ALIGNMENT PLAN AND SURVEY RESULTS OF THE EQUIPMENT FOR J-PARC 3GEV RCS

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Abstract

Misalignment of several millimeters of the magnets of J-PARC 3GeV RCS in both horizontal and vertical directions was caused by the Tohoku Region Pacific Coast Earthquake on March 11, 2011. As the result of orbit calculation showed that the beam loss was acceptable for beam operation at 300kW, beam operation with the current placement has been implemented. Realignment of the equipment will be carried out from August to December in 2013. As the survey carried out in the summer of 2012 found out misalignment of vacuum ducts, their positioning is necessary.

In this paper these measurement result and latest alignment plan for J-PARC 3GeV RCS are reported.

INTRODUCTION

On March 11, 2011 the 9.0-megnitude Tohoku Region Pacific Coast Earthquake occurred. Before the earthquake, the beam operation had been carried out without realignment at 3GeV RCS as deformation in the accelerator tunnel was small since its inauguration in October 2007. However in the slope measurement of the magnets and reference level after the earthquake, minor deformation was found in the accelerator tunnel. In order to study misalignment of the magnet, in July 2011 the survey of magnets was carried out using a laser tracker. 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 to generation of beam loss and beam halo. 3GeV RCS restarted its beam operation in December 2011 and beam test of 300 kW and 420 kW was carried out.

DISPLACEMENT OF MAGNETS

3GeV RCS has 24 dipole magnets, 60 quadrupole magnets and 18 sextupole magnets as main magnets. Accuracy of the alignment was within ±0.2 mm at the time of installation of magnets. After the installation, the position of the magnets has been gradually changed according to the deformation of the RCS building. But the earthquake caused drastic displacement for the magnets. The survey of the magnets was carried out using a laser tracker and a digital level. As the result, it was found out that the maximum displacement of magnets about 10 mm in horizontal direction, about 3.7 mm in vertical direction and about 5 mm in longitudinal direction [1] [2].

INFLUENCE ON BEAM OPERATION BY MISALIGNMENT

The result of the beam test showed at the 300kW operation, there was not a big difference in beam loss before and after the earthquake but at the 420 kW beam loss near the injection collimator almost doubled, showing the obvious effect of misalignment [1]. The maximum beam power of the 3GeV RCS is 1MW. The result of a simulation of the beam loss and expansion of the emittance at that time is shown below.

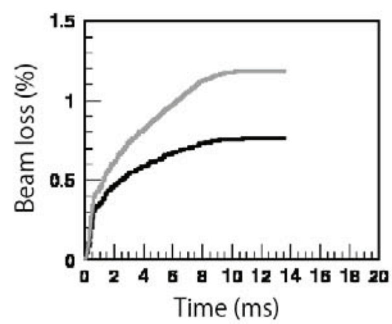

Figure 1: A simulation result of the beam loss at the 1MW operation. Black line shows a case of realignment and gray line shows without realignment.

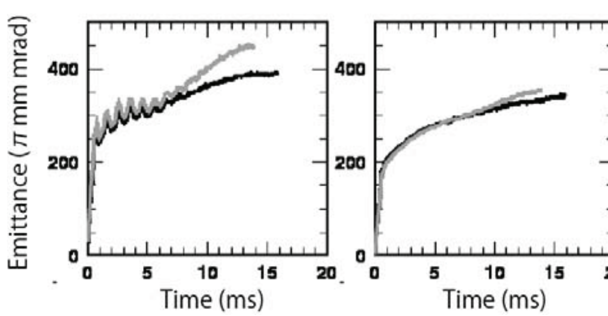

Figure 2: A simulation result of the emittance by the 1MW operation. Black line shows with realignment and gray line shows without realignment.

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Figure 1 shows a simulation result of the beam loss. And Fig. 2 shows a simulation result of the emittance in horizontal and vertical direction. The beam loss increased and the horizontal emittance expanded without realignment. This suggests that 1MW operation is difficult without realignment.

DISPLACEMENT OF CERAMIC CHAMBERS

Ceramic chamber is used for a vacuum duct of RCS main magnets in order to reduce eddy current. As displacement of magnets was found out during the measurement in 2011, a measurement of displacement for ceramic chambers of dipole and quadrupole magnets was also carried out last summer. Alignment accuracy of ceramic chamber at the time of installation was within ± 0.5 mm. Measurement of up/down stream parts of each ceramic chamber was implemented by attaching a measurement device on a titanium sleeve connecting ceramic part and flange part of a ceramic chamber.

Figure 3 shows the measurement result of dipole magnets and Fig. 4 shows that of quadrupole magnets.

Ceramic chamber shifted from the ideal position. It is considered this displacement was mainly caused by the earthquake. Acceptance was calculated based on the results. Accordingly, it was found out that for some ceramic chambers acceptance was not enough. Therefore realignment was necessary also for ceramic chambers.

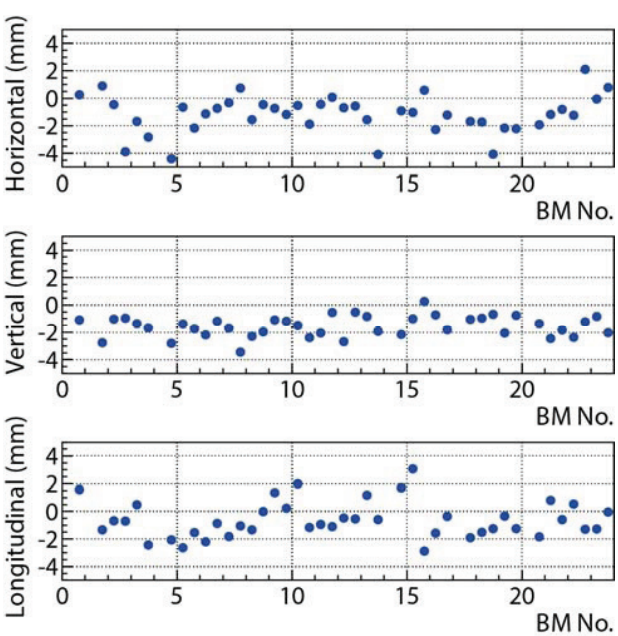

Figure 3: Displacement of the ceramic chamber installed on a dipole magnet from its magnetic pole center.

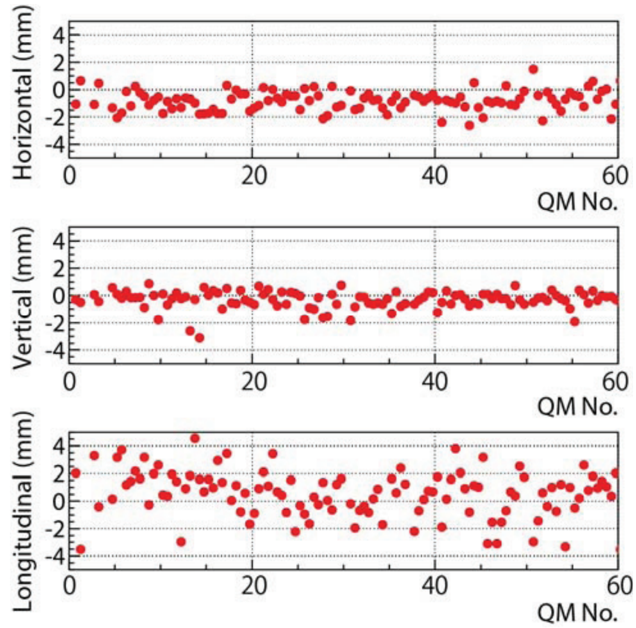

Figure 4: Displacement of the ceramic chamber installed on a quadrupole magnet from its magnetic pole center.

REALIGNMENT PLAN

Ring Coordinate Adjustment and Realignment

As for realignment, the most difficult part is adjustment of magnets (QDL4 and QFL5) near the injection collimator. Therefore for realignment it was planned for vertical direction to adjust QDL4 and QFL5 to the reference and for horizontal direction to evaluate and adjust displacemenrt of each magnet so that misalignment of magnets at the injection straight section becomes as small as possible [2]. The displacement of each magnet calculated from the result of the measurement in 2011 is shown in Fig. 5 and 6.

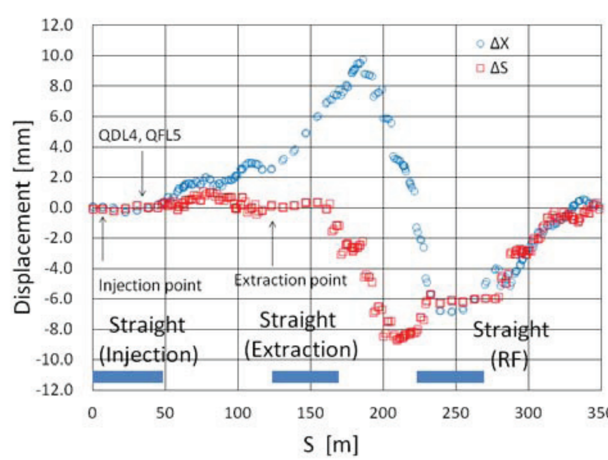

Figure 5: Displacements of magnets in horizontal direction standardized based on the injection straight.

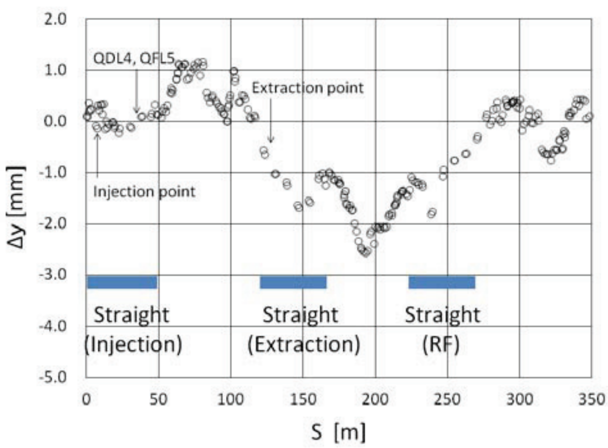

Figure 6: Displacement of magnets in height direction standardized based on the height of magnets near collimators (QDL4 and QFL5).

For realignment, equipment such as 24 dipole magnets, 53 quadrupole magnets, 9 sextupole magnets, 2 septum magnets, 2 kicker magnets, 3 ionization profile monitors and 12 cavities are adjusted. It was necessary to adjust the magnets and other equipment about nearly 10 mm in horizontal direction. This displacement can be adjusted sufficiently within the range of the magnets movement.

Ceramic Chamber Realignment

According to the calculation result of acceptance which takes account of the installation accuracy of ceramic chambers and COD of 3 mm, it was found out that alignment is necessary at least for ceramic chambers whose design acceptance is lower than 486 π mm mrad. Mainly dipole magnets (BM) and quadrupole magnets (QFN and QFX) are subject to this. In fact, the number of ceramic chambers that need alignment is 18 for diapole magnets, 23 for quadrupole magnets and 6 for sextupole magnets. These are all placed in the arc section. Accuracy smaller than $\pm$0.5 mm is required. If a bellows is not able to accept displacement between ceramic chambers, a ceramic chamber next to a candidate chamber must be moved. Thus a method of realignment becomes very important.

For a dipole magnet duct, to use a method applied at the time of installation to align by separating into upper and lower parts of magnets is very difficult at the accelerator tunnel of RCS. So a special measurement device will be newly made for alignment. Accuracy of the device is less than $\pm$0.2 mm.

Also for quadrupole and sextupole magnets, methods for alignment without separating a magnet into upper and lower parts were studied. But it was found out that working space was small and alignment would be complicated. Therefore just as was the time of installation, it was decided to carry out alignment by separating a magnet into upper and lower parts. The same measurement device as used during installation will be used for alignment.

Schedule

The schedule of the realignment is shown in Fig. 7.

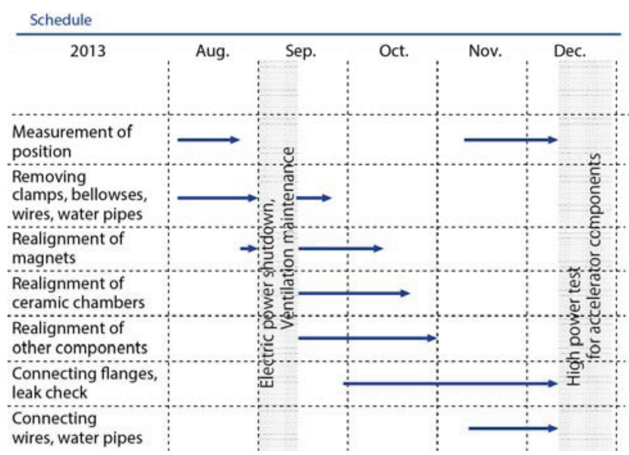

Figure 7: Schedule of the realignment.

SUMMARY

The earthquake on March 11, 2011 caused large displacement of the RCS magnets. It is necessary to restore the beam line of RCS in order to reduce beam loss and expand emittance. The ceramic chambers shifted from the ideal position so it is necessary to correct it to maintain enough acceptance. Realignment work should be completed within 5 months from August to December 2013. Therefore a detailed schedule has been made for the realignment. Consequently we decided to move all the magnets except for the ones in the injection section. It was also decided to implement alignment of ceramic chambers.

REFERENCES

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[2] N, Tani et al.,”Status Report on Survey and Alignment of J-PARC after the Earthquake,” IWAA2012,(2012); http://conference.fnal.gov/iwaa/iwaa.html

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