DTL TANK DEVELOPMENT OF 132 MeV LINAC FOR CSNS

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Abstract

A conventional 324 MHz DTL has been designed for China Spallation Neutron Source (CSNS) to accelerate H^- ion beam from 3MeV to 81MeV and up to 132MeV in its second phase. There are 7 tanks in the 132MeV DTL and currently the R&D of the first tank is under progress. In the design, tank-1 has a tilt field distribution partial for obtaining the most effective energy gain and keeping the low Kilpatrick parameter. This tank is under fabrication and the manufacture technique was verified by the measurement results. Concerning of the difficulty of tuning a partial tilt field distribution, the complex RF measuring and tuning procedure is introduced.

INTRODUCTION

China Spallation Neutron Source (CSNS) mainly consists of an H^- linac and a rapid cycling synchrotron of 1.6GeV[1]. The DTL linac are designed in two phases, with energy of 81MeV for phase I and 132MeV for phase II. R&D program for some key technologies involves a prototype of the first unit of the DTL tank, which is the most difficult section in the whole DTL linac. A 3-meter module covers an energy range from 3MeV to 8.9MeV. The tilt field is designed in this module with an electrical field from 2.2MV/m to 3.1MV/m. The electrical field will keep 3.1MV/m after tilt part through whole DTL tank. Concerning the difficulty in tuning this kind of RF field, a procedure for measuring and tuning the tank is designed. In this paper, we will introduce the progress of module tank fabrication and RF tuning procedure.

DTL CAVITY DESIGN

The main parameters of the CSNS DTL are listed in Table 1. There are four tanks for phase I and additional three tanks for phase II. The first tank is composed of three short module tanks, and the first module tank is under manufacturing.

Table 1: DTL main parameters

	CSNS-I	CSNS-II
Input Energy (MeV)	3	3
Output Energy (MeV)	81	132
Chopping rate (%)	50	50
Average I (μA)	75	150
Pulse Current (mA)	15	30
RF frequency (MHz)	324	324
Repetition frequency(Hz)	25	25
Duty factor (%)	1.05	1.05

Mechanical parameters for this unit are listed in Table 2. In the drift tube, the electromagnetic quadrupole (EMQ) is used to supply a gradient 75T/m focusing strength in maximum. The focusing periods are designed as the FD lattice and each drift tube contains one quadrupole.

Table 2: The parameters of first module tank

Tank length (m)	2.85
Energy range (MeV)	3-8.88
Average E_0 (MV/m)	2.2 ~ 3.1
Synchronous phase (deg)	-30 ~ -25
Tube face angle (deg)	0 ~ 9 ~ 14
Tank inner diameter(mm)	566.27
Cells number	29
No. of Slug tuners	4
Bore radius (mm)	6
DT diameter (mm)	148

TANK MANUFACTURE

The tank body was made of carbon steel with a copper inner surface. To develop the technology, we tried various approaches with some short test tanks. At the beginning, an explosive bonding technology was tested. A thin copper plate was tightly bonded with a steel tank in the inner surface. Since the tank had many ports and holes for vacuum and for holding drift tubes, here the bonding condition was not as good as the inner surface, resulting in vacuum leakage at some ports. Then we turned to adopt the technology of the Periodic Reverse (PR) copper electroforming method. It has been successful for both inner surface and all ports/holes. Figure1 shows the 2.8m tank module after electroforming. The inner copper surface was polished and the ports are now under fine machining for high accuracy and high flatness. There are twelve straight water cooling channel embedded into tank out-wall. Size of the channel is 26mm×13mm. The tank end plate is separated into two parts for water cooling with opposite water flow direction. Water channels on the end plate are shown in Figure 2.

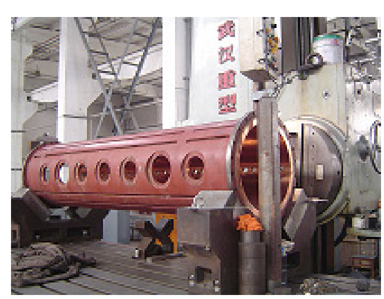

Figure 1: The first module tank is under fine machining after copper electroform.

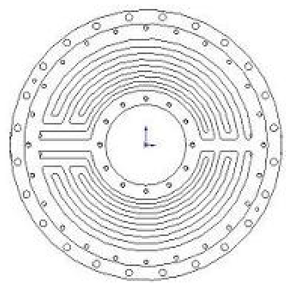

Figure 2: Water channels inside of end plate.

Elements in the first module tank are consist of 28 drift tubes with stems, 14 post couplers, 4 slug tuners, 3 vacuum ports, 1 vacuum detecting port, 4 pickups, 1 viewing window and 29 quadrupoles. There are 29 physical cells in this module tank. The downstream ending plate is made of aluminium as a dummying end plate and thus there is no magnet in the half drift tube. Concerning the permanent magnets hardly have a good uniformity, all the quadrupoles in DTL are electromagnetic quadrupole. The magnets cores have the same thickness of 34mm and the same gradient of 75T/m. The magnet coil is the SAKAE type made by electroforming method which was used in J-PARK DTL linac[2]. Figure 3 shows the magnet inside with the half copper drift tube.

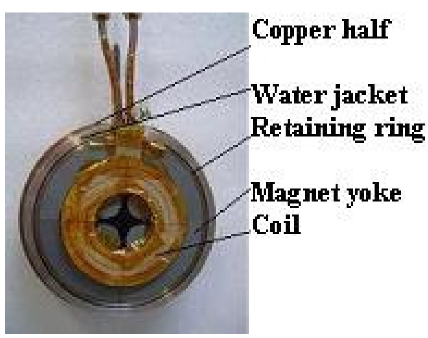

Figure 3: Magnet with SAKAE coil inside the drift tube.

Some field measurements have been carried out with six model magnets in IHEP. The effective length, magnet field gradient in transverse plane, B-H curve and magnet field centre were measured and analyzed. Detailed results can be found in another paper in this conference[3].

The magnet installed into drift tube has a concentric tolerance of less than 50μm error. The mechanical centre is fixed by a set of supporting structure on the rotating coil measurement system. Then beam pipe and outer diameter of the drift tube are machined in accordance with the magnetic centre which is defined as the position with a minimum dipole component. The supporting structure is shown in Figure 4.

OFC DRIFT TUBE MANUFACTURE

The drift tube of DTL for CSNS is made of oxygen free copper (OFC). The advance is there is no electroplating after electron beam welding (EBW) of the two halves of a drift tube, and the surface machining demands only one time according to the mechanical centre fixed from magnetic measurement, saving a lot of time in mass production.

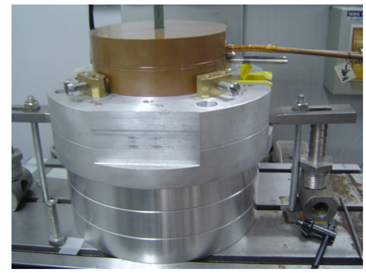

Figure 4: Supporting structure for rotating coil measurement.

In fact, a stainless steel drift tube was constructed in the early R&D stage. The welding deformation was more than 1mm, which was thought bigger than expected. Then we tried to manufacture drift tube with OFC. By using OFC drift tube, the deformation in EBW is 0.4mm, and this error will be corrected by fine machining after welding.

However the major concern is its intensity of OFC drift tube in comparison with stainless steel one. We have done two experiments to check the intensity of OFC drift tube. The first is to check the deformation of the drift tube surface under a giving high air pressure inside the welded drift tube, as shown in Figure 5. The result was 0.02mm deformation when the air pressure was increased from 0 to 1.5kg/cm^2, while it recovered back to 0 when no air pressure was applied. The second is to check deformation of the total length of the stem with an additional hanging load for a long time, as shown in Figure 6. The result was 0.01mm length change with a 150kg hanging load for 23 hours, while it became 0 when taking away the load. These tests demonstrate the intensity of OFC is high enough for our design.

Figure 5: Deformation check of an OFC drift tube under a high air pressure.

Figure 6: DT Deformation test with a hanging heavy load.

DESIGN OF THE ELECTRICAL FIELD

In the analysis of tilt field design of the first tank, the accelerating field distribution generated by MDTFISH code is different with the design data[4]. Figure 7 shows the difference between these two fields. This difference will cause beam property completely different with the design, especially beam loss. In order to recover the electrical field as designed, a cell gap adjustment in special position is adopted. The modified field becomes nearly the same as the designed field, as plotted in Figure 8, but on the other hand it causes the beam synchronous phase in adjusted cells different with the design. As a result, the beam energy is 0.2% lower than the design value in simulation.

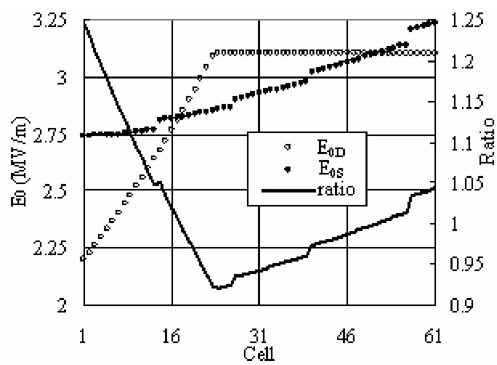

Figure 7: The code generated field before adjusting

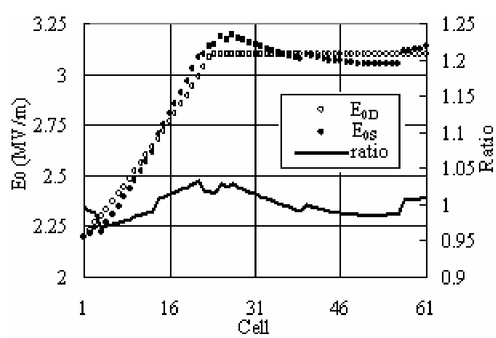

Figure 8: The code generated field after adjusting.

RF TUNING DESIGN

In the RF tuning of DTL for CSNS, the field is required to be no more than 1% different from the design one. There are several procedures on RF tuning for that goal. First, separate the perturbation of slug tuners and post couplers. Second, adjust the slug tuners by calculating the transfer matrix for field modification. Third, check the sensitivity of RF field in a 5% tilt field. And last, check the effects of the movable tuners both on field tilt and on field flatness.

According these procedures, the RF tuning of DTL is designed for three aims: resonant frequency, flatness and field sensitivity. The most concerned issue is how to get the designed field distribution for both tilt field section and flat field section. While the sensitivity in different sections, including movable tuners effect on tilt part, is also under thorough detecting.

In the tank 1 there are 12 fixed tuners and 2 movable tuners, as shown in the Fig 10. All the 14 slug tuners have a 150mm diameter and 10mm corner radius. The maximum penetrating depth is 100mm. Frequency adjustment is designed as ±1MHz.

1. Frequency tuning The designed field is complicated, so the tuning of post couplers is separated from frequency tuning with slug tuners. The frequency shift caused by the insertion of the post couplers is 486.34 kHz in simulation. Here the simulated post couplers are fixed in length and have no tip angle. In the frequency tuning, post couplers are all pulled out. The slug tuners penetrate into tank with different length to obtain the required field distribution as designed at the resonant frequency. And the position changes of slug tuners for ±5% are recorded to check the sensitivity afterwards.

2. Flatness tuning When the frequency is proper and field is flat, post couplers are inserted in a same length and same tip angle. According to the frequency shift and field perturbation, the post couplers are tuned in several groups with different length. Flatness tuning is an iterating process between resonant frequency and designed flatness approach.

3. Sensitivity tuning The sensitivity is judged by 2 points. Firstly, 5% field change introduced from fixed tuners has a perturbation on designed field. Rotate the post couplers angle until the perturbation has no effect on field distribution. Secondly, check the waveform by bead pulling system to ensure the RF field as designed. After the post couplers adjustment, movable tuners perturbation is measured with 1% field variation.

For the RF tuning of DTL for CSNS, the target field distribution is different from any other design. So the RF tuning, especially the flatness and sensitivity, is more difficult. After the module tank is manufactured, more experiment will be conducted to check the design.

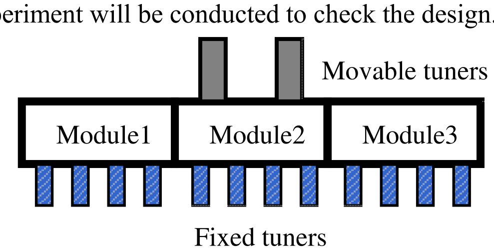

Figure 9: Tuner distribution on the first DTL tank

ACKNOWLEDGEMENTS

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