STUDY ON THE REALIGNMENT PLAN FOR J-PARC 3GEV RCS AFTER THE TOHOKU EARTHQUAKE IN JAPAN

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Abstract

J-PARC 3GeV RCS suffered a big damage to its building and cooling and electric facilities by the Tohoku Region Pacific Coast Earthquake on March 11, 2011. After the earthquake, RCS magnets were measured to confirm the state of accelerator beam line. As a result, it was found out that there was an alignment error of several millimetres in both horizontal and vertical directions that caused a deformation in the J-PARC 3GeV RCS tunnel. In this paper, we report the survey result in the accelerator tunnel after the earthquake and realignment plan for J-PARC 3GeV RCS.

INTRODUCTION

On March 11, 2011 the 9.0-magnitude Tohoku Region Pacific Coast Earthquake occurred. At K-Net Nakaminato [1] which is located about 10km south of J-PARC facilities, the maximum acceleration of 546 gal in a horizontal direction and 412 gal in a vertical direction was recorded. According to Geospatial Information Authority of Japan, the coastal ground of Ibaraki Prefecture moved 1m toward the ocean and subsided about 30cm [2].

At 3GeV RCS, the beam operation had been carried out without realignment as deformation in the accelerator tunnel was small since its inauguration in October 2007 until the earthquake happened. However in the slope measurement of the magnets and reference level after the earthquake, minor deformation was found in the accelerator tunnel. Therefore in order to study effect on the structure of the tunnel and misalignment of the magnet, GPS measurement of the whole J-PARC facilities was implemented in April 2011 and leveling of the main tunnel floor and the magnet measurement using a laser tracker in May and June [3]. Also precise leveling of the magnets was carried out in July. As a result, it was found out that realignment of the magnets was inevitable but J-PARC already decided to restart its beam operation by the end of the year so the time of realignment and adjustment amount were considered very important.

After that an orbit analysis using the measurement results was implemented and it was found out that COD correction with the current magnets alignment was possible. In addition it was confirmed that 300kW beam operation same as before the earthquake was possible by COD correction of distortion of beta function which contributes generation and loss beam halo. 3GeV RCS restarted its beam operation in December 2011 and beam test of 300 kW and 420 kW was carried out.

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MISALIGNMENT CAUSED BY THE EARTHQUAKE

3GeV RCS has 24 dipole magnets, 60 quadrupole magnets and 18 sextupole magnets as main magnets. These magnets were measured using a laser tracker after the earthquake. As the tracker was vertically set (within 0.02 mrad) for vertical analysis only y-coordinate value was taken to independently calculate height of the magnets. For analyses of longitudinal direction and horizontal direction, data of reference wall next to each other were geminated and data obtained by the method of least squares were connected. Then it was overlapped based on 6 quadrupole magnets (QDX) set at both ends of straight section of the beam line to calculate the location.

Misalignment of Horizontal Direction

ΔX in Fig. 1 shows the displacement in horizontal direction against the design value. The data taken before the earthquake showed the maximum of about 3 mm bulge in the outer direction in displacement, but there is no large misalignment. However the date taken after the earthquake showed a large displacement between the lower extraction straight section and the upper injection straight section so the affect from the earthquake was considered. The amount of displacement was about 10mm.

Misalignment of Longitudinal Direction

Similarly, Δs show the displacement in the longitudinal direction against the design value. In the data taken before the earthquake the amount of displacement in the longitudinal direction was small. The data taken after the earthquake shows the displacement of about 5mm. Also it was found out that after the earthquake the circumference of 3GeV RCS expanded by 10.4 mm.

Misalignment of Vertical Direction

Δy in Fig. 1 shows displacement of the magnets in vertical direction since August, 2010. As there was no fixed point, the reference was represented on the assumption that altitude of the reference point of the quadrupole magnet QDX60 installed near the injection point was same as in August 2010. There was a settlement tendency from the extraction to the RF straight section and the tendency corresponded to displacement of the floor [4]. Difference in height of magnets became approximately 3.7 mm.

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Misalignment of Rotation Direction

To find out the rotation of the magnets, rotation around the beam axis was measured by a digital level (Wyler MiniLevel NT). Forward direction of the rotation inclined toward the inside. Δθ in Fig. 1 shows the rotation error of the reference point of magnets in September 2010 and April 2011. The rotation error before the earthquake was small and fell 0.1mrad. The rotation error after the earthquake was still small but it was obvious that the arc section inclined toward the outside.

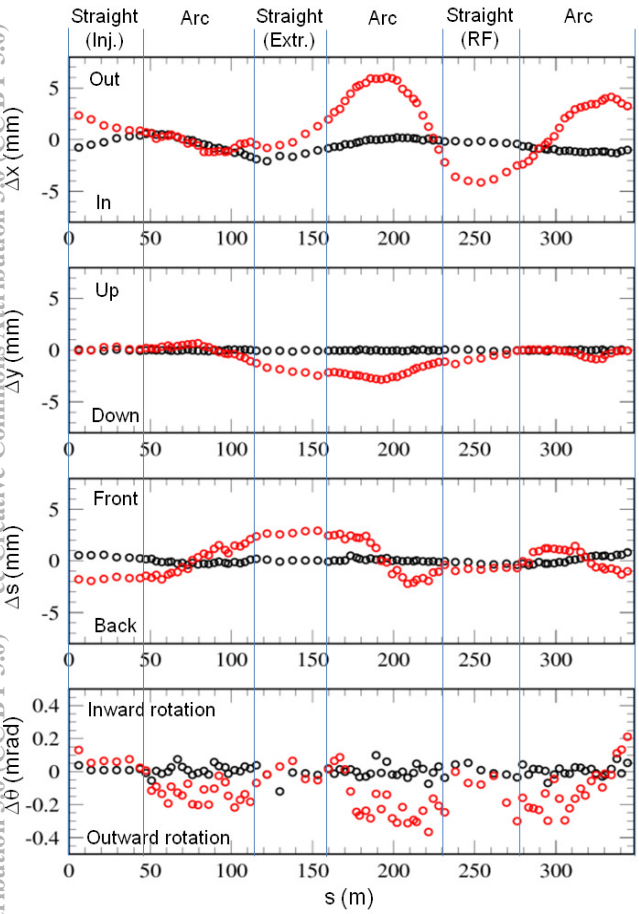

Figure 1: Misalignment of RCS magnets before/after the earthquake. Black dots are values taken before and red dots are values taken after the earthquake.

INFLUENCE ON BEAM OPERATION BY MISALIGNMENT

Fig.2 shows COD measured at the beam condition equivalent to 30 kW. Parameter before the earthquake was used for the steering magnets. COD value nearly conformed to the value calculated from the survey result of magnets after the earthquake.

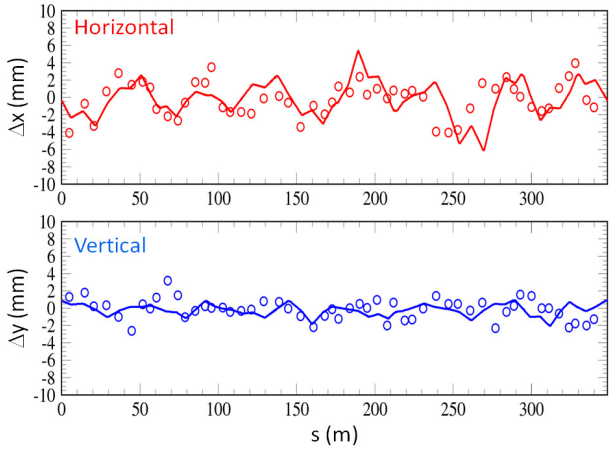

Figure 2: Result of COD measurement after the earthquake using the parameter of the steering magnets before the earthquake. Solid line shows calculated value and dots shows measured value.

Fig.3 shows the result of COD correction carried out with the same condition. It was found out that COD correction could be measured with the magnet alignment after the earthquake at almost the same precision as that of before the earthquake.

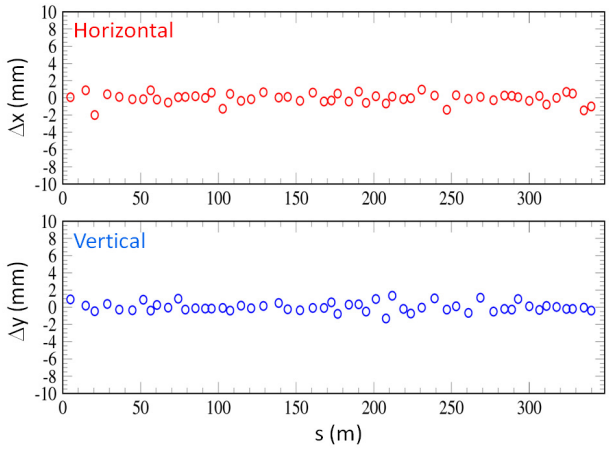

Figure 3: Measurement result after COD correction.

Having confirmed reproducibility of beam orbit, beam power was increased and the effect of misalignment against the beam was surveyed with the operation condition before the earthquake. Beam loss was measured by using loss monitor of the proportional counter-type (P-BLM). P-BLM is mainly installed near quadrupole magnets. P-BLM power is coordinated with machine protection system (MPS) just as beam operation stops when beam loss is high. Fig. 4 shows beam losses generated on the orbit during the operation at 300kW and 420 kW. At 300kW operation, there was not a big difference in beam loss before and after the earthquake but at 420 kW beam loss near the injection collimator almost doubled, obviously showing the effect of misalignment.

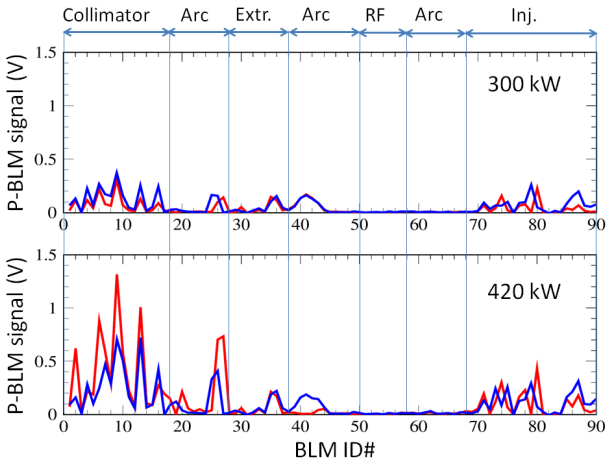

Figure 4: Comparison of beam loss before/after the earthquake at beam tests with 300kW and 400kW. Blue line shows beam loss before and red line shows beam loss after the earthquake.

REALIGNMENT PLAN

Realignment of 3GeV RCS is planned for 5 months from July 2013 in conjunction with installation of Linac ACS. For the first 1.5 months equipments on the beam line will be measured and cables and duct flanges will be removed. After that misalignment is to be corrected based on the measurement result for 2.5 months. For the last 1 month connection of cables and flanges and vacuum evacuation of the beam line will be carried out.

As for realignment, the most difficult area is near the injection collimator. Workability of this area is very low due to the shieldings installed to avoid high radiation dose this area caused by beam loss. Accordingly the misalignment of magnets was studied in order to reduce adjustment amount of the magnets this area (QDL4 and QFL5). The result showed a necessity of magnets to be adjusted at a maximum 7.5 mm in horizontal direction. In terms of height, floor of the extraction section was about 3 mm lower than that of the injection section due to uneven settlement even before the earthquake so height adjustment including this uneven settlement was studied during the realignment. Fig. 5 shows the misalignment of magnets in height direction.

In regard to realignment of injection and extraction septum magnets and charge-exchange devices whose peripheral equipments are very crowded, its adjustment procedure is planned to be confirmed during the shutdown in this summer.

It is also necessary to carry out realignment for equipments of L3BT located in the upper part of 3 GeV ring and 3NBT and 3-50BT located in the lower part. Injection point from L3BT needs to be shifted about 1.5 mm in horizontal direction based on the displacement of magnets closely installed. Adjustment in height is not necessary. Similarly for extraction point, it needs to be shifted about 3 mm in horizontal direction and lifted about 1 mm in height direction. 3GeV bump is installed in 3NBT and a collimator is in 3-50BT on the extraction beam line. It is necessary to study where in each beam line these shifts should be absorbed.

The amount of shifts for all equipments will be decided based on the result of the survey to be implemented in July 2013.

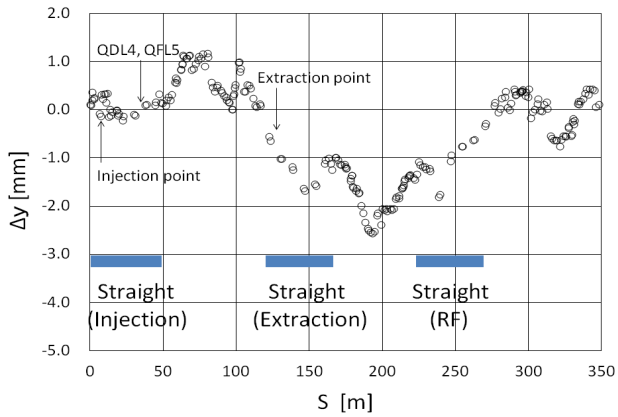

Figure 5: Displacement of magnets in height direction which is standardized based on the height of magnets near collimators (QDL4 and QFL5).

SUMMARY

J-PARC RCS tunnel was deformed by the 9.0-magnitude earthquake occurred in eastern Japan on March 11, 2011. Realignment of 3 GeV Ring was concerned but from the survey after the earthquake it was found out that operation at 300 kW could tolerate misalignment of magnets. Then Beam loss at 300 kW and 420 kW was evaluated during the beam test after December 2011. It was also found out that influence of magnets misalignment becomes larger at operation with higher beam power. Realignment of 3GeV RCS is being planned to implement from July and November 2013.

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