ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-THPAB173

FUNDAMENTAL STUDY ON ELECTROMAGNETIC CHARACTERISTICS OF HALF-WAVE RESONATOR FOR 200 MeV ENERGY UPGRADE OF KOMAC PROTON LINAC*

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Abstract

A superconducting linac has been developed at Korea Multi-purpose Accelerator Complex (KOMAC). A goal of the SRF linac is to increase proton beam energy from 100 MeV to 200 MeV. 350 MHz half-wave resonator (HWR) is developed to provide 3.6 MV accelerating voltage and achieve the energy upgrade. An electromagnetic (EM) analysis on the parametrically designed HWR cavity was conducted. The cavity design was optimized to reduce a peak electric field and a peak magnetic field while satisfying the required accelerating voltage. In addition, a mechanical-EM coupled simulation was conducted to estimate a helium pressure sensitivity. Also, a Lorentz force detuning was simulated. The design of the cavity and a helium jacket was optimized to minimize the frequency detuning due to the helium pressure and the Lorentz force. The helium sensitivity is 1.7 Hz/mbar, and the Lorentz force detuning coefficient is -3.37 Hz/(MV/m)^2.

INTRODUCTION

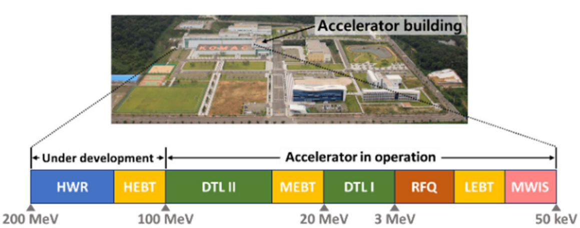

Figure 1: Layout of the proton linac in KOMAC.

The proton linac at KOMAC provides 100 MeV beam for a proton irradiation research and a neutron production since 2013. There are requests for higher energy beam by the accelerator users, in recent years. Also, the higher beam energy is required to develop an intensive neutron source. Thus, a study has been conducted to improve the performance of the accelerator. A superconducting accelerator is being developed for the 100 MeV further acceleration as shown in Fig 1. A design baseline of the SRF accelerator was optimized using a GenLinWin code [1]. The accelerator consists of the 36 HWRs whose accelerating voltage and optimum beta are 3.6 MV and 0.56, respectively. The driving frequency is 350 MHz which is same with the existing accelerator. An electromagnetic analysis using CST MWS was performed to derive a design that can reduce peak electric field and magnetic field while satisfying the accelerating voltage and the optimum beta. Also, the EM-mechanical coupled analysis was conducted to evaluate the helium pressure sensitivity and Lorentz force detuning coefficient.

ELECTROMAGNETIC ANALYSIS AND DESIGN OPTIMIZATION

Based on many studies designing the HWR [2-4], the electromagnetic analysis was performed to optimize the HWR cavity shape. The cross-sectional view of the HWR and its design parameters are shown in Fig. 2. The feature of the HWR shape are a conical inner conductor and an elliptical cross-section central drift tube (CDT). The basic design parameters such as an inner radius of an outer conductor (R_{OC}), a length of the CDT (L_{CDT}) and a length of a beam port cup (L_{BPC}) were guided by the accelerator design baseline [1]. R_{OC} is fixed at 225 mm, while the other basic design parameters were somewhat adjusted during a design parameter optimization process. A beam aperture is 40 mm which is requested by a beam optics.

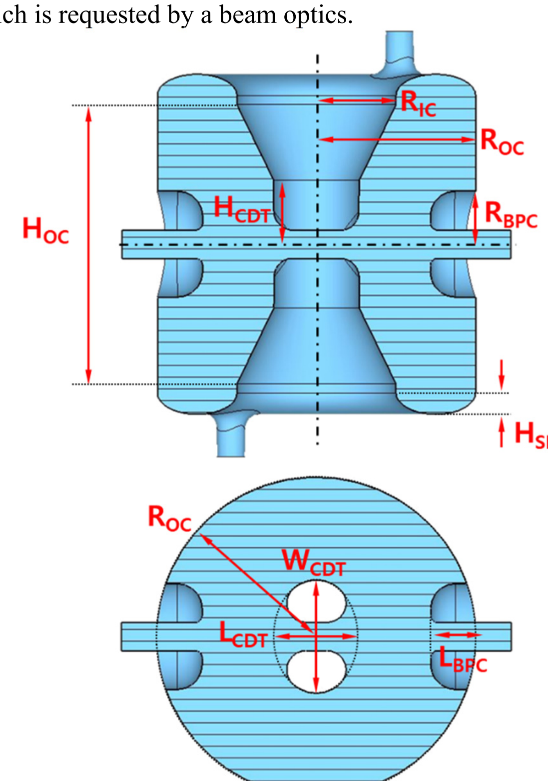

Figure 2: Parametrically deigned HWR.

*This work has been supported through KOMAC operation fund of KAERI by the Korea government (MSIT).
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The purpose of the design parameter optimization is to reduce the peak electric field and magnetic field by adjusting detail design of the central DT, a beam port cup, and a short plate. The peak electric field is affected by a width (W_{CDT}) and a height of the central DT (H_{CDT}), fillet radii of the central DT and the beam port cup. The peak magnetic field is sensitive to an outer radius of the inner conductor (R_{IC}), the height of the central DT(H_{CDT}), a height of a short plate (H_{SP}) and a r insing port design. The electromagnetic analysis on the HWR model constructed by the various combination of these design parameters were performed and the optimized design were deduced. Figures of merits of the cavity are listed in Table 1. The E_{pk}/E_{acc} and B_{pk}/E_{acc} are 3.9 and 8.2 mT/(Mv/m), respectively. These values are similar or slightly higher than those of the FRIB 0.53 HWR [5].

Table 1: Figures of Merit of the HWR

Parameter	KOMAC HWR
Frequency [MHz]	350
Optimum beta	0.56
V_{acc} [MV]	3.6
E_{acc} [MV/m]	7.5
E_{pk} / E_{acc}	3.9
B_{pk} / E_{acc} [mT/(MV/m)]	8.2
R/Q [Ω]	256.6
G [Ω]	116.1
Stored energy (J)	23.1

ELECTROMAGNETIC – MECHANICAL COUPLED ANALYSIS

After the cavity RF parameter optimization, the EM-mechanical coupled analysis was carried out to estimate a detuning of the cavity due to a deformation by an external force such as a helium pressure and the Lorentz force. The cavity detuning due to a helium pressure fluctuation can be a severe limitation of the HWR operation [6]. Also, a compensation of the Lorentz detuning is important in pulsed machine [7].

The mechanical simulation can quantify a deformation of the cavity by an external force Based on the mechanical simulation result, the EM simulation was conducted again to quantify the frequency detuning by the deformation of the cavity. Through this procedure, the helium pressure sensitivity and the Lorentz force detuning coefficient was estimated. Also, the HWR and the helium jacket design was optimized to minimize the frequency detuning. The CST were utilized for the coupled analysis. In the mechanical simulation, a fixed boundary condition was assigned on both beam port ends. Since the position of the beam port will be controlled by a tuner, the fixed beam port condition is more reasonable than a free condition.

Helium Pressure Sensitivity

The HWR cavity was equipped with a cylindrical helium jacket for the helium pressure sensitivity simulation. The material of the jacket is a titanium. The helium pressure sensitivity of the jacketed HWR was -8.2 Hz/mbar while that of the bare cavity was 10.6 Hz/mbar. That is, the change of the sign was occurred by the helium jacket. The flat ends of the jacket swelled by the helium pressure deformed the short plate of the HWR. Thus, the helium jacket design was reinforced to reduce the deformation. L-shaped stiffeners and rod connecting the flat ends were added to the jacket as shown in Fig. 3. Finally, the stiffener rib is installed on the inner conductor of the cavity. The helium sensitivity of the improved HWR and the jacket design is 1.3 Hz/mbar.

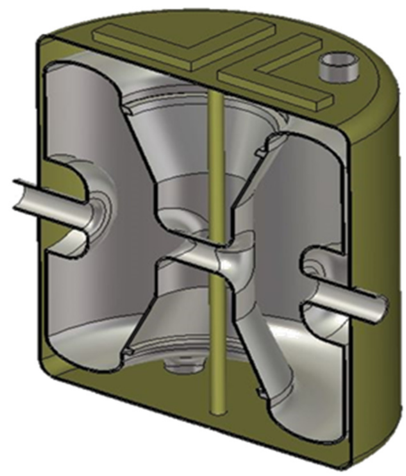

Figure 3: Reinforced design of the cavity and the helium jacket.

Lorentz Force Detuning

The Lorentz force detuning is important because the KOMAC proton linac is a pulsed machine. The Lorentz force detuning were estimated based on the reinforced design. The Lorentz force density and the displacement are shown in Fig. 4. The Lorentz force detuning coefficient is -3.37 Hz/(MV/m)^2. This value will be utilized in a RF system design.

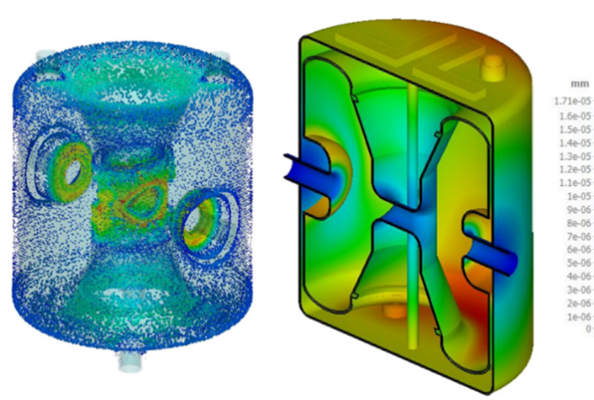

Figure 4: Lorentz force density (left) and the displacement (right) normalized to the stored energy 1 J.

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SUMMARY

The KOMAC develops the HWR to increase the proton energy from 100 MeV to 200 MeV. The EM analysis was conducted and the HWR design was optimized to reduce the peak electric and the magnetic field while satisfying the accelerating voltage and the optimum beta. Also, the helium pressure sensitivity and the Lorentz force detuning were estimated by the mechanical-EM coupled analysis. The helium sensitivity is 1.7 Hz/mbar, and the Lorentz force detuning coefficient is - 3.37 Hz/(MV/m)^2.

FUTURE WORK

The simulation and design improvement are underway. The EM-mechanical simulation is conducted to evaluate a tuning sensitivity. Then, the tuner will be designed. A power coupler and coupler port are being designed with the EM simulation. Then, a multipacting simulation can be followed.

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