R&D on the modification of an existing bending magnet

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ABSTRACT

An existing bending magnet is modified to investigate the mechanical deformations due to the heavy work from the welding of the end plate at one of the magnet ends. The magnet core was divided into two halves and one of them has been reproduced as a new short magnet fabricating a new coil. Another half core has been also reproduced as a complete core but no coil. Mechanical deformations were measured for both cores.

INTRODUCTION

A bending magnet to be modified (Fig.1) has a core of stacked iron laminations (0.5 mm in thickness) welded to the iron slabs between stainless steel end plates. Its original core length is 5 m. An original coil has been removed to cut at the center of the core to get two core with the same length. New cores are a little bit short compared to the half length of the original core because an enough space was used for machining and for the test of welding method. In order to cut the core at KEK a portable milling machine was used to cut off the welding slabs.

As the core has been made solid only by these slabs, it was supported rigidly using tightening bars through the whole length of the core and stands prior to the machining. If the supporting structure was week, a heavy deformation of welding slabs were anticipated. The milling machine was fixed on the side surface of the core as shown in Fig.2 using a special fixture which was fabricated for this work.

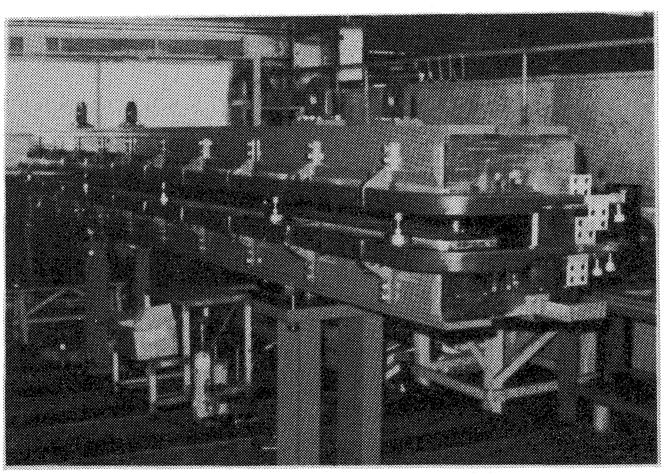

Fig.1 Original bending magnet developed for the TRISTAN R&D several years ago.

After machining a new stainless steel end plate has been welded at an end of each short core. Both new cores have a length of 2.42 m and a set of new coil has been added to one of them to check the magnet performance.

The mechanical deformation was measured during the process of the magnet modification. Since no deformation during machining at KEK was observed, a main cause of the mechanical deformation is due to the welding. Before the final welding of the stainless steel end plate, a dummy steel end plate was used to test the welding process. After this test a small part of the core was removed to eliminate the deformation coming from this experiment.

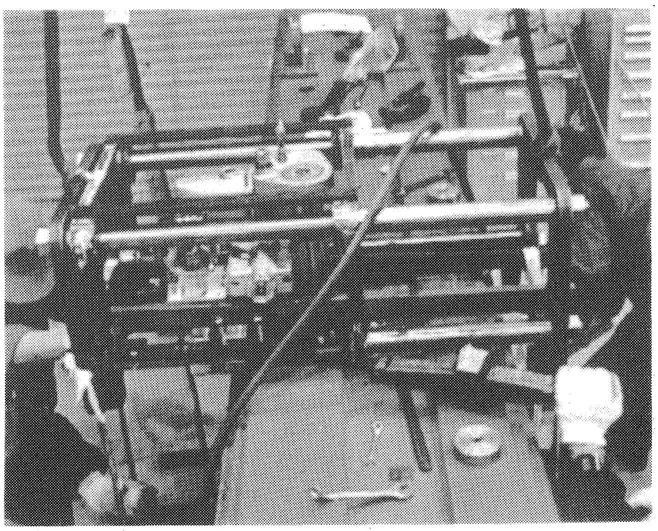

Fig. 2 Machining of the magnet core at KEK.

WELDING EXPERIMENT

The deformation of the magnet core due to welding of the dummy end plate made of structural iron at a magnet end was measured under the following conditions,

(1) Not filling small gaps between the side welding slabs and end plate, and
(2) Not filling small gaps with laminations between the end plate and stacked lamination.

To see the effect of gaps to the welding deformation, these gaps were not filled intentionally. Deformation coming from this welding will be released if the welded end plate is removed from the iron core. This test section extended to about 3 cm into the iron laminations. Temperature rise of the welded part was decreased very quickly and it was 30 to 40 degrees in Centigrade after 1 min. No heat effect beyond the small welding region was not found except for the deformation coming from the local internal stress stored at the welding region. The overall deformation is the vertical bends of the iron core of about 60 μm and fairly big deformation was observed close to the welding point (Fig.3). The magnet gap was also measured before and after the welding. The gap height is conserved within an error of measurements. It differs from point to point by about 50 μm because of the fluctuation of gaps at the stamping stage of lamination.

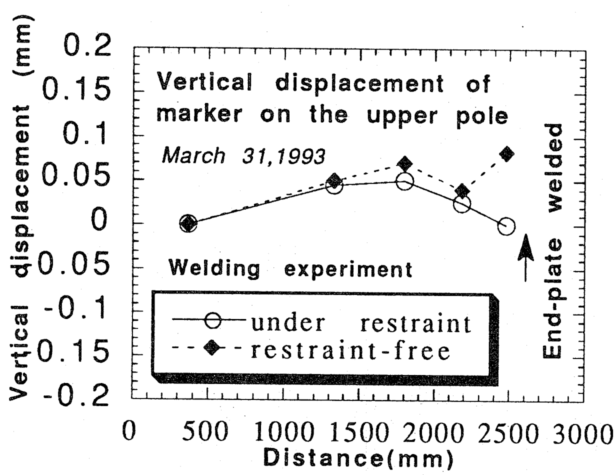

Fig.3 Vertical core deformation due to the welding of the dummy end plate (Core#1).

WELDING OF STAINLESS STEEL END PLATE

A magnet end plate was welded taking some cares into considerations according to the results obtained at the stage of the welding experiment. The deformation of the magnet core due to the welding of the end plate at a magnet end was measured under the following conditions. In this case the end plate is made of stainless steel, SUS316. In an experiment the structural iron was used, so the welding condition differs from the case of stainless steel.

(1) Filling small gaps between the side welding slabs and end plate, and
(2) Filling small gaps with laminations between end plate and stacked core.

In the followings, two half cores are distinguished as Core#1 and Core#2. The welding experiment was performed for Core#1.

Welding of Core#1

Every gap to the end plate was filled with iron spacers prior to welding to avoid the welding deformation of the magnet core. The end plate was welded for 8 side welding slabs in 16 steps by the steppingstones method. Heat input for the weld of stainless steel was estimated similar to the case of the dummy end plate using the same welder, MIG. However it took about 3 minutes the welding point to become the room temperature after welding. Lower heat conductivity of stainless steel compared to iron resulted in rather big deformation of the magnet core as shown in Fig.4. From this the magnet deformed as large as 0.13 mm at the longitudinal center. This deformation is two times larger than that obtained in the welding experiment (Fig.3). But the gap height given in Fig.5 did not change so much, so this deformation would be the vertical bend of iron core.

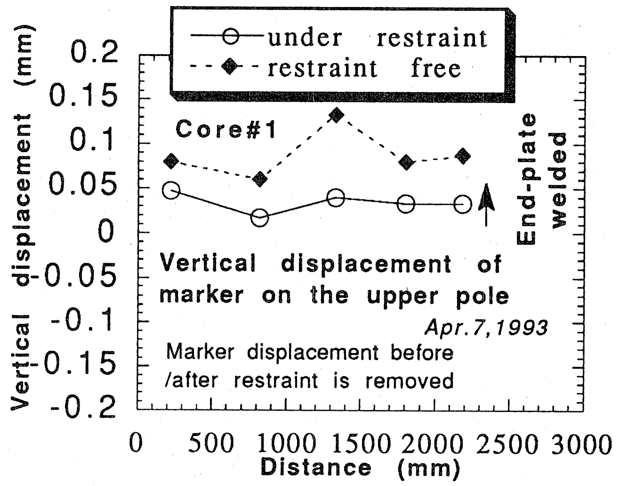

Fig.4 Vertical core deformation due to the welding of the stainless steel end plate.

The magnet gap was measured before and after welding the stainless steel end plate for the final stage after removing the end plate for the experiment. These measurements were performed under both restraint and no restraint for suppressing the welding deformation. Gap heights have been reproduced well. Restraints given to the magnet core were as follows,

(1) Pressed from every side with 20 bolts (M16) by the torque of 200 kg-cm,
(2) Pressed longitudinally with 15 bolts (M22) by the torque of 3200 kg-cm, and
(3) Both pole gap and coil slot extending over about 30 cm longitudinally close to the welding end plate were propped up using leveling blocks to avoid the gap height reduction.

The change of the magnet pole length was not observed within an accuracy of the measurement (0.1 mm). However, the yoke shrunk by 0.3 mm because the small gap existed even after filling the gap between the end plate and yoke. This gap results from the curved surface of the lamination which contacts the end plate. The stacked lamination had an effect of the original welding around the side welding slabs and the core length differs from point to point (8 mm at max.).

The present magnet was developed for R&D of the TRISTAN main ring magnet and laminations were stacked roughly considering the 0.02 mm thickness deflection of the lamination. Considering the deflection the laminations were stacked inversely at every 1000 plates to adjust the core length. For the actual TRISTAN magnets, laminations have been inversely stacked sheet by sheet because they were stamped upside down at every stamping step. Therefore the core length will not differ so much except for the small region close to the welding points.

To determine the average central height of the gap, the finished core was placed on a machine table and surveyed the pole surface using a micrometer attached to a spindle (Fig.6). New deformation due to the welding is 0.2 mm at the maximum and is very small compared to the original deformation.

Welding of Core#2

The order of welding of the Core#2 was changed for the last 8 steps to investigate the effect on the core deformation and the similar measurements were performed. In this case the vertical deformation was obtained at the close end of the welded stainless steel plate as shown in Fig.7 when the restraint was removed.

There is no serious change in the gap height after welding. The bend of the core has been reflected to the pole surface distortions (Fig.8) which were measured on the machine table by the same method as the Core#1. As the core deformation has well reproduced the original one, the deformation in Fig.7 is considered that the mechanically forced bend due to the restraint is released after removing it.

The horizontal distortion was also measured but there was no serious distortion except for the original 0.3 mm for both Core#1 and Core#2.

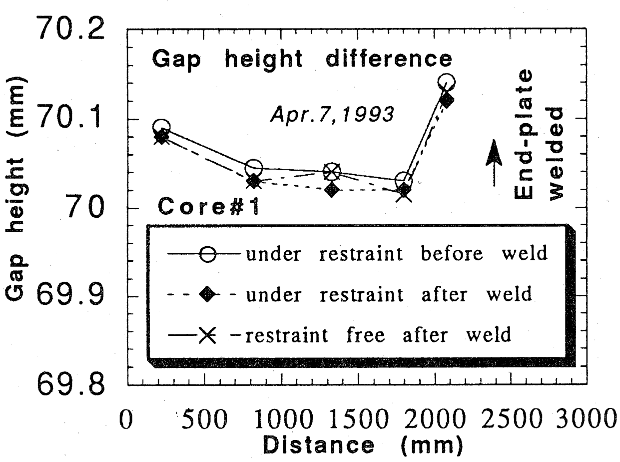

Fig.5 Effect of the welding of the stainless steel end plate on the gap spacing.

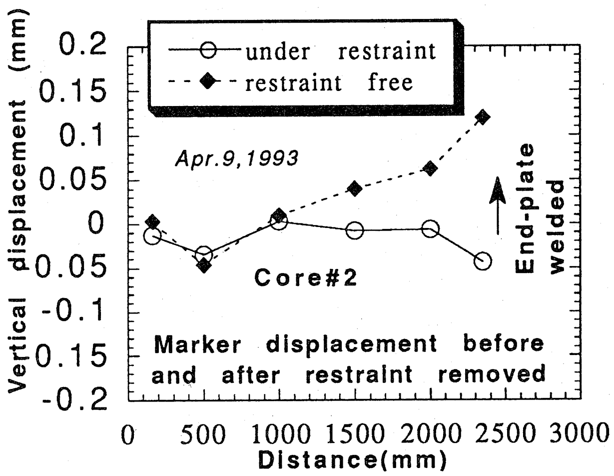

Fig.7 Vertical deformation of the Core#2 after welding the stainless steel end plate

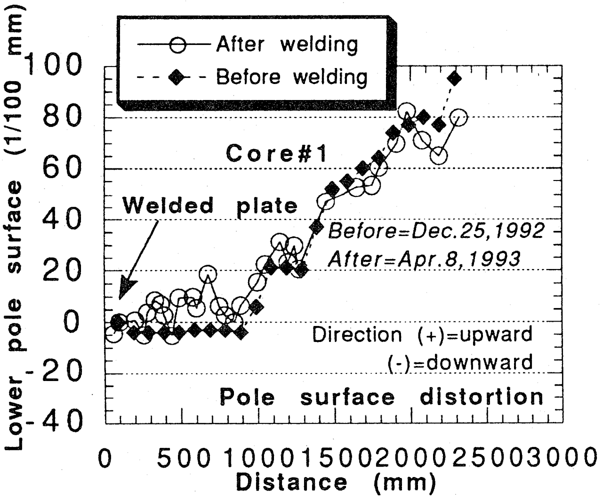

Fig.6 Comparison of the pole surface distortion measured with the precision level before welding and the micrometer after welding for Core#1.

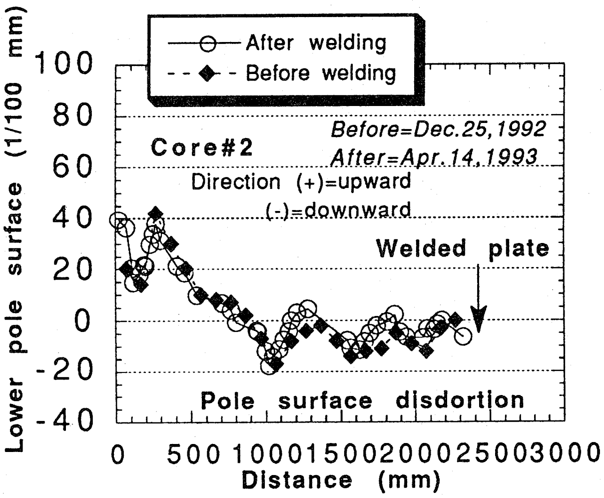

Fig.8 Comparison of the pole surface distortion measured with the precision level before welding and the micrometer after welding for Core#2.