INNER DIAMETER CHANGE OVER THE YEARS OF MA CORES OF RF-CAVITIES AT THE J-PARC 3 GEV SYNCHROTRON

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Abstract

The 11 RF cavities at the J-PARC 3 GeV synchrotron use 198 MA cores. Buckling occurred in some cores since the operation started in October 2007. We have measured the inner diameters of the cores as part of the investigation to determine the cause of buckling when the cavities were disassembled for maintenance. We obtained inner diameter change values of 18 cores over a longer than 2 years interval in November 2011. We noticed deformations of the inner shapes of the cores related to the manufacturing process, and that inner diameter changes over this period were not detected in most of the cores without buckling. Furthermore, an effective core manufacturing process to avoid the buckling has been established [1]. We are going to replace old type cores with new type cores in summer shutdown periods every year and will have finished the replacement work in several years. We report the relation between inner shapes of the cores and the manufacturing process and inner shape changes over the years.

INTRODUCTION

The J-PARC 3 GeV synchrotron has 11 RF cavities. Each cavity consists of 3 accelerating gaps. In order to generate an accelerating voltage of 15 kV at each gap, 3 magnetic alloy (MA) cores are used per one accelerating electrode, 198 cores are used in total. The outer diameter, the inner diameter and the thickness of a magnetic material core are 850 mm, 375 mm and 35 mm, respectively. The cores are heated and thermally stressed by RF in operation, therefore, the cores are cooled by circulated water in a tank. Figure 1 shows the cores in the tank. Figure 2 shows a schematic diagram of cross section of one core. The thermal stress by RF heating deforms the cores [2]. The resin influences the flexibility of the core against thermal stress.

MEASUREMENT METHOD OF THE INNER DIAMETER

Figure 3 shows the measurement method of inner diameters of a core. In order to reduce the measurement error, we measured the same direction twice turning over the inside-micrometer. In this measurement, the difference of the twice measured values was controlled to less than several ten micrometers.

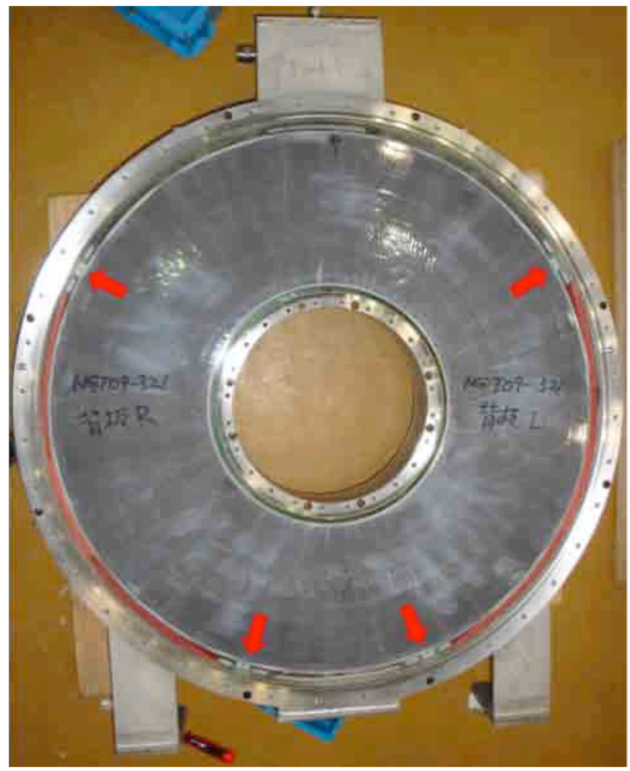

Figure 1: Cores in a water cooling tank. Three cores are supported using wedges shown by the 4 red arrows to the inside of the tank. The beam pipe will pass through the center hole. After assembling the cavity, the upper side of this photo becomes the zenith direction.

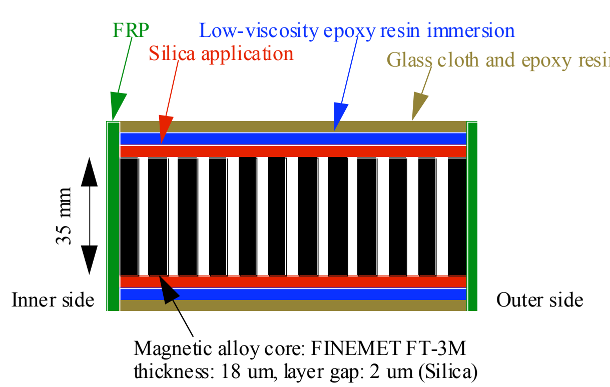

Figure 2: Schematic diagram of cross section of one core.

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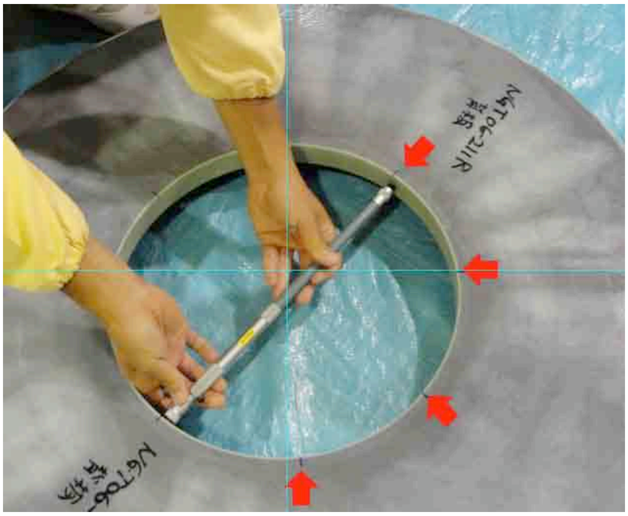

Figure 3: Measurement method of inner diameters of a core. We measured 4 inner diameters at 45 degree interval by using an inside-micrometer at the median point of the thickness direction of the core. We marked the measuring position indicated by 4 red arrows in order to measure at the same position in a later time.

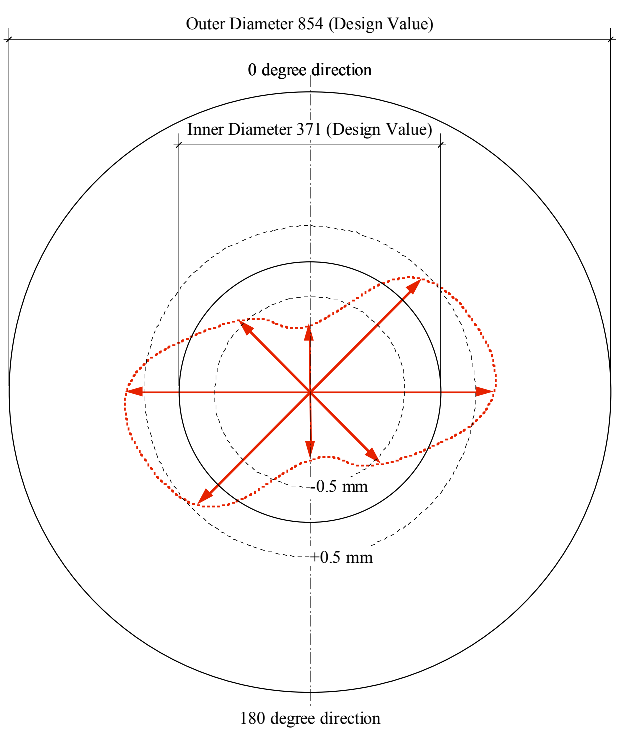

Figure 4: Example of the measured inner diameters of a core. 2 solid line circles show design inner and outer diameters of the core including surface FRP parts. 0 and 180 degree show the zenith and nadir directions in an assembled cavity, respectively. 2 dashed line circles show the distance from the design inner surface. 4 red two-way arrows show the measured inner diameters. The variation from the design diameter (371 mm) is one hundred times magnified. The red dashed closed curve is made by a cubic spline method.

RESULTS

Figure 4 shows an example of the measured inner diameters of a core. The red closed curve is not an actual figure. However, it helps us to examine the shape visually.

In order to quantitatively study deformations of inner shapes of the cores, we calculated a standard deviation from 4 measured inner diameters for every core.

Figure 5 shows the standard deviations of inner diameters of the cores. The cores were manufactured by 3 different processes. Type 1: silica applied and low-viscosity epoxy resin immersed, type 2: no silica applied but low-viscosity epoxy resin immersed, and type 3: silica applied but no low-viscosity epoxy resin immersed. The cores were used in operation before these measurements except 3 new cores.

In the type 1, the standard deviations are small. And only one core showed buckling. Applying silica on the surface of magnetic material encumbers to immerse the layer gaps with low-viscosity epoxy resin. Thus it keeps flexibility of cores against the thermal stress.

In the type 2, the standard deviations are small and large, variously. And many cores showed buckling. Immersion to the layer gaps with low-viscosity epoxy resin decreases the flexibility of the cores. On the other hand, the standard deviations of the new cores are not large. Therefore, most of this type cores were deformed and buckled by thermal stress in the RF operation.

In the type 3, the standard deviations are small. And no core showed buckling. This type is the hardest to be buckled because it is not really possible to immerse the narrow spaces between the layers with the resin. This type of core is used for replacements in summer shutdown periods.

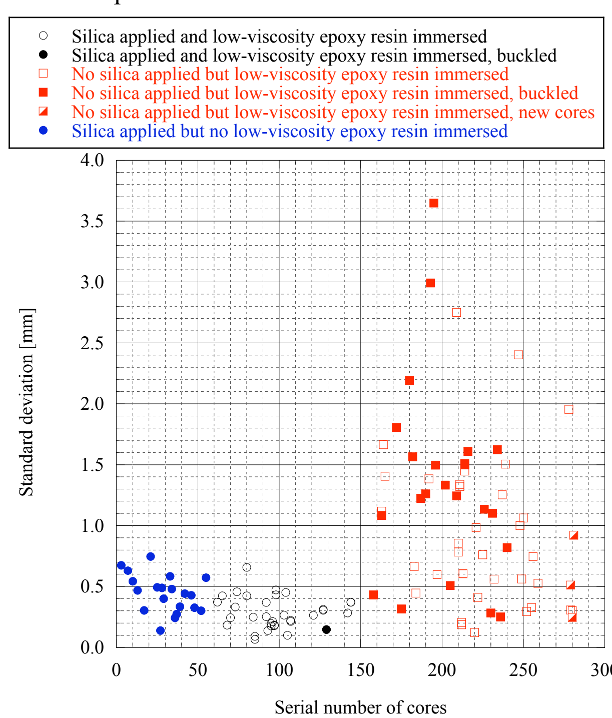

Figure 5: Standard deviations of inner diameters of cores.

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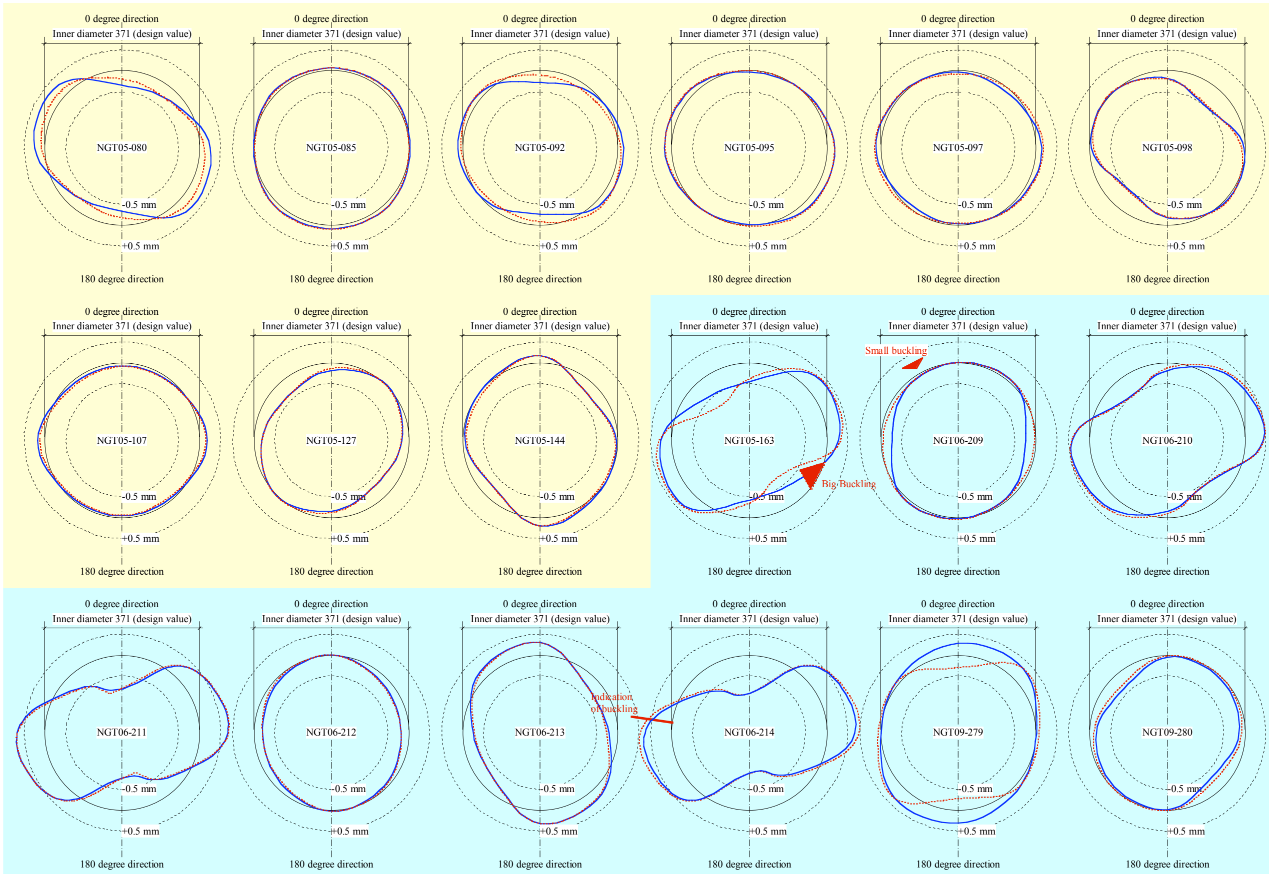

Figure 6: Inner diameter changes of cores from August 10 2009 to November 11 2011. Red dashed curves and blue solid curves show the inner diameters measured on August 10 2009 and November 11 2011, respectively. The cores in the yellow region and the blue region are "type 1: silica applied and low-viscosity epoxy resin immersed" and "type 2: no applied silica but low-viscosity epoxy resin immersed", respectively. All cores were used in the same cavity (cavity 03).

Thus we found the relation between deformations of inner shapes of the cores and the manufacturing process.

Figure 6 shows the inner diameter changes of 18 cores of the cavity 03 from August 10 2009 to November 11 2011. The RF system was operated in this period except regular maintenance periods and the recovery period from the major earthquake.

In the yellow region (the type 1 cores), deformations developed in only 2 cores. But they were small. No core showed signs of buckling.

In the blue region (the type 2 cores), deformations developed in 3 cores. Moreover, they are larger than the deformations of the type 1 cores. But new buckling did not occur.

Deformations did not develop in most of the cores in this period. We think that the deformation may occur not continuously but in the early stage in the RF operation.

At November 2011, we replaced all cores of the type 2 (blue region) of cavity 03 with new cores of the type 3.

SUMMARY

We obtained the relation between the deformation of the inner shapes of the cores and the manufacturing process. We make sure that the cores which are silica applied but not low-viscosity epoxy resin immersed are the hardest to be buckled in the 3 different manufacturing processed cores. This type of cores is used for replacements in summer shutdown periods every year.

We will continue to measure the inner diameters of the core when the cavities were disassembled for maintenance in order to watch the development of the deformations of the cores.

To measure inner diameter of cores is simple work, however, it is an effective method to obtain information of soundness of cores.

REFERENCES

[1] M. Nomura et al, NIM-A, Volume 623, Issue 3, 21 November 2010, Pages 903–909.
[2] Shimada et al, IPAC2010, pages 3717-3719.