FABRICATION TECHNIQUE OF DRIFT TUBE WITH PERMANENT QUADRUPOLE MAGNET FOR THE LINAC OF THE JHP

Y. Iino, T. Adachi, T. Kawasumi and M. Ozaki
Mitsubishi Heavy Industries, Ltd. (MHI)
Nagoya Aerospace System Works

T. Kato, F. Naito, E. Takasaki and Y. Yamazaki
KEK-National Labolatory for High Energy Physics

Abstract

A compact drift tube will be used for the drift-tube linac (DTL) which is under development for the Japanese Hadron Project (JHP). The methods are briefly described for holding the permanent quadrupole magnet fixed into the drift-tube cell and for assembling the drift tube onto the DTL cavity tank.

Introduction

The 432-MHz drift-tube linac (DTL) for the Japanese Hadron Project (JHP)[1] is about half as small as conventional 200-MHz DTL's; the inner diameter of the tank is 441 mm, the outer diameter of the drift tube 80 mm, and the bore diameter for a beam 10 mm. This requires the developments of more precise machining of their components and more precise alignment of their quadrupole magnets (Fig. 1). Among various technical developments for this purpose we briefly describe the following three interesting techniques:

(1) Fixation of the permanent quadrupole magnet into the drift-tube inner cell.
(2) Insertion of the inner cell into the drift-tube outer cell.
(3) Assembly of the drift tube onto the DTL tank.

Since strong permanent magnets, such as SmCo and NdFeB are used for the DTL, special care is necessary to take into account effects of the strong magnetic field and property of the magnets.

Assembling procedures of Drift Tube

The drift tube comprising a permanent quadrupole magnet, an inner cell and an outer cell with a stem is assembled as follows. First, the permanent magnet is held fixed into the inner cell. Second, this inner cell is inserted into the outer cell and made vacuum-tight by the cold-shrinking method. Finally, the drift tube thus completed is assembled in the DTL tank, by inserting its stem into a tapered hole in the tank. In order to maintain the high quality of products it is important to eliminate any application of machining or surface finish after assembling. In other words, the plan of the assembling procedure should be formed so as to complete all the machining and surface finish on each part prior to the assembling.

Mounting Procedures of Permanent Quadrupole Magnet

A permanent quadrupole magnet comprises sixteen pieces with the same dimension, whose magnetized axes are respectively oriented to their specified directions (Fig. 2). All the pieces are mechanically assembled together with eight shims to form the quadrupole magnet, and held tight by a couple of spot-welded bands against the magnetic force. For the precise alignment of the magnet pieces into a drift-tube cell, it is important to measure the dimensions of the pieces as precise as possible which are used to determine the shim thickness. Also, special care is necessary in order to take into account complicated effect of the magnetic force in each assembling process.

The mounting procedure thus devised is as follows:

(1) The magnet pieces are classified into two groups (Fig. 2). The first group comprises four pieces whose magnetized axes are in the radial direction. Each piece of this group will be referred to as a single-piece unit. The other twelve pieces belong to the second group, characterized by an attractive force between three neighboring magnet pieces. Taking advantage of the attractive force, we adhere three neighboring pieces together into a three-piece unit with epoxy resin.
(2) A jig, a holding device illustrated at the right in Fig. 2, clamps the four single-piece units and four three-piece unit.
(3) A jack in the jig drives each unit toward the center of the jig, until the tip of the unit touches the surface of a central jig part which simulates the inner drift-tube cell. This is a place where the unit should be held fixed. Each unit was machined so that a gap should appear between any two neighboring units when all the units are thus placed.

Since the gap was prepared for being filled by a shim, the next step is to measure the size of the gap in order to determine the appropriate shim thickness.

(4) For this purpose, two single-piece units facing across each other are pushed further inwards, where openings are prepared in the central jig part. Measuring how far the two units can be pushed inwards, we can calculate the appropriate thickness of the shim, assuming that the angle of the arc of each single-piece unit is correctly machined. This method of the measurement of the gap should be very accurate.

(5) Two shims with the thickness thus determined are attached to each single-piece unit with an adhesive.

(6) All the units are reassembled in an inner drift-tube cell, by use of the same jig as used in (3), and tightly banded to secure.
The completed inner cell is illustrated at the center in Fig. 2.

Insertion of the Inner cell into the Drift-Tube Outer Cell

We have been developing the cold-shrinking method in order to fit the inner cell into the drift-tube outer cell for the following reasons. First, a silver-brazing method cannot be used, since permanent magnets cannot stand high temperature during the silver brazing. Second, an electron-beam welding (EBW) is difficult, since the strong magnetic field of the magnets bends the electron beam. Third, an electroforming method requires very elaborate care to prevent the electroplating fluid from leaking into a drift-tube cell during electroplating process. Otherwise, the leaked fluid would erode the permanent magnets. Finally, both the EBW and the electroforming method require machining and/or surface finishing after the assembly. This is a very painstaking process, since the magnet contained in the drift tube easily attracts magnetic microdust, giving rise to scratches on the surface. Thus, the cold-shrinking method being free from any of these troubles seems to be most suitable for mass production of quality drift tubes.

In the cold-shrinking method the inner cell is cooled down prior to the fitting. The condition of the cooling, the surface roughness, and the optimum fitting allowance and the fitting shape have been determined through a series of experiments. In particular, it is proved that the vacuum seal functions satisfactorily well.

In order to apply the cold-shrinking method to the assembly of drift tubes the inner cell should be positioned accurately with respect to the outer cell and quickly inserted into the outer cell. During the process, dewing should be eliminated and good heat balance should be ensured. In order to meet these requirements we fabricated a prototype of an assembling device shown in Fig. 3. The device is a case filled with dry nitrogen gas in order to prevent the inner cell from being dewed. A liquid-nitrogen vessel is used for cooling the inner cell, a holding rod for holding the inner cell, and a vertical rail for guiding the rod. A base plate made of ceramics is equipped with holes in order to vent the evaporated nitrogen.

Although we have obtained quite satisfactory results for the cold-shrinking method, there remains a problem to be solved: the inner cell was shifted in the axial direction with respect to the outer cell by a few microns to a few ten microns. At present we are attempting to solve this problem, supposing that this phenomenon is closely related to an effect of the thermal conduction and transfer in the holding rod and/or the base plate.

Assembling Procedures of the Drift Tube onto the DTL Tank

Another important item to be developed is how to mount drift tubes to a DTL tank, ensuring both vacuum-tight RF contact and precise alignment of the drift tubes that can stand long-term operation. If necessary, the drift tubes should be replaceable. In order to meet these requirements, attempts have been made to use a taper fitting by tapering both the stem of a drift tube and the hole of a tank. Needless to say, it is very important to keep the accuracy of the taper in micron order, requiring a ultra-precision numerically controlled turning machine. For the tapered hole in the tank, we are developing the method of roller-burnish finishing.

If we use the same material for both the stem and the hole in the taper fitting, mutual wedgelike slips between the tapered surfaces will arise from seizure and adhesion due to the securing pressure, resulting in vacuum leak. Thus, we are attempting to electroplate the upper part of the tapered stem with hard metal such as chromium and the lower part with soft metal; the hard metal will prevent the surface from seizing due to the friction, while the soft metal will help quality of vacuum seal.

REFERENCES

1. Y. Yamazaki and M. Kihara, “Development of the High-Intensity Proton Linac for the Japanese Hadron Project”, this conference.

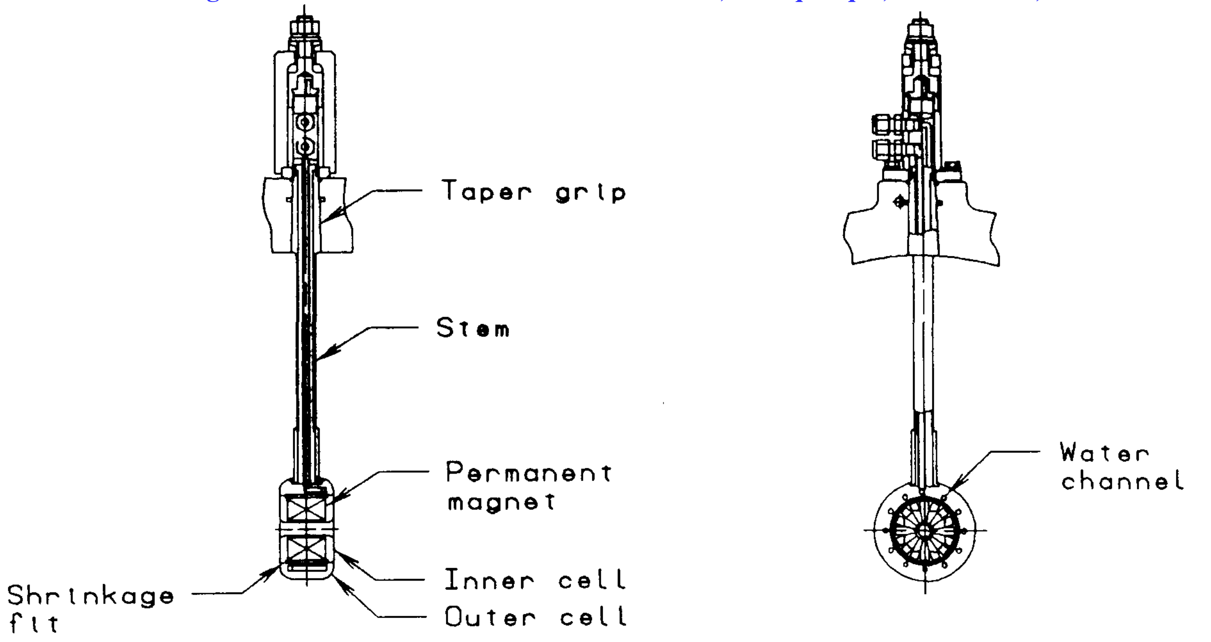

Fig. 1. Assembled drift tube

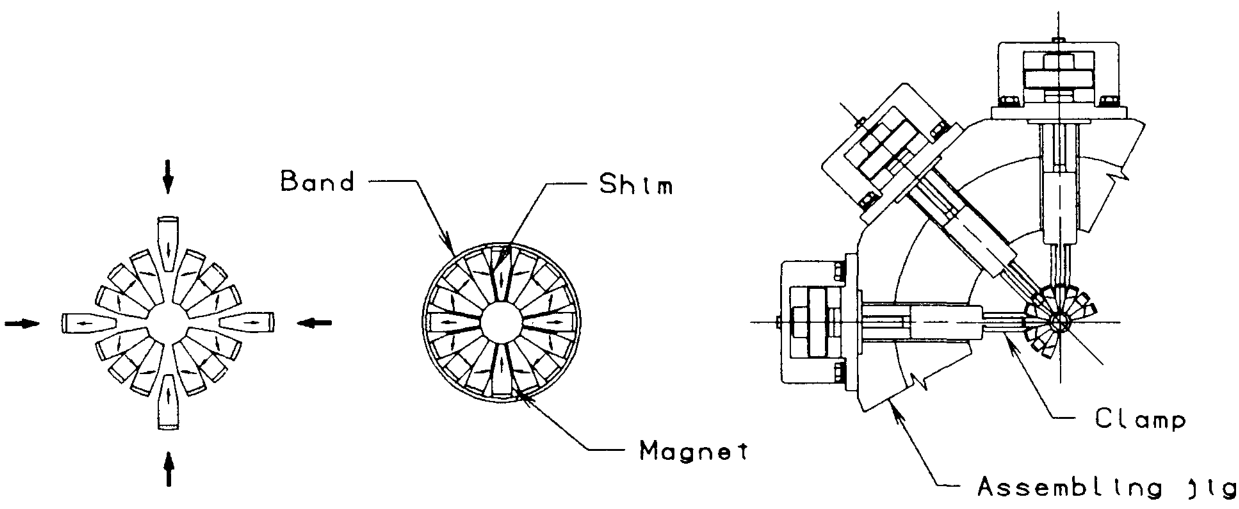

Fig. 2. Permanent quadrupole magnet

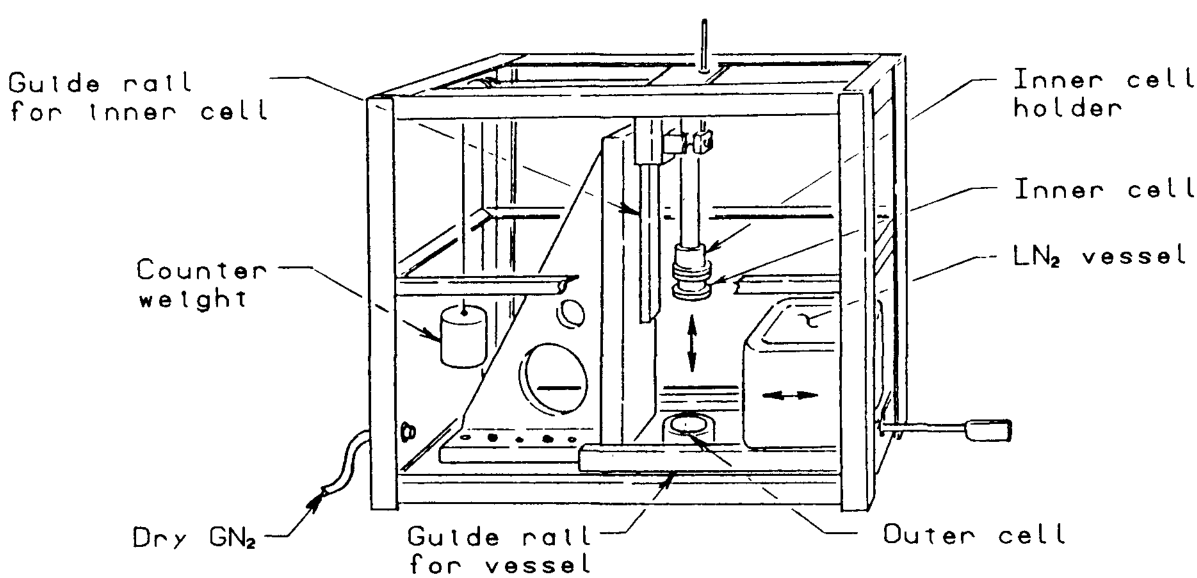

Fig. 3. Drift tube assembling jig