MULTIPACTOR PROBLEM OF J-PARC SDTL

Takashi Ito†, Takatoshi Morishita, Jun Tamura, JAEA/J-PARC, Tokai-mura, Japan
K. Nanmo, Takashi Sugimura, KEK, Tukuba, Japan

Abstract

The multipactor problem has affected a few SDTLs after the Great East Japan Earthquake. Because the designed operating rf power of SDTLs is in the multipactor region, we had to operate them at a higher power than the designed one. From the simulation result and observation of the SDTL cavity, it was clear that the multipactor effect occurred on the inner surface of the cavity. We believe that one of the causes of the multipactor effect is contamination on the inner surface of the cavity. Therefore, we cleaned the inner surface of the cavity by using acetone. The cleaning was very effective, and the multipactor region shrunk or disappeared. The multipactor problem has not occurred since then.

INTRODUCTION

Four types of accelerators are used at the linac facility in Japan Proton Accelerator Research Complex (J-PARC), namely, radio frequency quadrupole linac, drift tube Linac (DTL), separated type DTL (SDTL), and annular-ring coupled structure (ACS), to accelerate negative hydrogen ions (H-) from 3 MeV to 400 MeV [1, 2].

Table 1 shows the main parameters of SDTL. The SDTL section contains 32 cavities, and it accelerate H-ions from 50 MeV to 190 MeV. The operating frequency is 324 MHz. The cavity diameter is 520 mm, and its length varies from 1.5 m to 2.5 m. Each SDTL cavity has five acceleration cells, an rf coupler, a movable tuner, and two fixed tuners. One klystron feeds rf power to two SDTL cavities. An SDTL unit consists of these two cavities, for example, SDTL01A and 01B (i.e., SDTL01 unit).

Table 1: Main Parameters of SDTL

Number of cavities	32
Diameter	520 mm
Length	1.5 m~2.5 m
Drift tube diameter	92 mm
Bore diameter	36 mm
Number of cells	5
Operating frequency	324 MHz
Operating power	180 kW~800 kW
Repetition	25 Hz
Rf macro-pulse width	600 µs
Energy	50 MeV~190 MeV

The multipactor problem occurred in a few SDTL cavities, and it worsened after the earthquake [3]. The multipactor effect, which interferes with beam operation, was observed in the range of approximately 250 kW to 450 kW. Especially, it affected the SDTL05 unit because the designed operating rf power of this unit is in this power region. Therefore, we operated the SDTL05 unit at a higher rf power than the designed value [4]. To solve this problem, we observed the inside of the SDTL cavity and performed particle tracking simulation. From the results of these activities, it became clear that the multipactor effect occurred on the inner surface the cavity. In this paper, we present the cause that we deduced and the countermeasures we employed to solve the multipactor problem.

OUTLINE OF MUTIPACTOR PROBLEM

In the multipactor region, the rf power reflected by a cavity increases abnormally. The rf macro-pulse waveform takes on a strange shape in the multipactor region. Figure 1 shows the typical macro-pulse waveform of SDTL05A and 05B in the multipactor region. The blue and the cyan waveforms denote the tank power, and the magenta and the green waveforms denote the reflection power. These waveforms are extremely distorted, and the rf amplitude and phase are unstable in this power region. In addition, vacuum pressure in the tank increases from 10^{-6} Pa to 10^{-5} Pa due to outgassing by the multipactor.

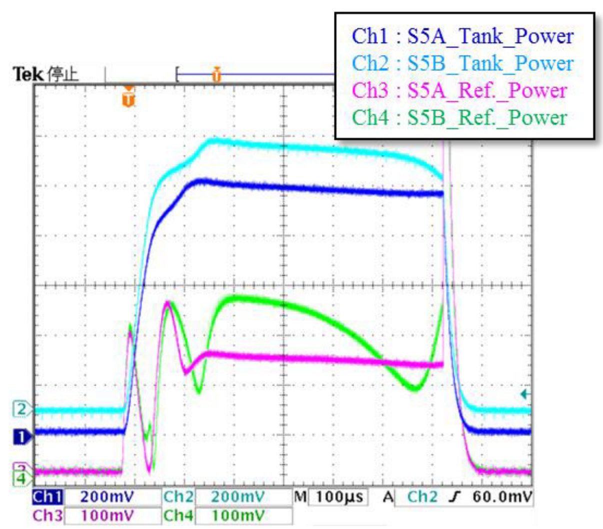

Figure 1: Macro-pulse waveform of SDTL05A and 05B in multipactor region.

After the earthquake, the multipactor region expanded to the nominal operating power region. Then, we had to operate the SDTL05 unit at a higher amplitude (109 -116 %) than the designed rf power. However, the upper limit of the multipactor region continued to increase gradually during operation, and we solved this multipactor problem fundamentally.

† itou.takashi@jaea.go.jp

CAUSE OF MULTIPACTOR PROBLEM

To investigate the problem, we observed the inside of the cavity and conducted simulation.

Figure 2 shows a photograph of the inside view of the SDTL05B cavity. As shown in this photograph, there are two circumferential discolored bands on the inner surface at each drift tube (DT) gap position.

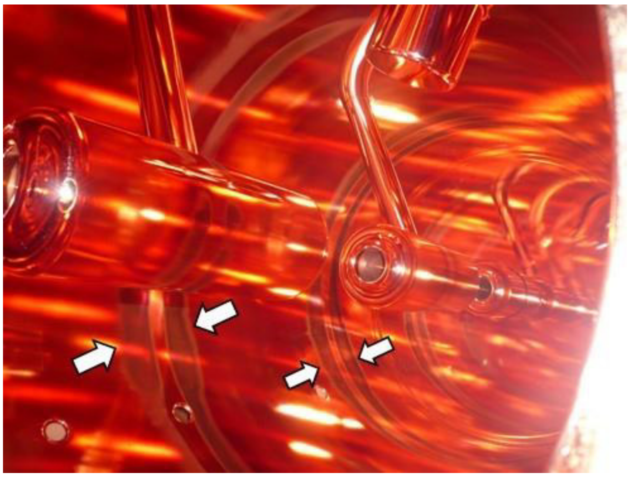

Figure 2: Photograph of inside view of SDTL05B. The arrows show the discolored bands.

The particle tracking simulation (CST PARTICLE STUDIO) was conducted in the peripheral areas such as rf coupler, tuner, and DT, but we could not find any multipactor condition in these places. Then, we conducted the simulation by focusing on the cavity wall. The simulation showed the occurrence of one-point multipactor at the same position as the observed discolored bands within the reasonable rf amplitude range. Figure 3 shows the simulated trajectory of electrons. The electrons return to the generated area.

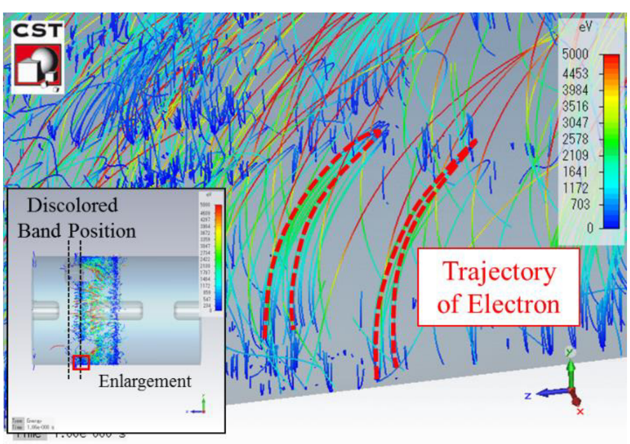

Figure 3: Example of particle tracking simulation.

We thought that one of the causes of the multipactor effect was contamination on the inner surface of the cavity. Before the earthquake, an rotary oil pump was used from SDTL01A to 06B. We suspected that an oil component was adhered to the inner surface derived from the rotary pump. It was thought that the multipactor region expanded because the level of contamination of the inner surface worsened as the interior of the SDTL was exposed to air owing to destruction of the beam monitors and the bellows due to the earthquake [5].

COUNTERMEASURES

Then, based on observation of the inner surface and the simulation, we decided to clean the inner surface of SDTL05A, 05B, 06A, and 06B. We used acetone to remove the oil component from the inner surface. As shown in Figure 4, the surface was densely covered with adhering foreign substances, mostly the oil component.

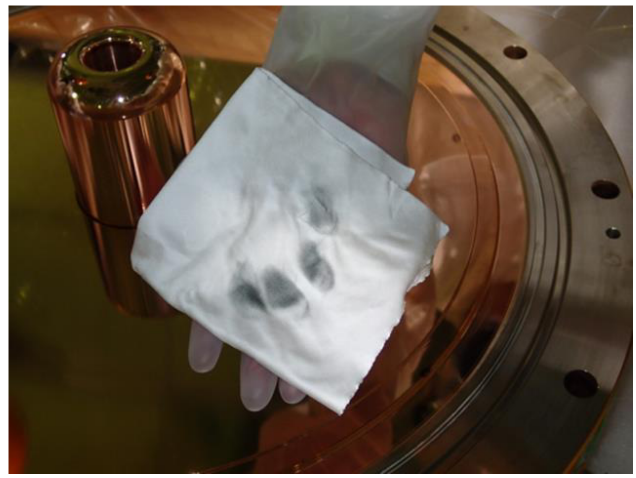

Figure 4: Wiping cloth after wiping inner surface of end plate of SDTL05B.

The cleaning was very effective, and the multipactor region shrunk or disappeared.

Figure 5 shows VSWR as a function of tank power before and after cleaning of the SDTL05B cavity. Before the cleaning, as the tank power increased, VSWR increased in the mulipactor region. After cleaning, the multipactor region disappeared, and VSWR was almost constant over the entire tank power region. Therefore, SDTL05B can be operated in all power regions. The multipactor problem has not reoccurred ever since.

Figure 6 shows trends of the upper limit of the multipactor regions of SDTL05A, 05B, and 06A (there is no data to plot for SDTL06B because the multipactor condition was not serious, so there was no upper limit value). To mitigate the multipactor problem, we employed a few countermeasures in 2012, 2013, and 2014, for example, replacement of the rotary pump with an oil-free one, changing the direction of the rf coupler loop, and frequent cavity conditioning. After these countermeasures were performed, the cavity condition improved, and the multipactor region shrunk. However, the multipactor power region expanded gradually during the operation.

In 2015, SDTL05B was cleaned, and the multipactor region disappeared. Similarly, we cleaned SDTL05B, 06A, and 06B in 2016. As a result of cleaning, the multipactor

ISBN 978-3-95450-182-3

region of SDTL06A disappeared, and the upper limit of the multipactor region in SDTL05A was reduced.

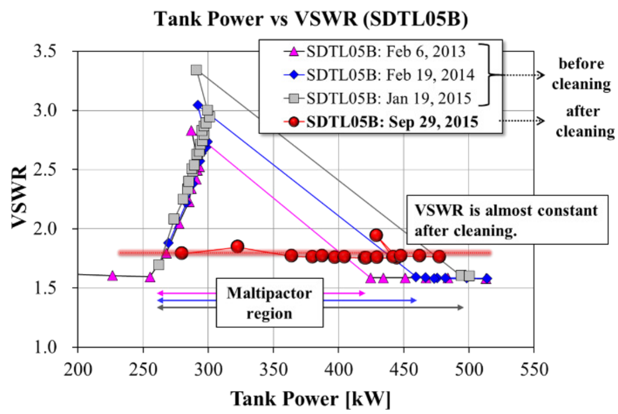

Figure 5: VSWR as a function of tank power before and after cleaning (SDTL05B).

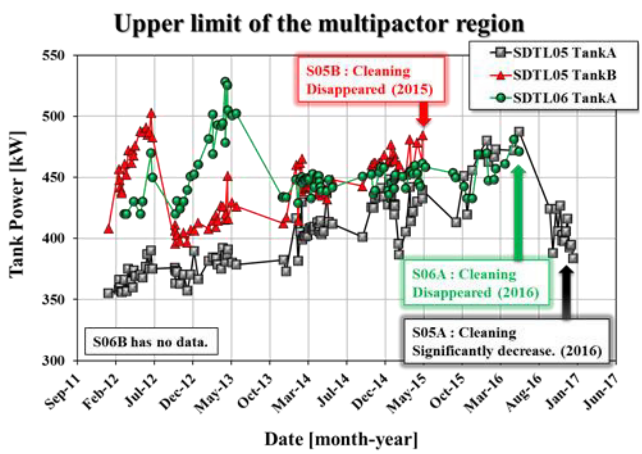

Figure 6: Trends in upper limit of multipactor regions of SDTL05A, 05B, and 06A.

As a result of cavity cleaning, we concluded that the cause of the problem is the multipactor effect caused by contamination on the inner surface of the cavity.

SUMMARY

We encountered the multipactor problem after the March 2011 earthquake. We employed a few countermeasures, but their effects were temporary, and the multipactor condition kept worsening. As a result of observing the inside of the cavity and by particle tracking simulation, it was clear that the multipactor effect occurred on the inner surface of the cavity. We thought that the cause of the multipactor effect was contamination due to the oil component. Therefore, we cleaned the cavities by using acetone. The cleaning was very effective, and the multipactor region disappeared or shrunk significantly. The multipactor problem has not re-occurred since cleaning.

ACKNOWLEDGEMENTS

The authors would like to thank members of Mitsubishi Electric System Service Co. for their help in cavity cleaning.

REFERENCES

[1] "Accelerator Technical Design Report for High-intensity Proton Accelerator Facility Project, J-PARC", JAERI-Tech 2003-044, KEK Report 2002-13 (2003).

[2] T. Kato, “Separated-type Proton Drift Tube Linac for a Medium-Energy Structure”, KEK Report 92-10 (1992).

[3] T. Ito *et al.*, “Multipactor at SDTL Cavity in J-PARC Linac”, in Proc. the 9th Annual Meeting of Particle Accelerator Society of Japan, Aug. 2012, paper THPS088, pp.1152. (in Japanese).

[4] T. Ito *et al.*, “RECOVERY AND STATUS REPORT OF DTL/SDTL FOR THE J-PARC AFTER EARTHQUAKE”, in *Proc. linac'12*, Tel Aviv, Israel, Sep. 2012, paper TUPB100, pp. 693-695.

[5] A. Miura *et al.*, “BEAM MONITOR DEFORMATION BY TOHOKU EARTHQUAKE AND ITS RECOVERY PROJECT”, *Proc. IPAC'11*, San Sebastian, Spain, Sep. 2011, paper WEPC144, pp. 2328-2330.