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EM Analysis of Superconducting Half Wave Resonator for KOMAC 100-MeV Proton Accelerator Energy Upgrade

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1. Introduction

Since 2013, a 100-MeV proton linac has been under operation at Korea Multi-purpose Accelerator Complex (KOMAC) and the accumulated operation time reached 11,062 hours at the end of 2016 [1]. To expand the application field of the 100-MeV proton accelerator, we are planning to develop the generation and the utilization of the secondary particle beam produced by the proton bombardment on the production target and pulsed neutron beam is one of major items under consideration.

Preliminary analysis shows that the neutron yields of about 2.5E13 pps can be obtained on the tungsten target with the average beam power of 1 kW and 100 MeV beam energy. In addition, the neutron yields can be increased by 2.5 times if the incident proton beam energy increases from 100 MeV to 160 MeV. Therefore, we performed basic study to increase the beam energy by adding additional accelerating section at the end of the existing accelerator. The technology of choice for beam energy ramping is SRF (Superconducting Radio-Frequency). The existing accelerator tunnel has room for linac extension up to 160 MeV based on 350 MHz superconducting accelerator.

Several types of SRF cavity structure are currently used for acceleration of the low-beta proton beam such as quarter-wave resonator (QWR), half-wave resonator (HWR), spoke cavity, and so on. For example, two-gap spoke structure is chosen as a baseline design for European Spallation Source (ESS). Though spoke structure has some advantages over HWR and intensive study has been given to that structure, there is no operating accelerator based on spoke structure mainly due to its technological difficulty. In this study, we chose HWR structure as shown in Fig. 1 and performed preliminary design study on the HWR suitable for accelerating proton beam from 100 MeV to 180 MeV. Once the proton energy is increased up to about 180 MeV, a well-developed elliptical structures can be used thereafter.

2. Optimum beta and Transit time factor

To design a superconducting HWR for low-beta proton beam, first we have to determine the optimum beta or geometric beta considering the velocity range of the HWR, because the critical dimensions of the HWR and the energy gain heavily depend on the choice of beta.

To determine the optimum geometric beta, we performed a parametric sweep on various beta value and compared the transit time factor and energy gain per cavity as shown in Fig. 2 and Fig. 3. Based on the sweep result, the geometric beta was fixed as 0.58. With this value, we can estimate the output energy of the accelerating cavity. Considering the available space at the end of existing accelerator tunnel, we determined to put 28 cavities, through which the proton beam can be accelerated up to 180 MeV if we assume the E_{acc} of 7.2 MV/m.

Required RF power per cavity ignoring the cavity loss is about 49 kW for 1st cavity and 62 kW for 28th cavity. Because the estimation of the RF power is based on 20 mA peak beam current and the optimum coupling case, RF system should be designed with a lot of margin to be on safe side. If 100 % of RF power margin considering transmission loss and feedback control, peak RF power of 120 kW is required. This RF power is not too demanding for modern solid state amplifier. By using solid state amplifier, we can avoid a vacuum tube or a klystron and high voltage power supply. Basically same type of digital low-level RF system for existing 100-MeV machine can be used for SRF cavity.

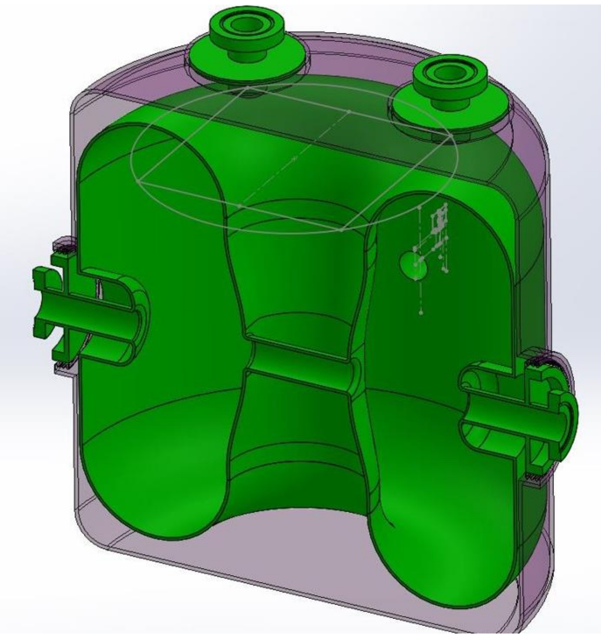

Fig. 1. Superconducting half wave resonator.

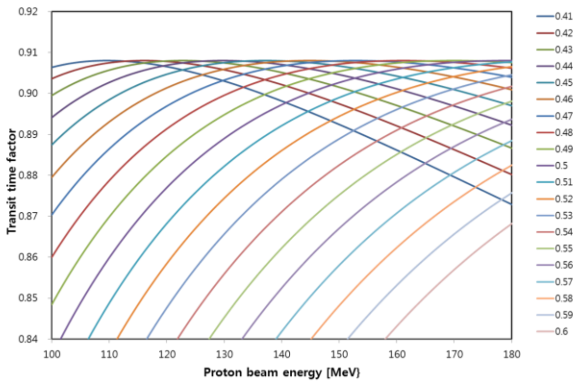

Fig. 2. Transit time factor sweep results.

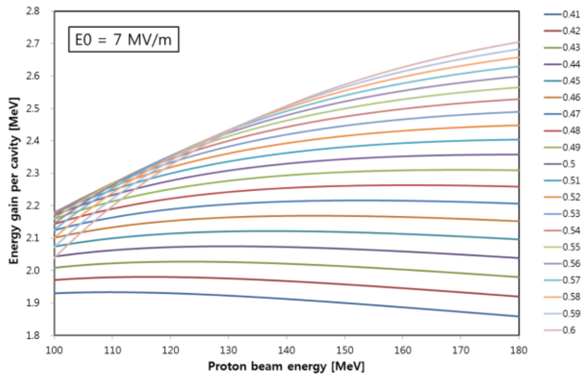

Fig. 3. Energy gain per cavity.

3. Electromagnetic Analysis

Preliminary design of the HWR cavity is shown in Fig. 1. Outer diameter and height of the cavity is about 460 mm and 440 mm, respectively. One of design goal is to reduce the peak field as low as possible. We set the maximum electric field less than 35 MV/m and maximum magnetic field less than 70 mT. According to the CST Microwave Studio simulation as shown in Fig. 4, the peak electric field and the peak magnetic field was 30.25 MV/m and 64.4 mT, respectively [2]. The operating temperature is going to be 2.0 K and the BCS resistance at 2.0 K is about 1 nΩ. If we reduce the surrounding magnetic field as low as 15 mG, then the resistance due to magnetic field is estimated about 3 nΩ. Design value of total surface resistance is 20 nΩ assuming residual resistance of 16 nΩ. With 20 nΩ surface resistance, the unloaded Q is estimated to be about 6.19E+09. The main design parameters are summarized in Table 1.

4. Summary

Preliminary design and electromagnetic analysis of the HWR cavity was carried out. It turns out that it is possible to accelerate the proton beam from 100 MeV to 180 MeV by using 28 HWR cavities and these additional accelerating section can be fitted into the existing linac tunnel at KOMAC.

Acknowledgment

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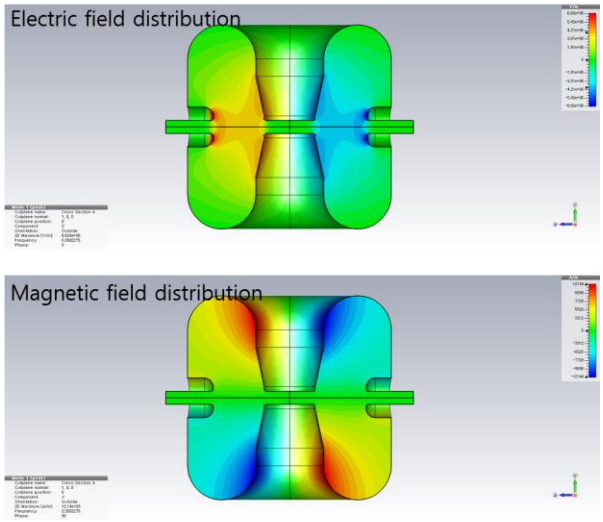

Fig. 4. CST Simulation results of HWR.

Table 1. Summary of EM Analysis.

Parameter	Unit	Value
Frequency	MHz	350.0
Optimum beta	-	0.64
Geometric beta	-	0.58
Stored energy	J	17.728
Vacc @ βopt	MV	3.336
Eacc	MV/m	7.212
E0	MV/m	8.200
Ep	MV/m	30.252
Bp	mT	64.392
Ep/Eacc	-	4.195
Bp/Eacc	mT/(MV/m)	8.928
R/Q @βopt	ohm	285.2
G @ 20 nΩ	ohm	123.8
Q_0 @ 20 nΩ	-	6.19E+09
Loss @ 20 nΩ	W	6.38
Aperture	mm	35
Leff	m	0.4625

REFERENCES

[1] Y. S. Cho, *Operation Experience at KOMAC*, 57th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams, July 3-8, 2015, Malmo, Sweden.
[2] P. N. Ostroumov, Z. A. Conway, R. L. Fischer, S. M. Gerbick, M. P. Kelly, A. A. Kolomiets, *Beta=0.285 Half-Wave Resonator for FRIB*, Proceedings of SRF2011.