CONDITION OF MA CORES IN THE RF CAVITIES OF J-PARC SYNCHROTRONS AFTER SEVERAL YEARS OF OPERATION

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Abstract

J-PARC 3 GeV Rapid Cycling Synchrotron (RCS) and 50 GeV Synchrotron (MR) employ the Magnetic Alloy (MA) loaded RF cavities. We observed the impedance reductions of the RF cavities in RCS three times during 3 years of operation. We figured out that the impedance reductions were resulting from the MA core buckling. The MA core buckling was caused by the thermal stress that was enhanced due to the impregnation with epoxy resin. We also observed the impedance reductions of MR RF cavities during 2 years of operation. Opening the RF cavity, we found that the impedance reductions were caused by the corrosion on the MA core cutting surface. The copper ions and colloids in the cooling water might accelerate the corrosion process.

INTRODUCTION

We have been operating the RF cavities loaded with MA cores with a high field gradient in the order of 20 kV/m in RCS since September 2007 and MR since May 2008 [1].

The MA cores are produced by a winding process using MA ribbons with about 18 μm thickness and 35 mm width. In order to create enough electrical insulation, a coating of SiO_2 with average 2 μm thickness was put on one side of the ribbon. We employ the un-cut cores for RCS RF cavity and cut cores for MR. We increased the Q-value of the MR cavities from 0.6 to 26 by the cut core technique [2].

The RF cavity consists of six water tanks in which three MA cores are stacked. The length of the RF cavity is about 2 m and it has three accelerating gaps. We employ a direct water-cooling system and therefore the core surface except the cutting surface was covered with epoxy coating to prevent rusting. The cutting surface is so smooth that it is difficult to put an epoxy coating on it.

We measured the impedance of RF cavities during shutdown periods to check the core conditions in the installed RF cavities. We observed impedance reductions of the RF cavities in RCS and MR. In the following sections, we describe the causes of the impedance reductions and the condition of MA cores.

MA CORES IN RCS RF CAVITIES

We detected the impedance reduction of cavity 7 in January 2009 [3] and January 2010 and of cavity 4 in June 2009. The results of impedance measurements of RF cavities in RCS are shown in Figs. 1 and 2.

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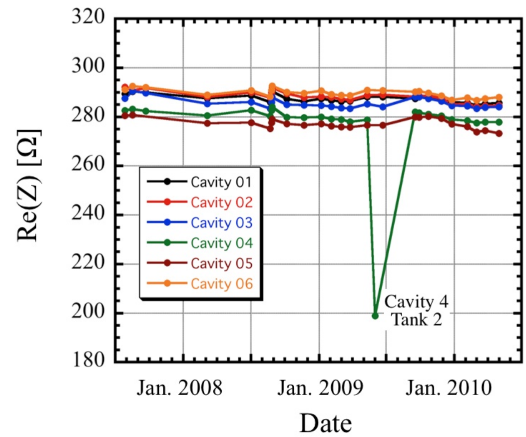

Figure 1: The result of impedance measurements of RF cavity 1 to 6 in RCS.

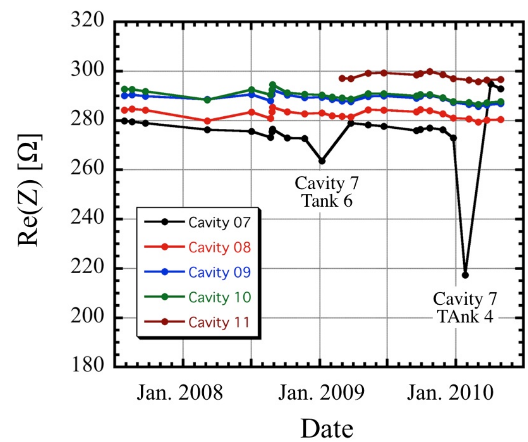

Figure 2: The result of impedance measurements of RF cavity 7 to 11 in RCS.

Opening the cavities 3, 4, 5, 6 and 7 to examine the MA core conditions, we found that 26 cores out of 90 in total showed buckling. Most of the buckling sizes are small like NGT05184 in Fig 3. The cores with small buckling caused no impedance reductions. The cores with small buckling are still used and the impedances are monitored carefully. On the other hand, the cores with large buckling, NGT06199, 189 and 188 in Fig 3, caused impedance reductions. Those three buckled cores were damaged by the large buckling. Fig. 4 shows the photograph of the buckling area after removing the epoxy coating on the core surface. The buckling part is deformed by the pressure due to the buckling part pushing against the column of the FRP inner cylinder and the MA core was torn by the buckling.

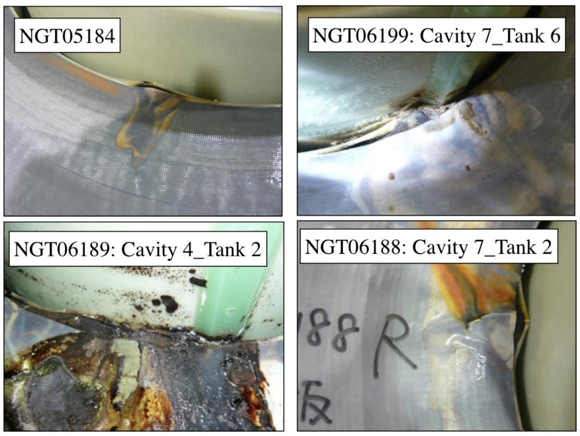

Figure 3: Photos of MA core buckling. The MA core NGT05184 shows small buckling and the other three cores show large buckling.

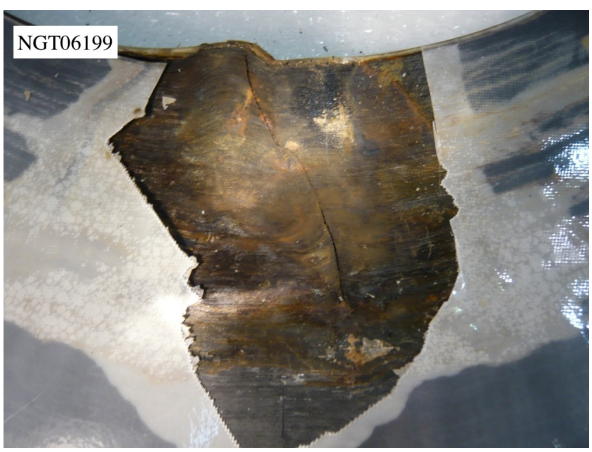

Figure 4: The photo of the buckling area of NGT06199 after removing the epoxy coating.

In the case of MA core buckling, it is basically caused by the thermal stress of the cavity operation. The local core temperature rise is inverse proportional to the core radius. In operation, the temperatures inside the core, 17.5 mm from the core surface, of the inner and outer radius are about 110 and 43 degrees Celsius, respectively. This temperature difference makes a compressive stress along the circumferential direction around the inner radius. From the correlation between the occurrence of core buckling and core coating type, we figured out that the MA core buckling was caused by the thermal stress that was enhanced due to the impregnation with epoxy resin [4]. The core without the impregnation of epoxy resin has small spaces, about few μ m, between ribbon layers, and hence the ribbons can release the stress from the thermal expansion by spreading outward in the small spaces. On the other hand, the core with the impregnation of epoxy resin has almost no space to release the stress from the thermal expansion.

In March 2010, we replace with MA cores without the impregnation of epoxy resin in one RF cavity and have been observing its impedance carefully.

MA CORES IN MR RF CAVITIES

The impedance of all RF cavities in MR started to decrease from October 2009. The result of impedance measurements is shown in Fig. 5.

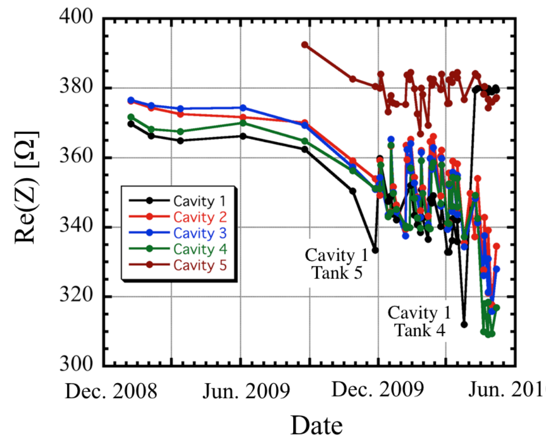

Figure 5: The resul t of impedance measurements of RF cavity 1 to 5 in MR. The RF cavity 1 was replaced in April 2010.

First of all we explain the impedance fluctuation from December 2009. When we opened the RF cavity 1 to see the core condition in November 2009, we noticed that the cavity impedance recovered to some extent by draining off the cooling water from the RF cavity. We also found that the recovery did not occur if draining off water with nitrogen gas. This recovery of the impedance might be caused by the change of the conductivity of the cutting surface by oxidization.

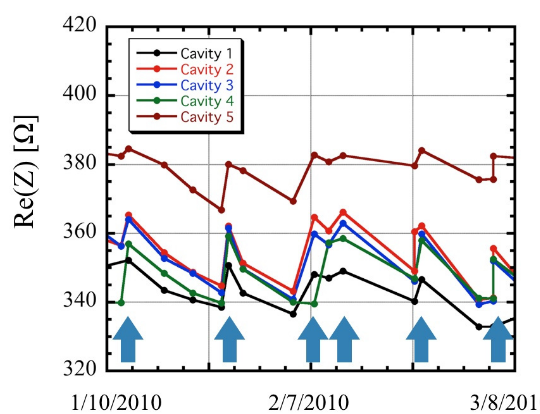

Figure 6: The change of the impedance by exposure to air. The arrows show the date of exposing the cutting surface by draining off the cooling water.

From December 2009, we regularly expose the cutting surfaces to air by draining off the cooling water from the RF cavity in order to recover the impedance as much as possible (See Fig. 6).

Next, we describe the MA core condition in RF cavity 1. Opening the Cavity 1, we found that the cutting surfaces of all cores were rusted like KE06-30 in Fig. 7. The cutting surface of the core, KE06-38 Acc. gap side B in Fig. 7, was damaged, and it might be caused by the high RF field. The slow impedance reductions were caused by the corrosion. However large reductions were caused by the damage of the cutting surface.

Figure 7: Photos of cutting surfaces.

Fig. 8 shows the core KE06-38 in the water tank 4. From the rust color in Fig. 8, it is found that the flow of cooling water was not symmetrical. This asymmetry was caused by the position of the cooling water hose. The cutting surfaces that face the flow of cooling water, in this case cutting surface B, were damaged. It is noteworthy that CuO was detected on the damaged cutting surface.

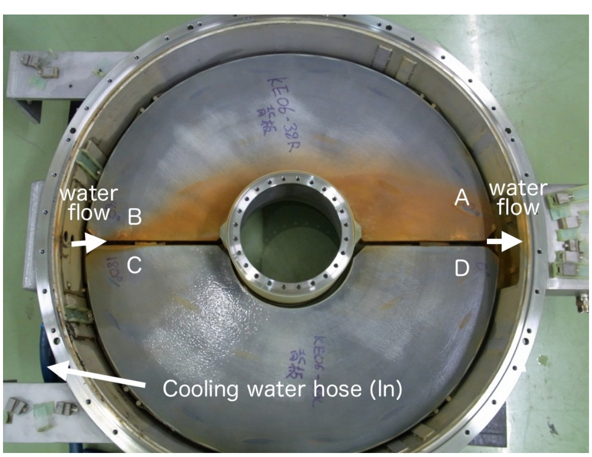

Figure 8: Photo of the core KE06-38 in the water tank 4.

Before installation of the RF cavities, we had 1000 and 2000 hours long tests at a test stand. We didn't observe the impedance reduction related to the corrosion on the cutting surfaces. The only difference between the test stand and MR is the quality of cooling water. The MR cooling water contains copper ions and colloids.

For the following circumstances, we speculate that the copper ions or colloids in the cooling water accelerate the corrosion process.

(1) The MR cooling water contains copper ions and colloids.

(2) From October 2009 when the impedance started to decrease, the duty of MR was increased, and accordingly copper ions or colloids in cooling water from copper hollow conductors of the main magnets (B, Q) is thought to be increased.

(3) The cutting surfaces that face the flow of cooling water were damaged.

(4) The CuO was detected on the damaged cutting surface.

To solve the issue of cutting surface corrosion, we have two different approaches. One is improving the cooling water quality by adding filters and separating the cooling system of RF cavities from the main magnets. Another is coating of cutting surfaces to prevent rusting. We have been developing the coating on the cutting surface with an inorganic polymer to prevent the corrosion.

In this summer, 3 cavities that seem to be damaged by corrosions will be replaced cavities with re-polished cores.

SUMMARY

The reductions of the RF cavity impedance in RCS were caused by the cores that were damaged by the large buckling. We figure out that the MA core buckling was caused by the thermal stress that was enhanced due to the impregnation with epoxy resin. We replaced with MA cores without the impregnation of epoxy resin in one RF cavity in March 2010 and have been observing the cavity impedance carefully.

All RF cavities in MR showed impedance reductions from October 2009. The impedance reductions were resulting from the corrosion on the cutting surface of the MA cut cores. Some of the cutting surfaces were damaged due to the high RF field. We speculate that the copper ions or colloids in cooling water might accelerate the corrosion process. We have been developing the coating on the cutting surface with inorganic polymer to prevent the corrosion.

REFERENCES

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