COLD MODEL TEST OF THE KOMAC CCDTL CAVITIES

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Abstract

The Korea Multipurpose Accelerator Complex (KOMAC) project has been initiated to develop and build a high current proton linear accelerator capable of delivering an one GeV cw proton beam with an intensity of 20mA in the final stage. For the first phase of the KOMAC project, a CCDTL (Coupled Cavity Drift Tube Linac) [1, 2] which accelerates 20mA proton beam from 3 MeV to 20 MeV is designed. A cold model cavities are fabricated to check the design, the tuning method, the coupling, and the fabrication methods. The test results will be presented.

1 INTRODUCTION

The KOMAC CCDTL has been designed to accelerate a 20 mA cw proton/H- beam from a 350MHz, 3MeV cw RFQ and to inject the 100MeV beam to a 700 MHz, final energy 1GeV cw super-conducting linac. In the 1st stage of the project, we will develop cw accelerating structure upto 20MeV, and operate the accelerator in 10% duty pulse mode. After the 1st stage, we will challenge the cw operation of the accelerator. The 20MeV proton accelerator is constructing in the KTF (KOMAC Test Facility), and will be commissioned in 2003. After the commissioning, KTF will provide the proton beam for the many industrial applications.

In the KTF, we are developing the proton injector, 3MeV RFQ, 20MeV CCDTL, and RF system. The proton injector is already developed, and the 3MeV RFQ will be constructed in this fiscal year. Also we have a plan to develop the basic Super-Conducting cavity technology in the KTF for the 2nd stage super-conducting accelerator of the KOMAC. Fig. 1 shows the plan of the KTF and Fig. 2 shows the status of the KTF. The floor size in Fig. 1 is 36m x 9m.

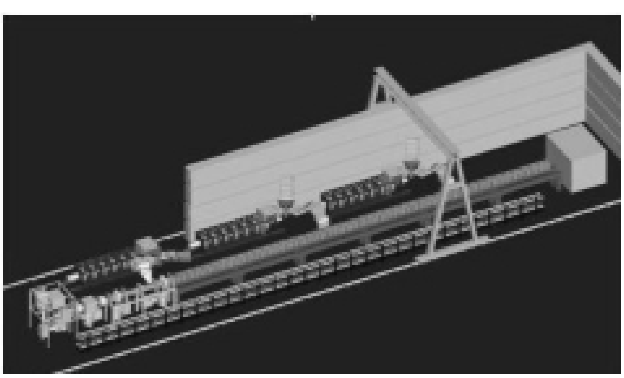

Figure 1: Plan of KTF 20MeV Accelerator

Figure 2: Status of KTF 20MeV Accelerator

2 CCDTL DESIGN

The specifications of CCDTL accelerator for KTF are given as Table 1. It will accelerate the 3MeV proton beam to the energy of 20MeV. The duty factor of the accelerator for the 1st stage is 10%. But the final goal of the duty factor will be 100%. The design of the CCDTL is based on the 100% duty factor.

Table 1: Specifications of CCDTL Accelerator

- Ion : Proton
- Input Beam : 3MeV (From 350MHz RFQ)
- Max. Beam Current : 20mA
- Input Beam Emittance :
0.3 π mm mrad (Transverse)
0.4 π Deg. MeV (Longitudinal)
- Final Energy : 20MeV
- Duty Factor :
10% (1st Stage)
100% (2nd Stage)

The design parameters of the CCDTL cavity are shown in Table 2. The values of the surface E-field and real estate accelerating gradient are conservative for easy fabrication and cw operation.

Table 2: Design Parameters of the CCDTL cavity

- Frequency : 700MHz
- Space for Quadrupole : >8cm
- Real Estate E : <1MV/m
- Surface E : <0.9 Kilpatrick
- Synchronous Phase : -60 ~ -30 degree
- Focusing : 8 $\beta\lambda$ FODO
- Aperture : Acceptance > 2 transverse emit.

The aperture of the CCDTL can be optimised by iterative calculations of the shunt impedance and the beam trajectory for the optimisation. A larger aperture decreases the shunt impedance, but increases the ratio of aperture to beam size (less beam loss). The transition energy for the number of gaps per focusing period is determined by the space for the quadrupole magnet.

The cavity shapes are determined by SUPERFISH code. In spite of the small aperture, the effective shunt impedance is small in the first part of the CCDTL. This is not serious problem because this part works as a buncher and a matching section.

Beam dynamics for the KOMAC CCDTL are performed using the PARMILA code. For longitudinal matching with 350MHz RFQ, the synchronous phases and the amplitudes of the first part of the CCDTL are adjusted [3]. The calculated longitudinal emittance is 0.4 pi degree MeV, and the transverse rms emittance is 0.32 pi mm mrad with the 6 cm pole EMQ. The phase and amplitude of the first part for matching is given to obtain the smallest emittance growth. In the final simulation, there is virtually no growth in transverse emittance, and no more than 10% growth in longitudinal emittance, which is not critical.

To estimate the tolerances of the CCDTL structure, an error analysis has been done with PARMILA code. With the error in Table 3, which is achievable, the beam envelop calculated with PARMILA code does not grow more than 20%.

Table 3: Tolerances of the CCDTL

- Field Amplitude : 1%
- Field Gradient : 1%
- Phase : 1 Degree
- Quadrupole displacement : 0.05mm
- Quadrupole rotation : 1 Degree
- Quadrupole strength (GL) : 1%

To evaluate the manufacturing tolerances of the CCDTL cavity, the perturbation analysis of coupled resonators is used [4]. The tolerance of the cavity frequency is 100kHz, and the coupling coefficient is 0.02 with a tolerance of 1%.

The coupling coefficient between the accelerating cavity and the coupling cavity has been calculated by using the frequency shift between modes, which can be calculated with MAFIA code. Also, the machining tolerance for the coupling coefficient is 0.1mm, which can calculated by MAFIA code From this analysis, it has been found that there is no critical problem in fabricating the KOMAC CCDTL cavities. The technology for conventional CCL, which is well established, can be used in fabrication, tuning, installation, alignment, and operation

For the cooling of CCDTL cavities, the water-cooling channel has been designed and analysed by ANSYS code [5]. The frequency shift due to the thermal expansion is 50kHz with the coolant water velocity of 3 m/s, and the bulk temperature increase of the coolant water is less than 5 K.

Table 4: Design Summary of the CCDTL cavity

- Structure : 700MHz CCDTL
- Length : 25m
- Aperture Diameter : 10/15mm
- No of EMG : 130
- Total Structure Power : 1.15MW
- Sturcture Power per length : 50kW/m avg.
- Surface E : <0.9 Kilpatrick

3 COLD MODEL

The CCDTL cold models are fabricated to check the design, the tuning method, and the coupling coefficients and the fabrication method. The fabricated OHFC copper cold model is shown in Fig. 3. The measured resonant frequency is 700.8 MHz without air and humidity compensation. The measured Q value of the cavity without brazing is 87% of the SUPERFISH calculated Q without any surface cleaning. The super-drilled coolant path is well fabricated, and this type cooling method will be used for the CCDTL construction.

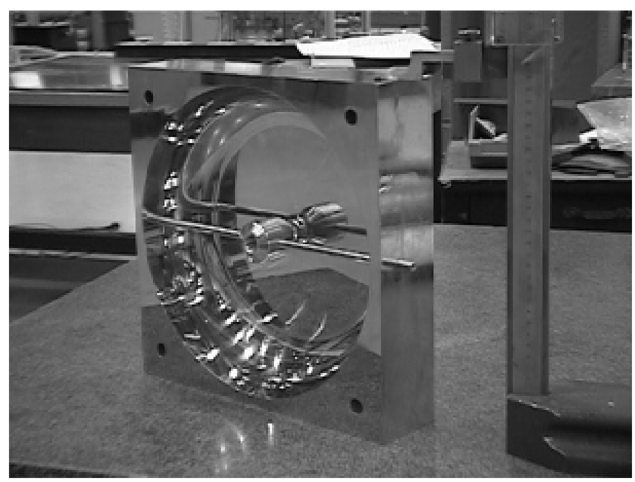

Figure 3: CCDTL Cu Cold Model

Fig. 4 shows the assembly drawing of aluminium cold model, and Fig. 5 shows the fabricated model.

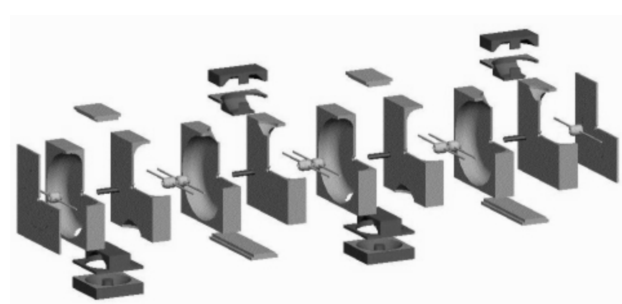

Figure 4: CCDTL Al Cold Model Assambly

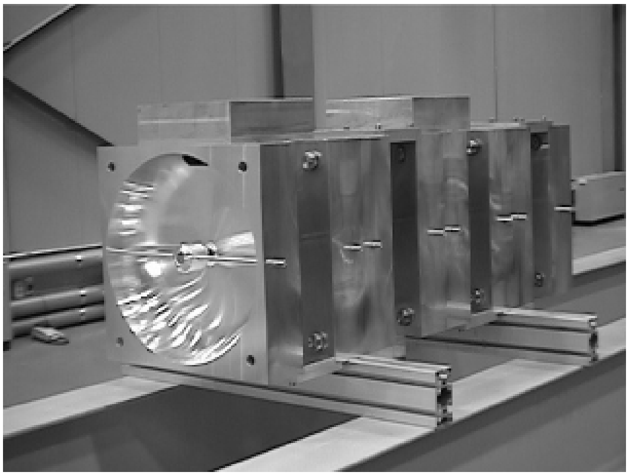

Figure 5: CCDTL Al Cold Model

The measured resonant frequency is 699.5MHz for the accelerating cavity (design: 700.0MHz), and 700.3MHz for coupling cavity (design: 700.5MHz).

3 COLD MODEL TEST

The field profile is measured with bead perturbation method. The field measurement system is shown in Fig. 6. A 2mm diameter and 2mm long alumina cylinder is used for the bead. The stepping motor drive system controls the position of the bead with an accuracy of 0.2mm. The frequency shift is measured with a network analyzer (HP4306A/85064A). Because the temperature controlled room is not available, the measurement was carried with the careful check of the unperturbed resonance frequency before and after the experiment.

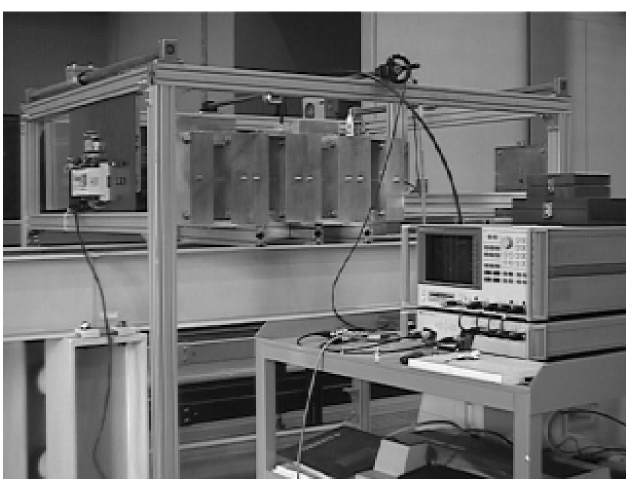

Figure 6: CCDTL Field Measurement

Fig. 7 shows the one measured field profile in one cavity of the aluminium cold model. The measured field profile in a cavity agrees with the calculated profile. But, the field uniformity in the multi-cavity is not good. It is necessary to increase the field uniformity by the fine tuning of the cavity. This will be done with the brazed copper cold model which will be fabricated in this year.

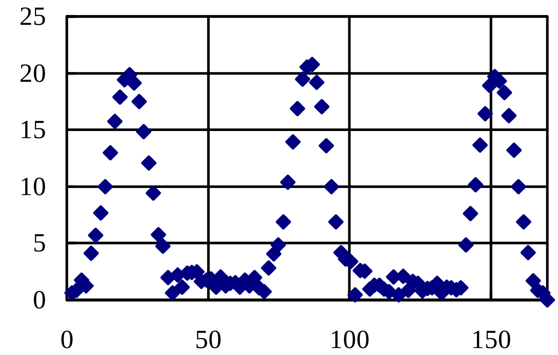

Figure 7: Measured Field Profile in One Cavity (x: Position(mm), y: Field(Arb.))

4 SUMMARY

The CCDTL for KTF is designed, and the copper and the aluminium cold model are fabricated, and tested. The fine tuning of the cavities is necessary for the field uniformity. These models will be used for the design check and fabrication method check. The fabrication method has been studied. The copper model will be fabricated with the study. As a back-up of the CCDTL, the design study for conventional DTL will be performed.

ACKNOWLEDGEMENT

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REFERENCES

[1] J.H.Billen, F.L.Krawczyk, R.L.Wood, and L.M.Young, 'New RF Structure for Intermediate-Velocity Particles', Proceedings Of the 1994 International Linac Conference, Vol. 1, p. 341.

[2] 'National Spallation Neutron Source, Conceptual Design Report', the NSNS Collaboration, May 1997.

[3] S.Nath, J.H.Billen, J.E.Stovall, H.Takeda, and L.M. Young, 'Front-end Physics Design of APT Linac', Proceedings of the 1997 Particle Accelerator Conference.

[4] D.E.Nagle, E.A.Knopp, and B.C.Knapp, 'A Coupled Resonator Model for Standing Wave Accelerator Tanks', Rev. Sci. Instr. 38, 1583 (1967).

[5] R.L.Wood, W.L.Clark, F.Martinez, and F.E. Sigler, 'Thermal/ Structural Design and Fabrication Development of High Power CCDTL and CCL Sturctures', Proceedings of the 1997 Particle Accelerator Conference.