reliable and cheaper than a magnetic alloy loaded cavity. The advantage of a magnetic alloy loaded cavity is its compactness, which is very important when the space for rf is limited like J-PARC RCS [1]. In PEPF RCS, ferrite is chosen as reference material, and after a preliminary design, magnetic alloy can be considered if the space is problem.

2.1 Requirements

The rf voltage profile for the acceleration is shown in Fig. 1 [2]. The voltage for the injection is 20kV and after 10ms from the injection, 50kV acceleration voltage is required with 22ms flat top. Because there are four empty spaces between the lattice magnets in the straight section, four 2-meter cavities can be installed. In this design the maximum voltage for each cavity is 20kV.

The peak rf power to beam is 350kW as shown in Fig. 2, which is calculated with the optimized synchronous phase and the beam current. The rf source to drive this cavity should have 400kW in peak power with 50% duty and 100kW in average power.

To minimize the beam loss during the acceleration, the aperture should be large enough. In this design, the aperture diameter is 250mm, which is almost same with lattice magnet aperture.

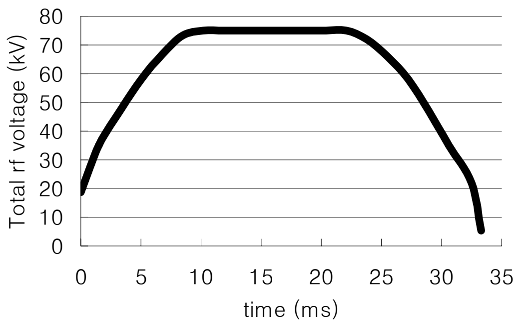

Fig. 1. Total rf voltage from injection to extraction for initial 1GeV operation

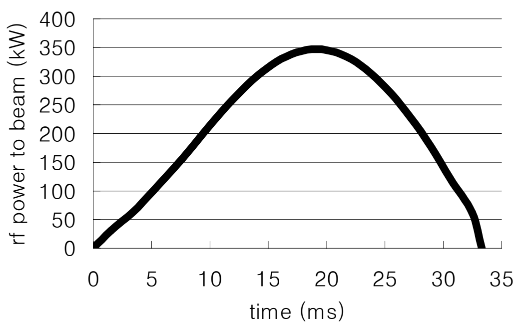

Fig. 2. RF peak power to beam by cavity from injection to extraction.

2.2 Ferrite Material

Ferroxcube 4M2 is chosen for the ferrite material, because it is the most widely used for synchrotron accelerator cavities. An easily available size of ferrite rings is 500mm outer diameter, 300mm inner diameter and 25mm thickness, which can give a good aperture size. Fig. 3 shows the magnetic flux density during operation.

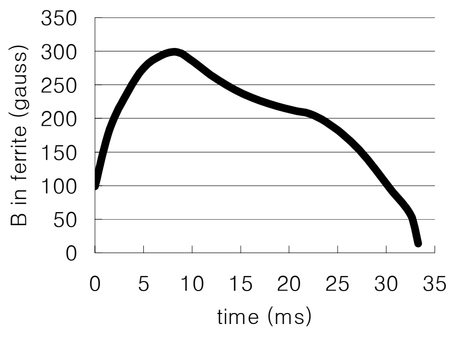

Fig. 3. Magnetic flux density in ferrite from injection to extraction.

The total number of ferrite rings is determined from the peak magnetic flux density. For a proper cooling, the maximum magnetic flux density should be less than 300 gauss, where the average power dissipation is less than 0.1W/cm^3. as shown in Fig. 4.

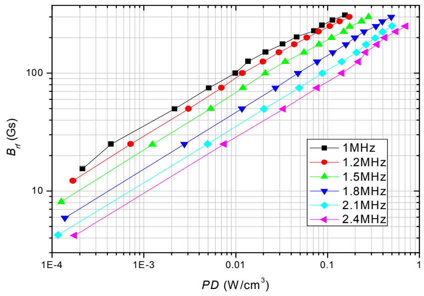

Fig. 3. Magnetic flux density in ferrite from injection to extraction.

2.3 Thermal Design

Ferrite rings are cooled with copper plate that has a water-cooling channel. The cooling plate surfaces are coated with a heat-conduction compound to make good thermal contact with the ferrite rings. The maximum temperature has been simulated with the model and the ANSYS program as shown in Fig. 5.

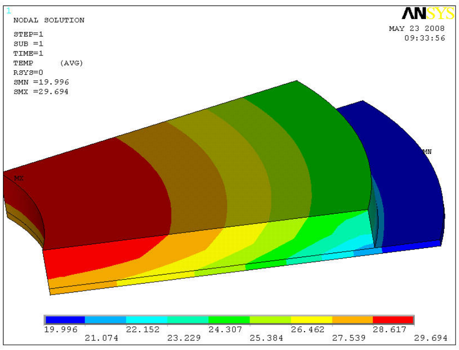

Fig. 5. Thermal analysis for ferrite cooling.

Fig. 6 shows the thickness dependence of temperature increase in a ferrite ring. 4mm-thick copper plates are enough to maintain the ferrite temperature increase less than 10K.

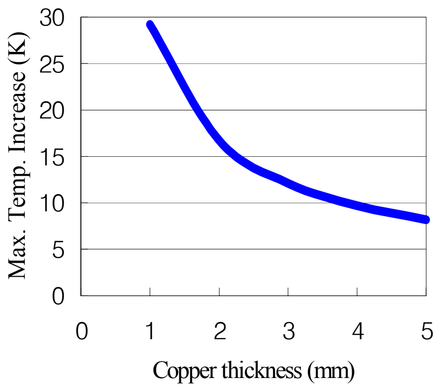

Fig. 6. Maximum temperature increase in ferrite ring versus thickness of copper plate for cooling.

2.4 Cavity Assembly [3]

For one cavity, 34 ferrite rings with copper cooling plates are required to obtain 20kV accelerating voltage with average power dissipation less than 0.1W/cm^3. The physical length of a cavity is less than 2m from flange to flange with an accelerating gap at one end.

Four bias windings are wound in the figure-eight configuration around a pair of ferrite assemblies so that the rf induction cancels at the input terminals of the bias supply. The switching power supply with a high efficiency and high current stability supplies DC bias current to change rf permeability of ferrite. The cavity is driven by a Class-A or Class-AB tetrode in grounded-cathode configuration. The amplifier for this cavity provides a 20kV rf voltage to the gap with a full link. Fig. 7 shows the assembled ferrite loaded cavity for 20kV accelerating voltage.

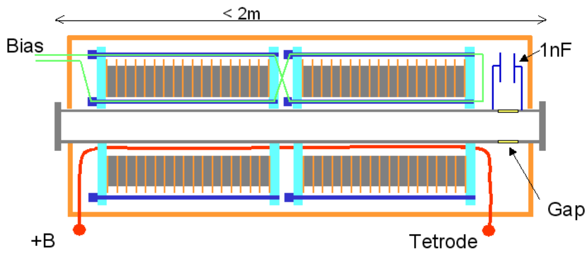

Fig. 7. Assembly of ferrite loaded cavity.

Beam pipe is made of stainless steel with 220mm diameter and accelerating gap is made of ceramic insulator with 40mm length. 1nF capacitor is installed at the gap.

3. Conclusions

Ferrite loaded rf cavities for a 1GeV operation of PEFP RCS has been studied. 2-meter cavities with a 20kV accelerating voltage, which satisfies the requirement of the size, have been conceptually designed. Feasibility of this cavity design should be examined and more engineering studies with a prototype fabrication should be done for a final design.

Acknowledgement

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