RECOVERY AND STATUS REPORT OF DTL/SDTL FOR THE J-PARC AFTER EARTHQUAKE

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Abstract

The Japan Proton Accelerator Research Complex (J-PARC) facilities had big damages because of an earthquake on March 11, 2011. A DTL and an SDTL that were installed at the linac area had also damages. The alignment of the cavity was deformed more than 40mm and there had been observed about 0.2mm misalignment of the DT position in the DTL, and so on. However the result of the recovery work over eight months, we restarted proton beam acceleration at the linac section. As is the case with before earthquake, the DTL and the SDTL are operating with a few trips per day, as of April 2012. In this paper, we will present the recovery works from the earthquake and the operating status of the DTL and the SDTL.

DAMAGES OF THE DTL AND THE SDTL

By the earthquake, the Drift Tube Linac (DTL), Separated type DTL (SDTL) and various equipment of the cavity had damages [1] [2]. The situation damage is described below.

Drift Tube Alignment

Fortunately there were no damages, like a dent and a crack, on the outside of cavity and focusing magnets between SDTL tanks by the visual inspection. A movable Tuner and an RF coupler attached on the cavity was also no damage. However, it was observed that the alignment of the all tanks of DTL and SDTL was broken by the deformation of the floor of the tunnel. Furthermore a few misaligned drift tubes in the DTL were also observed.

First, we check the DT position by using a digital camera and the alignment telescope. Figure 1 shows the pictures of the DT bore of the DTL and the SDTL.

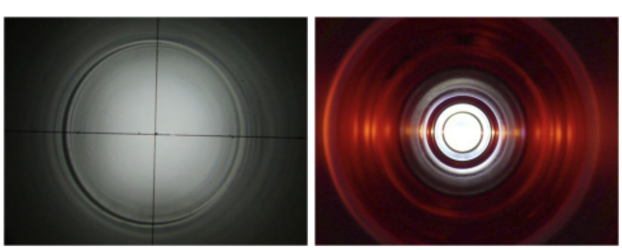

Figure 1: Pictures of the DT bore. Left:DTL, Right:SDTL

For the DTL bore picture (left picture), the black circular arc of the left side is broader than right side. This means that the DT bore center or DT position is decidedly sifted in a horizontal direction. On the other hand, the circles in the SDTL picture (right picture) were nearly arranged in a concentric pattern. Therefore we judged that there was no clear displacement of the alignment of the DT position for the SDTL.

Next we measured the center position of the DT bore of the DTL by using alignment telescope. Figure 2 is a schematic view of the measurement system and the measured center position of the DT bore for a D1-1 (unit tank #1 of the DTL1).

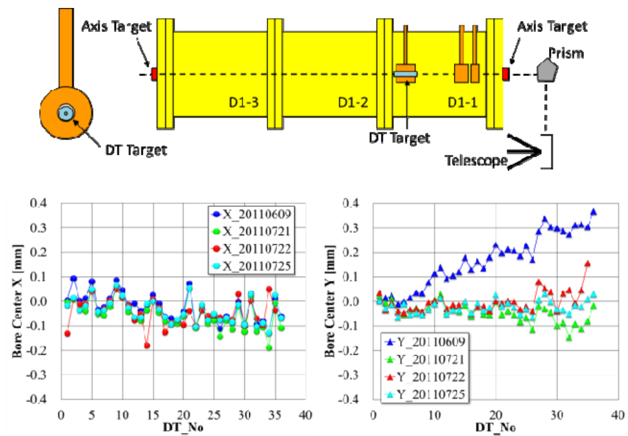

Figure 2: Schematic view of the measurement system and the measured center position of the DT bore.

The telescope axis was set on a line defined by the two axis targets and the DT target center position from the telescope axis was measured.

The graph shows the measured displacement of the DT bore center for the unit tank D1-1. The abscissa is DT number and the ordinate is the displacement of the bore center from the telescope axis.

There is about 0.2mm misalignment of bore center for X direction. The displacement for Y direction is less than X displacement except for the large DT number with large reading error. The reason is that the DT is swung like pendulum by horizontal vibration of earthquake because the DT is fixed at the top of the cavity.

There is a line with large tilt for Y measurement. This means that the unit tank D1-1 is inclined with respect to the telescope axis. This tilt line was measured before re-alignment of the DTL unit tank. Namely, the accelerator tunnel was deformed by the earthquake and the DTL was deformed along a floor of the tunnel. After re-alignment of the unit tank, the deformation of the DTL for Y direction is resolved (i.e. other three lines).

We did not measure the DT bore center of other cavities, because we could not prepare the target for DTL2 and the DTL3 soon. However, a drift of a resonant frequency of the cavity and an abnormal Q value were not observed. Therefor we concluded that there was no serious displacement of the DT.

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Cavity and Magnet Alignment

As mentioned before, Each DTL was deformed along the floor level [3]. The deformation was occurred at the joint part of the unit tanks (i.e. connection of cavity flanges). Maximum displacement was about 0.8mm for X direction and 1.5mm for Y direction.

SDTLs and the focusing magnets that are set on the same supporting frame of the SDTL tank were displaced very much. It had been measured that there are about 25mm misalignment of the horizontal position and 45mm of vertical position. The vertical displacement was due to the deformation of the floor level same as the DTL. The cause of the horizontal displacement was deformation of the floor. The SDTL cavity and the focusing magnet moved horizontally beyond the movable range of a cavity stage.

Furthermore, the tilt of the tank around the beam axis has been observed. The angle of it is 3-mrad. This tilt was also happened by the deformation of the tunnel.

Vacuum Pump

The linac tunnel was broken. As the result the floor and the wall of the tunnel are cracked in several places.

Groundwater was leaked and the accelerator tunnel was flooded up to 10cm. Therefore a lot of the mechanical vacuum pumps put on the floor were sunk. All soaked pumps were tested and broken pump was replaced with the new one.

Ion pumps and turbo molecular pumps were no damage because these pumps were attached to the cavity directly and the height of the ion pump is a few dozen centimeters above the floor.

Monitor

Monitors installed between the cavities had big damage. Many Beam Position Monitors (BPM), Current Monitors (CT) and bellows jointed to these monitors were broken. Therefore, the vacuum cannot be kept and the inner surface of the DTL and the SDTL were exposed to the air. Figure 3 shows the broken current monitor and bellows. The CT was broken at the brazing point between the ceramic cylinder and the metal pipe.

As it was impossible to repair the damaged monitors and the bellows, new equipment was made immediately.

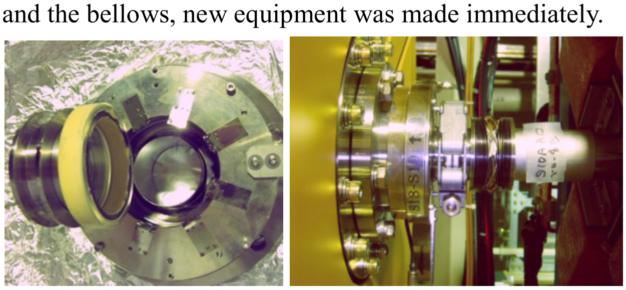

Figure 3: Broken CT (left) and bellows (rigtht)

Magnet Power Supply

Just after the earthquake, there was no damage for the outside of all magnet power supplies. At that time, the electric power was not available to turn on the power supply. However the power supply had been exposed to high humidity and high temperature atmosphere during several months because the air conditioning system of linac building was broken by the earthquake. Consequently, a lot of the power supply does not work well by the failure of the electric control boards in the power supply. We still continue to repair the broken power supply.

RE-ALIGNMENT

Drift Tube Alignment

Each DT in the DTL contains an electric quadrupole magnet (DTQ). Therefore the misalignment of the DT should be corrected in order to accelerate the beam with good quality. However it is necessary for the realignment of the DT to remove all electric cable for the DTQ and to separate the long DTL into the short unit tanks. It is really hard work to re-align the DTs. Since the beam simulation with the observed misalignment of DTs shows that the effect of the misalignment of DT is allowable level for the beam loss, we decided not to re-align the displaced DTs. [4] [5].

Cavity and Magnet Alignment

It is necessary to align the cavity and the focusing magnet. As mentioned previous section, there had been observed about 45mm and 25mm displacement for vertical and horizontal position respectively at the SDTL section in the accelerator tunnel. If we want to align the all tanks and magnets on the ideal one straight beam line, the adjustment length of the cavity is beyond the bounds of adjustable range of the cavity stage. So we decided to re-align the cavity at the DTL section and the SDTL section to the different axes respectively.

For DTL section, we determined the beam axis as the adjustment length of the unit tank was the minimum (~ a few mm). The unit tank was also aligned with docking condition and without removing the feeder cable to reduce the recovery work time.

Two targets of a laser tracker are mounted on each unit tank. The measured unit tank position of the DTL after the installation, the earthquake and the re-alignment by using a laser tracker is shown in Figure 4. The abscissa is the Z position of the DTL and the ordinate is the displacement from an axis defined by the two targets (see figure 4).

After the earthquake, the unit tank had large displacement for both directions X and Y. As the result of the re-alignment of the unit tank, the position was nearly equal to the position the after the installation measured in 2005.

For the SDTL section, the beam axis is different from the axis of DTL section. The axis is bent after the DTL section. The acceleration beam is bent by using first steering magnet installed between the S01A and the S01B. Because of this, it is possible to adjust the position of the cavities and the magnets within the limits of the adjustable range of the cavity stage.

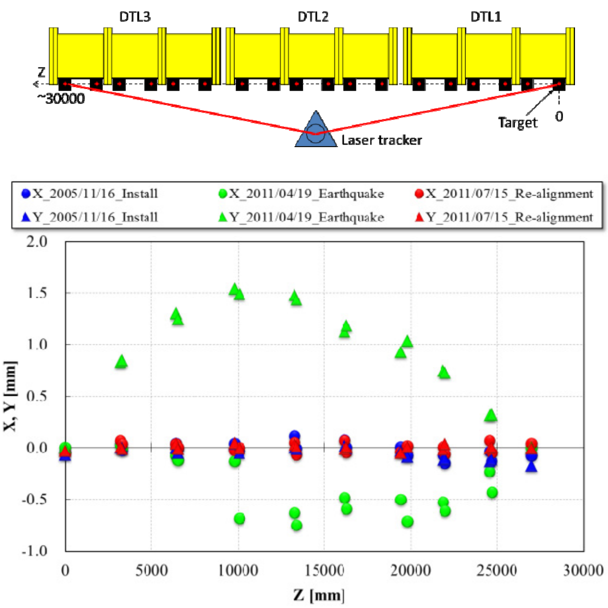

Figure 4: Displacement of the unit tank position.

Figure 5 shows measured position of the SDL and the focusing magnets after re-alignment. The SDTL and the magnets were measurement by using the laser tracker same as the DTL. The horizontal axis is the displacement of the Z (longitudinal). The vertical axis is the displacement of the X and Y (transverse) from the new beam axis. X and Y=0 is on axis.

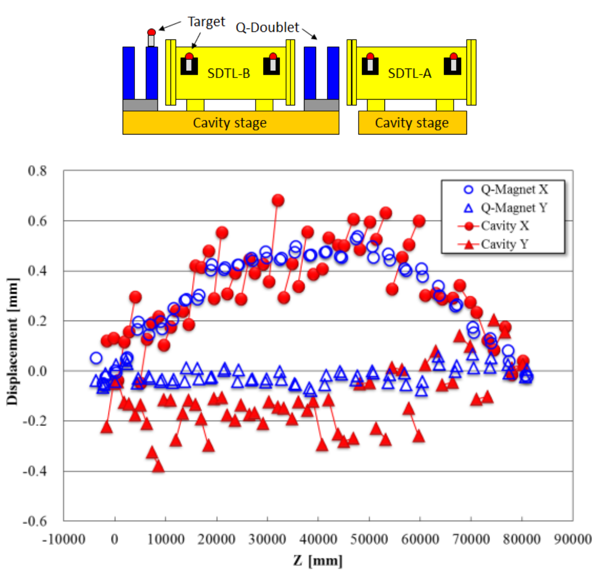

Figure 5: Displacement of the SDTL and the magnet.

Every focusing magnet has a target, and Each SDTL cavity has two targets as with the unit tank of the DTL. A cavity-A (S01A - A15A) is aligned individually. A cavity-B (S01B - S15B) and two doublets (four magnets) are aligned together on the cavity stage. The SDTL and the magnet are aligned smoothly within about 0.6mm from the new beam axis. The measured displacement of the X direction is larger than Y. This reason is an alignment error by the measurement limit of the laser tracker. The circumferential angle was corrected at the same time as the re-alignment of the X and Y direction.

After the vacuum pumps, the beam monitors and so on were attached, the final alignment of the cavity and the magnet was done. Figure 6 shows the result of the final alignment. It may be seen from figure 6 that the DTL and the SDTL is aligned to the different beam axis.

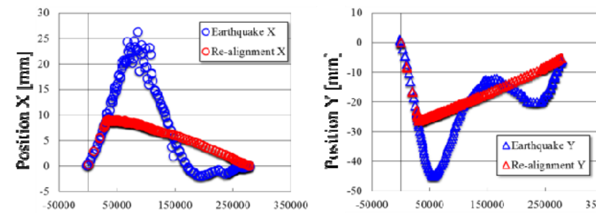

Figure 6: Result of the final alignment.

OPERATION STATUS

On November 2011, a conditioning of the DTL and the SDTL was started. The beam acceleration was re-started on December and we successfully accelerated the beam (the beam current is15mA, the pulse length is 500 micro seconds) at the linac section. It was almost the same as before the earthquake. Then, the user operation of the Materials and Life Science Experimental Facility (MLF) and the Neutrino Experimental Facility (NU) was started in January.

However, the several issues have been revealed. The beam loss is higher than it before the earthquake in several locations of the linac tunnel. For the S05B cavity, it was impossible to input an rf power from 300kW to 400kW. The operating power of the S05B was included in this range. Therefore the operating power was increased to 510kW that is about 1.4 times of those before the earthquake. After the investigation, a possibilities of a multipactor on the inner surface of the cavity emerged. We have continued our efforts to solve these problems.

ACKNOWLEDGMENT

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REFERENCES

[1] T. Ito et al., Proc. of 8th Annual Meeting of Particle Accelerator Society of Japan, August 1-3, 2011, p1316. (in Japanese)
[2] K. Hasegawa, et. al., Recovery of the J-PARC Linac from the Earthquake, FR2A01, in these proceedings
[3] T. Morishita, et. al., Floor Deformation of J-PARC Linac after the Tohoku Earthquake in Japan, Proc. of IPAC10, San Sebastian, Spain (2011), p2601, WEPS049
[4] M. Ikegami, Proc. of the 8th Annual Meeting of Particle Accelerator Society of Japan, August 1-3, 2011, p1131. (in Japanese)
[5] M. Ikegami, et. al., Study on the Realignment Plan for J-PARC Linac after the Tohoku Earthquake in Japan, , p44, MOOCB01