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DESIGN AND FABRICATION OF HYBRID RFQ PROTOTYPE

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Abstract

Hybrid RFQ is a potential good choice at the low-energy range of linear accelerator. The complexity of mechanical design and difficulty of fabrication are part of reasons impeding application of it and similar structures. In order to explore the practicable structure and research on RF parameters of this accelerating structure, an aluminium prototype is developed.

INTRODUCTION

Hybrid RFQ is a spatially periodic structure with RF quadrupoles [1, 2], which is combined by alternating CH-DTL sections and four-vane RFQ sections. It has higher accelerating efficiency than traditional RFQ, and shows stronger focusing strength than magnetic focusing DTL, especially when accelerating low r/q ions. [3] Over recent years, several similar accelerating structures have been proposed, they are not widespread yet. [4] The requirement for high machining precision and the inherent over-constraint condition make it difficult for fabrication. This paper presents the mechanical design and process of Hybrid RFQ prototype.

MECHANICAL DESIGN

According to the RF model (see Fig. 1), the mechanical structure of Hybrid RFQ prototype is developed.

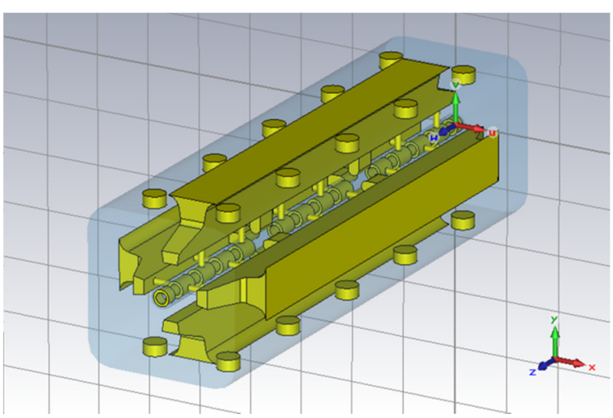

Figure 1: The RF model of Hybrid RFQ.

The cavity is designed as a rectangular body which is divided into four parts. RFQ section is formed by four electrode tips inserted into vanes respectively. CH-DTL section is composed by series of drift tubes distributed crosswise and fixed on both ends, which causes the unavoidable over-constraint. The horizontal vane is constrained simultaneously by the interface with vertical vanes and the other with drift tubes when assembling (see Fig. 2). This condition leads to the requirement of high machining precision. Through feasible dimensional tolerance design and strict quality control could avoid the failure of assembly caused by over-constraint.

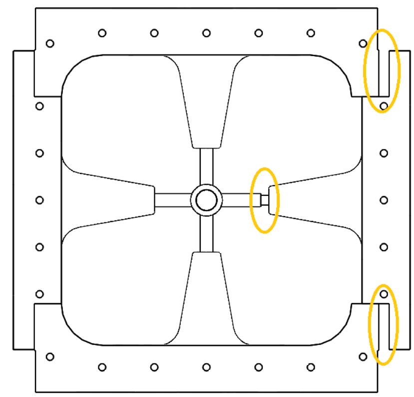

Figure 2: Sketch of over-constraint structure.

There are six drift tubes with support rods in the same direction, which means six group shaft and hole need to fit simultaneously while put the opposite vanes together. Therefore the setting of clearance is crucial. If the clearance is too small, it will make the assembly hard to achieve. While choice of big clearance would lead to the structural instability. Considering the factory's capability, the clearance between support rod and mating hole of vane is set as 0.04mm. In addition, all the drift tubes and electrode tips are fastened with bolts in case of looseness of them. This design also plays a supporting role in the assembling process. The overall mechanical model is as Fig. 3 shows.

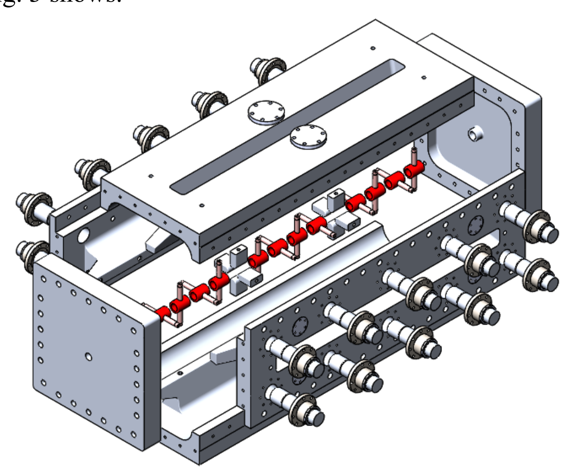

Figure 3: The overall mechanical model of Hybrid RFQ.

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FABRICATION AND ASSEMBLY

Fabrication

Processing technology of drift tube is researched and tested. Crossbar drift tube consists of a central tube and supporting rods on both ends. Processing it as an integral component is difficult for four-axis machining centers, and the fillet at joint can't be cleaned up. A new craft is proposed as putting a long rod into the mating hole of central tube through shrink fit and then turning the central bore (see Fig. 4). The value of interference is chosen as 0.06mm after tests. This craft not only guarantees the concentricity of supporting rods on the both ends, but also makes the joint stable.

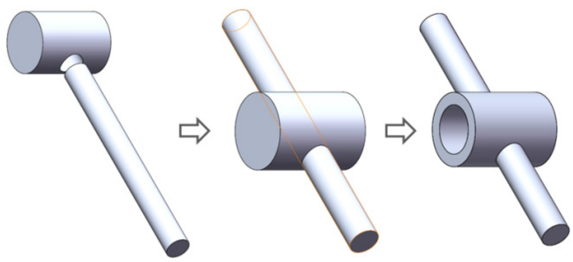

Figure 4: The processing of drift tube.

To insure processing precision of four vanes, the machining is carried out on CNC milling machine with high-speed and low-feed cutting parameters. The process includes four stages as rough machining, heat treatment, half finishing and finishing in turn. After every stage, aging treatment is done to release the process stress, which influences the precision obviously.

Assembly

Before assembly, some preparation is done. Inspection on dimensions of vanes is done first. Then we measured the concentricity and longitudinal distance of drift tubes on the condition that six of them were mounted on every single vane, to check the accuracy of fitting between vanes and drift tubes (see Fig. 5).

Figure 5: Measurement of accuracy of fitting between drift tubes and vertical vane.

The assembly includes three steps: assembly of L-type, U-type and O-type. The L-type is composed of a vertical vane and a horizontal vane, each with six drift tubes mounted. Second horizontal vane is assembled to form the U-type. Move smoothly and stop at the place several millimeters to the fitting position. Use a long bolt with threaded connection with supporting rod to adjust every drift tube radially and extract a little to fit with both of opposite vanes. With each drift tube fitting with opposite vanes, the second horizontal vane is moving to the fitting position and the assembly of U-type is completed. The way to assemble the second vertical vane to form the O-type is the same as above. Figure 6 shows the Hybrid RFQ prototype after assembly.

Figure 6: Hybrid RFQ prototype after assembly.

Measurement of Drift Tubes

Considering that it is difficult to have the probe of measuring arm contact with drift tubes in the middle of cavity after assembly, the measuring is implemented on the U-type with one side open. The results are shown in Table 1.

Table 1: Measurement Results of Centre of Drift Tubes on U-type Cavity

Serial number	X(mm)	Y(mm)
DTL 1	-0.09	0.03
DTL 2	0.02	0.08
DTL 3	-0.01	-0.09
DTL 4	-0.07	0.12
DTL 5	0.08	0.06
DTL 6	0	-0.09
DTL 7	0.06	0.06
DTL 8	0.07	-0.11
DTL 9	0.02	-0.16
DTL 10	0.06	0.07
DTL 11	0.05	-0.12
DTL 12	-0.16	0.05

The centre deviation of several drift tubes is over 0.1mm. This could be explained by the absence of the upper vertical vane. Before completely assembled, drift tubes with upright supporting rods (DTL 1,3,6,8,9,11) are

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lower in Y direction for tightened by bolts at bottom, those with level supporting rods (DTL 2,4,5,7,10,12) are higher in Y direction because the two horizontal vanes are not parallel but at a slight angle. The measurement method of complete assembly is under investigation. It can be referred that the results will show less concentricity error.

CONCLUSION

Hybrid RFQ prototype has been successfully developed. It provides processing experience and guidance on the mechanical design of the experimental cavity. The alignment and research on RF parameters will be performed soon.

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