

Conceptual Design of the Superconducting Linac for KOMAC

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Abstract

KOMAC (Korea Multi-purpose Accelerator Complex) is the 1 GeV, 20 mA proton linac. The superconducting linac for the high energy part acceleration from 100 MeV to 1 GeV is selected as a main candidate. As is well known, the superconducting linac has advantages for high current, high energy acceleration such as a large bore size, short accelerator length, and the RF efficiency. In this energy range, the velocity of proton increases from $\beta=0.43$ to $\beta=0.87$. For the design and fabrication simplicity, the cavity β stages are divided into 3 parts. The maximum electric field in the cavity is designed below 20 MV/m. In this paper the design concepts and guides for this superconducting linac are introduced.

I. Introduction

KOMAC is composed of normal conducting accelerating section that accelerates proton beam to the energy of 100 MeV and superconducting (SC) linac section that accelerates to the energy of 1 GeV.

Figure 1 is the schematics of KOMAC accelerator. The superconducting linac for high energy acceleration has many advantages such as saving the operation cost, reducing the beam loss, and shortening the linac length that result in the saving the area. In KOMAC, whole high energy acceleration from the end of CCDTL (Coupled-Cavity Drift Tube Linac) is designed with superconducting linac for the machine simplicity. The SC linac is divided into three beta regions for design and fabrication simplicity. The geometric betas of each section are 0.45, 0.54, 0.72.

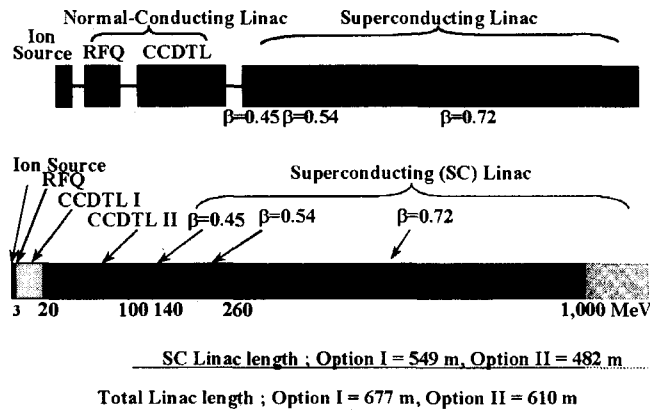


Figure: 1 KOMAC accelerator schematics (up), KOMAC scaled length (down)

II. Design guide

Generally the beam dynamics in the transition region is complex due to the difference of periodic condition. To minimize this effect focusing periodic condition is designed to be same along the whole SC linac, i.e. the same transverse beam dynamics periodicity (figure 2). Concerning the lattice, the doublet is selected, which is located outside of the cryostat. FODO lattice is excluded due to the stray magnetic field problem that can degrade the performance of SC cavities.

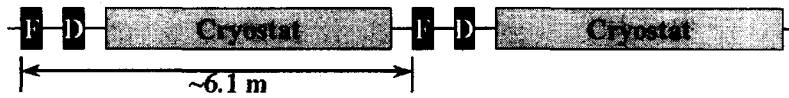


Figure: 2 Focusing period of KOMAC SC linac; same for all three beta regions

The lost beam activates the machine. In this case the remote maintenance systems are required. For hand-on maintenance, the beam loss must be limited to the certain level [1]. Especially in the high power above 100 MeV proton accelerator, the relative losses ($\Delta I/I$) should be kept below in the range $\sim 10^{-8}/m$ to $10^{-9}/m$. In KOMAC SC linac, the design value of beam loss is below 0.05 nA/m at 1 GeV.

III. Cavity design

Superconducting multi-cell cavities in a π mode operation is designed with SUPERFISH code. The number of cavities per cryostat is four for all beta regions. To satisfy the above mentioned periodic condition the number of cells per cavity for each beta are 6, 5, 4 respectively. Table 1 shows the major parameters of the KOMAC SC linac.

Table 1. Major Specification of the KOMAC SC linac

Beta	0.45		0.54		0.72	
	case I	case II	case I	case II	case I	Case II
No. of Cavities	16	20	48	48	296	248
No. of Cryostats	4	5	12	12	74	62
RF Power Input	50	40	50	50	50	60
Length (m)	24.4	36.6	73.2	73.2	451.4	372.1
Energy (MeV)	100~140		140~260		260~1,000	
Structure	6cells/cavity		5cells/cavity		4cells/cavity	
No. of Klystrons	1 (x 1MW)		3 (x 1MW)		19 (x 1MW)	
Focusing	Quadrupole doublet (period; 6.1 m)					
Avg. Sync. Phase	-30 degree					
Operating Temp (K)	2 K					

Case I : $E_0T=5MV/m$ for all beta regions

Case II; $E_0T=4MV/m$ for beta=0.45, $E_0T=5MV/m$ for beta=0.54, $E_0T=6MV/m$ for beta=0.72

The major design guidelines of SC cavities are summarized below.

- minimize the use of stiffener
- raise the lowest mechanical resonance frequency; >60Hz
- 10 Hz tuning sensitivity
- Inside or outside welding can be possible

To accomplish the above requirements the cavity shapes are optimized with thick Nb sheet (3.5~4 t), Ti helium vessel, increasing the wall slope. Figure 3 is the cavity shapes for each beta regions and Table 2 shows the major cavity parameters.

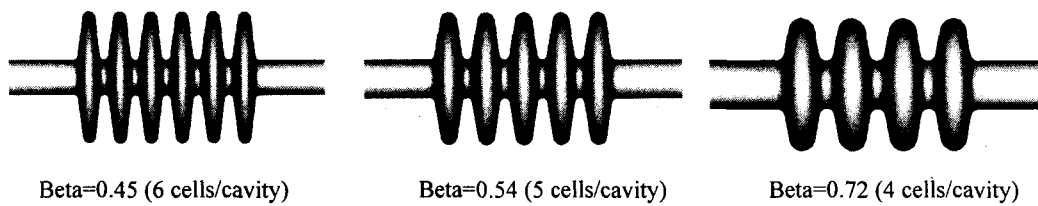


Figure : 3 The optimized cavity shapes for each beta

Table 2. Parameters of KOMAC SC cavities (Case II)

Beta	0.45	0.54	0.72	
Energy (MeV)	100~140	140~260	260~1,000	
Aperture Dia. (cm)	10	11	14	
Cavity Dia. (cm)	40	40	40	
Wall slope (degree)	7	9	10	
Corner Radius (cm)	Mid-cell	1.64	2.22	3.79
	End-cell	1.51	2.03	3.31
Cell length (cm)	9.64	11.56	15.42	
Unloaded Q	6.7e9	8.4e9	1.1e10	
ZTT (ohm/m)	1.2e12	1.9e12	3.3e12	
Eacc (MV/m)	4	5	6	
Ep/Eacc	3.52	3.05	2.54	
Hp/Eacc (A/MV)	7411	6289	5434	
RF loss/cavity (W) At Rres=10nohm	7.89	7.54	6.76	

IV. Other design aspects

IV.1 Mechanical Analysis

The external pressure and the effect of Lorentz force etc. which result in cavity deformation are considered as frequency shift sources. The considered mechanical tuning range is +/- 1 mm, it corresponds to ~300 kHz, so the allowable deformation due to the external pressure is set ~0.1 mm. And the cavities are designed that max.

stresses on the cavity wall are below 40 MPa. The natural mechanical resonance vibration is considered also. The lowest mechanical resonance frequency should be kept above 60 Hz. Table 3 shows the results of FEM analysis.

Table 3. Mechanical properties of KOMAC SC cavities

		Beta=0.45		Beta=0.72	
		Unstiff.	Stiff.	Unstiff.	Stiff.
Max. stress (2bar) (von Mises) Mpa		79.3	23.8	37.0	17.3
Max. Deformation (2 bar) mm		0.39	0.06	0.15	0.03
Lowest Resonance Frequency (Hz)	Long.	56.4	85.8	128.8	186.4
	Trans.	18.2	30.1	65.2	141.6

The transverse vibrational resonance frequency of the beta=0.45 cavity is below 60 Hz. Further study is required. It is expected that the change of the stiffener configuration and Ti He vessel structure can enhance the performance.

VI.2 Thermal Load

The required cryogenic capacity is estimated from the thermal analysis. The cavity wall losses are analyzed from the SUPERFISH result. In SUPERFISH cavity wall loss is calculated from the Piel semi-empirical formula [2]. The static losses are calculated from the CERN data. Table 4 is the results of thermal load analysis. The required cryogenic capacity is about 8 kW at 2 K with ~30 % margin.

Table 5. Thermal load of KOMAC SC linac

	Beta=0.45	Beta=0.54	Beta=0.72
RF loss*	189.4 W	362 W	1,650 W
Static loss	190 W	330 W	1,580 W
Sub-total loss	379.4 W	692 W	3,230 W
Total cavity loss	4.3 kW		
Transfer loss	1.2 kW		
Total loss	5.5 kW		

* Rres= 10 nano-ohm

VI.2 Input Coupler

The maximum required rating of input coupler for KOMAC SC linac is about 60 kW. This power level is achieved in the operating SC accelerators in the several facilities. Since the operating frequency is relatively high, there's no the multipacting problem. In KOMAC dual window is adopted for low thermal leak and easy maintenance (figure 4).

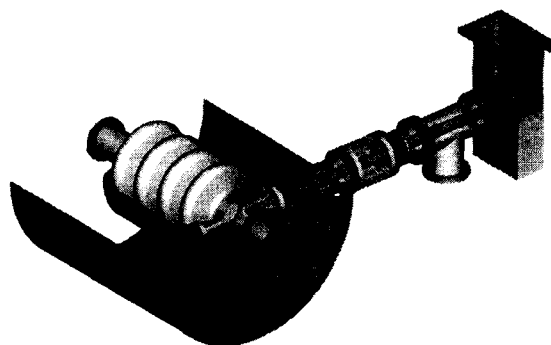


Figure : 4 Conceptual layout of KOMAC input coupler

VI.3 Magnetic and Thermal Shielding

In case of Nb SC cavity, it was revealed that the 100 % magnetic flux is trapped in the field smaller than 3 Gauss. This trapped magnetic flux degrades the performance of SC cavity. The TESLA criterion is adopted [3]. The max. allowable remanent magnetic flux density is below 20 mGauss. The shielding scheme is hybrid type that uses a high permeability material and Helmholtz coil. Figure 5 show the concept of magnetic and thermal shielding.

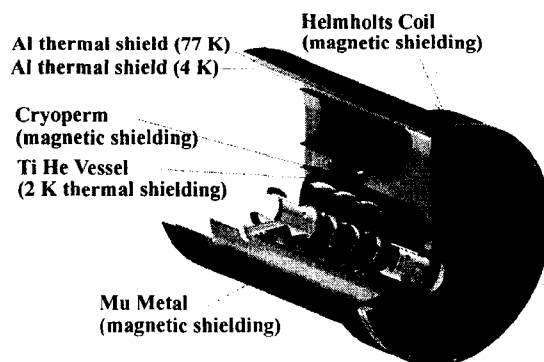


Figure : 5 Conceptual layout of magnetic and thermal shielding

V. Conclusion

Preliminary design of the KOMAC SC linac is done. The design guidelines and requirements of the major components are set. The R&D activities for the superconducting cavities are required prior to the starting of main work.

VI. Reference

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- [2] J. H. Billen, L. M. Young, POISSON SUPERFISH. LA-UR-96-1834 (1997)
- [3] E. A. Edwards, TESLA Test Facility Linac Design Report, version 1.0, March (1995)