CONCEPTUAL DESIGN OF SRF LINAC FOR SECONDARY PARTICLE GENERATION AT KOMAC

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A 100-MeV proton linac is under operation since 2013 at KOMAC (Korea Multi-purpose Accelerator Complex) and provides the accelerated proton beam to various users from the research institutes, universities and industries. To expand the utilization fields of the accelerator, we are planning to develop a secondary particle utilization facility including a pulsed neutron source and radio-isotope beam based on the existing linac. Especially for the pulsed neutron source, 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. Preliminary analysis shows that 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. Details on the conceptual design on the SRF accelerator for secondary particle utilization facility at KOMAC will be given in this presentation.

I. INTRODUCTION

A 100-MeV proton linac at KOMAC consists of a 50-keV proton injector based on 2.45-GHz microwave ion source, a 3-MeV RFQ (Radio-Frequency Quadrupole) based on four-vane type brazed structure and a 100-MeV DTL (Drift Tube Linac). To increase the proton beam energy beyond 100 MeV, we should add accelerating structure other than DTL because the accelerating efficiency of DTL becomes quite low at higher energy. We choose SRF technology for linac extension due to its high average accelerating gradient, which makes the length of the SRF accelerator shorter than that of normal conducting one, and high quality factor, which is intrinsic to superconducting cavity. High quality factor is important feature for high-duty machine like the one at KOMAC because the power dissipation in the wall of copper structure is substantial.

Several types of SRF cavity structure are currently used for accelerating particle beam such as quarter-wave resonator (QWR), half-wave resonator (HWR), spoke cavity, and so on. For example, an elliptical shape multi-cell structure is successfully used for proton acceleration up to 1 GeV in Spallation Neutron Source at Oak Ridge National Laboratory in U.S. For low-beta proton acceleration, HWR and spoke structure can be used. Two-gap spoke structure is chosen as 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 and performed preliminary design study on the HWR suitable for accelerating proton beam from 100 MeV to 180 MeV.

II. TANSIT TIME FACTOR AND ENERGY GAIN

Relativistic beta for 100 MeV and 180 MeV proton beam is 0.428 and 0.544, respectively. First step to design HWR is to determine the geometric beta optimized for energy gain. 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 1. 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.

III. CAVITY DESIGN AND 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, peak electric field and peak magnetic field was 30.25 MV/m and 64.4 mT, respectively. 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.

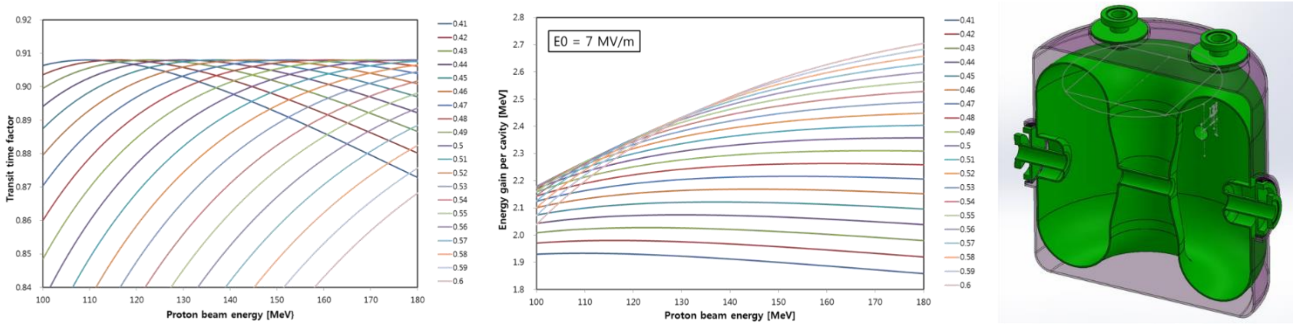

Figure 1. Transit time factor (left), energy gain per cavity (middle) and HWR with beta=0.58 (right).

TABLE 1. Main parameter of HWR cavity

Parameter	Unit	Value
Frequency	MHz	350.228
Optimum beta	-	0.64
Geometric beta	-	0.58
Stored energy	J	17.728
Vacc @beta=0.54	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 @beta=0.54	ohm	285.2
G @Rs=20 nΩ	ohm	123.8
Q_0 @Rs=20 nΩ	-	6.19E+09
Cavity loss @RS=20 nΩ	W	6.38
Aperture	mm	35
Leff	m	0.4625

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