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MAGNETIC FIELD MEASUREMENT AND ANALYSIS FOR DRIFT TUBE LINAC OF CSNS*

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Abstract

A 324MHz Alvarez-type Drift Tube Linac (DTL) is used to accelerate the H- ion beam from 3 to 80 MeV with peak current 15mA for China Spallation Neutron Source (CSNS). DTL is composed by 36 meters cavity and 161 DTs, the DT magnet coil adopted SAKAE structure with compact, smaller aperture. Magnetic field is measured by self-developed high precision rotating coil measurement system. This paper introduces the rotating coil measurement system simply and presents the 161 DTs magnetic field measurement results comprehensively, include magnetic field center offset, integral magnetic field, higher-order harmonics. In addition, cooling test result of magnet coil is also presented.

INTRODUCTION

Drift Tube Linac of CSNS which accelerating an H- ion beam from 3 MeV to 80 MeV has been designed as 4 tanks with a total length of approximately 36 m [1, 2]. The electromagnetic quadrupoles (EMQs) are used in DTL accelerator for transverse focusing since the magnetic field gradient can be adjusted by varying the current flow in the conductors. The major parameters of the designed DTL quadrupole (DTLQ) are presented in Table 1.

DRIFT TUBE AND ROTATING COIL MEASUREMENT SYSTEM

The structure of Alvarez-type Drift Tube is show in Fig. 1. We adopted an electroformed hollow coil- SAKAE type coil which has no bending radius, for its compact structure. The wire cutting and the Periodic Reverse copper electroforming method are applied to the coil manufacture process. The DT shell and stem are made of oxygen free copper and cooled via the supporting stem. The fabrication process is complex and time consuming accompanied with a series of tests. All joints of the DT and the stem are welded by the electron beam welding (EBW). The space around the magnet in the DT is filled with the epoxy resin by a vacuum impregnation method.

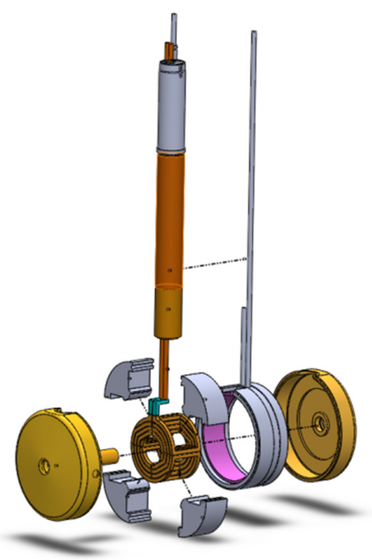

Figure 1: Drift tube structure.

Table 1: Design Parameters of DTL Quadrupole Magnets

Cavity number	Cavity 1		Cavity 2&3	Cavity 4
Magnet type	**DTL-QA**	**DTL-QB**	**DTL-QC**	**DTL-QD**
Quantity	26	39	69	27
Outer radius(mm)	108	108	108	108
Inner radius(mm)	19	19	23	27
Good field region(mm)	14	14	18	22
Higher-order harmonics(Bn/B2)	$<3.0\times10^{-3}$	$<3.0\times10^{-3}$	$<3.0\times10^{-3}$	$<3.5\times10^{-3}$
Effective length(mm)	40	50	75	70
Field gradient$(T/m)_{max}$	55	55	17	13.5
Integral field(T)	2.2	2.75	1.275	0.945
Field gradient$(T/m)_{min}$	40	25	12	12

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To verify the DTLQ's design specifications and fabrication quality, a precision harmonic coil magnetic field measurement system was designed for the measurement of the small aperture magnet. Figure 2 shows the overview of the measurement system, the alignment precision of the DTLQ is better than 0.004 mm, and the duplicate measurement errors of the integrated field and harmonics field of this measurement system are better than 4E-3 and 4E-4 respectively [3].

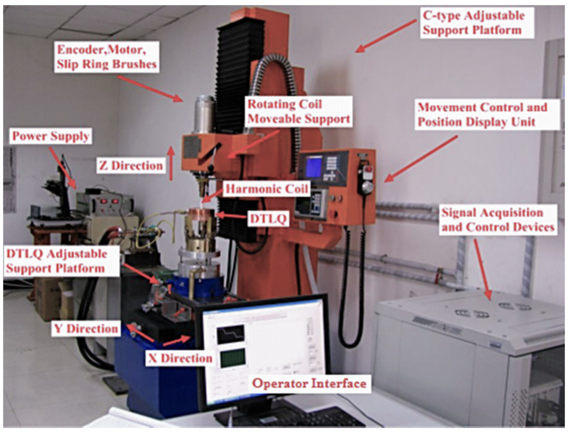

Figure 2: The practicality picture of the measurement system.

MEASUREMENT RESULTS AND ANALYSIS

Magnetic Field Center Offset

Five times at least rotating coil measurement were done during one DT's machining. Figure 3 presents the change trajectory of magnetic field center offset after each machining, finally, the center offset was milled to less than the requirement 0.03 mm.

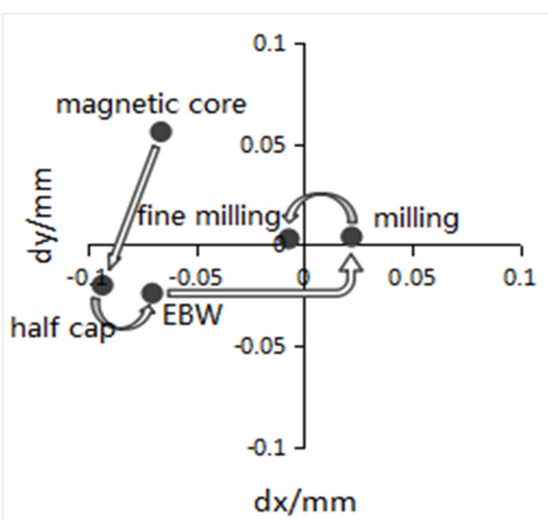

Figure 3: The trajectory of magnetic field center offset after each machining.

Figure 4 shows the measured magnetic field center offset from the mechanical centre defined by the excircle of the DT. It can be found that most of the deviations (dot) less than 0.03 mm, since the DT length increase, the processing precision decline, a few of deviations (circle) fall into [0.03, 0.05]. Appropriate calibrating was made during fabricating to satisfy physical requirements.

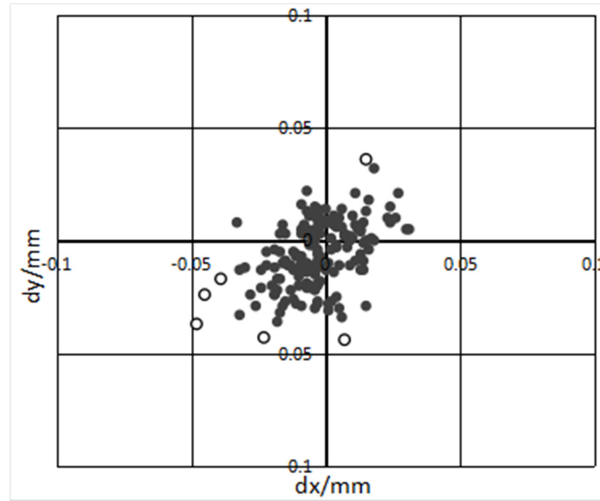

Figure 4: The magnetic field center offset deviation of the 161 DTs.

Integral Field and Higher-Order Harmonics

Four sizes quadrupole magnet were designed for DTL as show in table 1, since less sizes caused easily manufacture. Integral field was continuous through simulation by Trace Win code [4]. The measurement results are shown in Fig. 5 with design values, measurement integral field values that higher 5% corresponding to less than 30 A excitation current are acceptable.

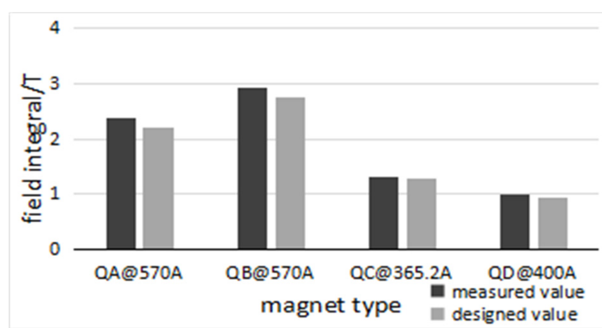

Figure 5: Field integral comparison of measurement value and design value for four sizes magnet.

Higher-Order Harmonics is another important quality index for EMQ. Figure 6 shows the harmonics component of four types magnet. B6/B2 of QA is 2.12E-3, QB is 1.44E-3 and QC is 2.00E-3, less than 3.00E-3, B6/B2 of QD is 3.30E-3, under 3.5E-3. The harmonics of all the 161 quadrupole magnet are low enough for our physical requirement.

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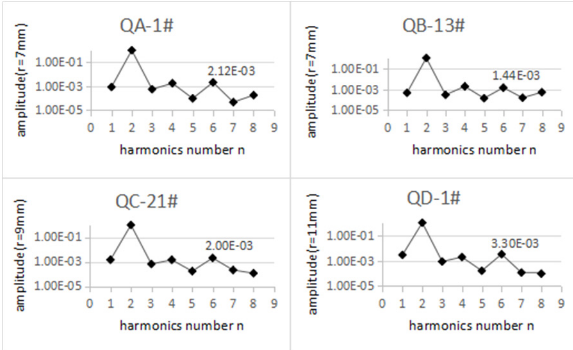

Figure 6: Higher-order harmonics of four types magnet.

COOLING TEST

Attention must be paid to the fever of EMQ, test was done with the maximum rated current 580A, cooling water flow 1.0L/min. The temperature on magnet coil surface is showed in Fig. 7.

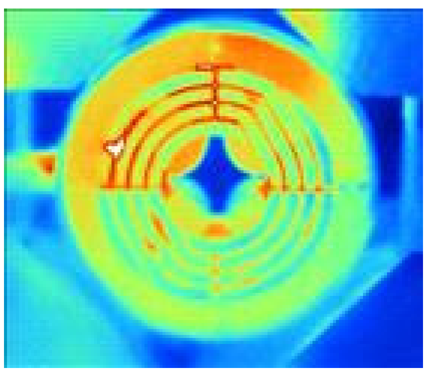

Figure 7: The distribution of temperature on magnet coil surface.

Test result of 9-hours is given in Fig. 8, temperature rise of magnet coil is 11.9° C, coincides very well with the theoretical value 11.5° C, magnet power on well.

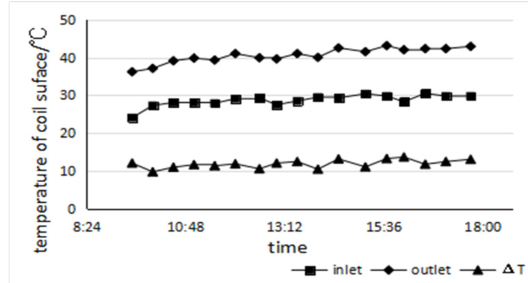

Figure 8: The variation of temperature on magnet coil surface.

CONCLUSION

It took about two and a half years to finish the manufacture of the 161 DTs, and now, the DTL has been running for some time. Although we met some vacuum problems on the working DT, a practical solution is found to overcome it. The DTL is running well and this validate the rightness and feasibility of the DT development technology.

REFERENCES

[1] S. Wang, S.X, Fang, S.N. Fu, *et al.,* "Introduction to the overall physics design of CSNS accelerators" [J]. Chinese Physics C, 2009, 33 (Supp2): 1-3.

[2] J. Wei, S X, Fang, J.Y. Tang, *et al.* "China Spallation Neutron Source: An overview of application prospects" [J]. Chinese Physics C, 2009, 33(11): 1033-1042.

[3] J.X. Zhou, W. Kang, B.G. Yin, *et al.* "The development of magnetic field measurement system for drift-tube linac quadrupole" [J]. Nuclear Instruments and Methods in Physics Research, 2015, 786(A): 142-146.

[4] J. Peng,"Physical design and study of CSNS drift tube linear accelerator" [D]. Beijing: Graduate University of Chinese Academy of Sciences, 2008.