MULTIPACTING STUDY OF ICHIRO END CAVITY

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Abstract

High gradient superconducting RF cavity named Ichiro type in KEK is developing as the Alternatives Configuration Document for the international linear collider. Multipacting is one of the most serious limitations to achieve high gradient. Several simulation research found out that multipacting at the tapered beam pipe is too strong. We investigated multipacting effects in various end cavities with beam tube and compared with experiments.

INTRODUCTION

Multipacting (MP) is a resonant phenomenon of the secondary emission multiplication. Emitted electrons from the surface are driven by RF fields and then collide back and make secondary electrons which can impact again and release more secondary electrons. If this process satisfies a proper condition in RF fields and the surface yield function, the number of electrons grows up resonantly. This electron collision leads to a temperature rise on the wall and eventually superconducting break down. It is one of the serious barriers to achieve the high accelerating gradient.

During high gradient tests of 9-cell prototype at KEK have suffered the multipacting barriers and its source part has found in the end-groups of the cavity from the simulation study [1,2]. In this paper, we will present the simulation and experiment results of the KEK (Ichiro) end cavities.

MULTIPACTING SIMULATION

Ichiro end cavities

Many prototypes for ILC RF superconducting cavities have designed and tested for high accelerating gradient and good properties such as lower surface fields and loss power. Ichiro type in KEK has experienced the multipacting barriers. To investigate the end groups of cavity, single cell cavities with different pipes designed as shown in Figure 1. The cavity parameters listed in Table 1. ISE #1 is connected with 108mm radius pipe, ISE #2 has a step in the pipe and ISE #3 has 80mm radius pipe.

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Table 1: Parameters of end cavities

	ISE #1	ISE #2	ISE #3
Freq. (MHz)	1294.6	1294.4	1294.4
Meas. Freq. (MHz)	1294.1	1294.6	1291.3
Q_0	$2.27\ 10^{10}$	$2.27\ 10^{10}$	$2.19\ 10^{10}$
R/Q	96.0	96.8	120.8
Geometric factor	294.8	294.8	284.1
H_s/E_{acc}(Oe/ MV/m)	44.1	45.5	38.4

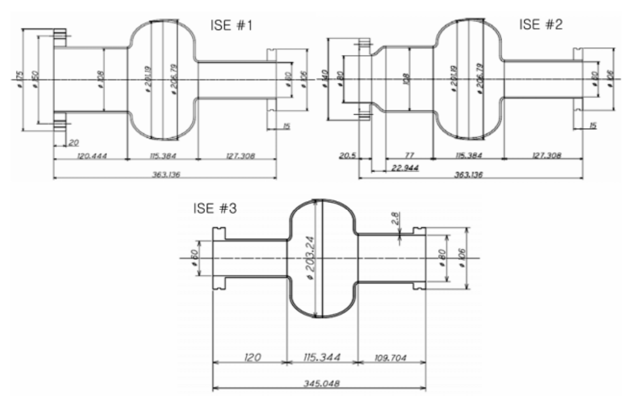

Figure 1: End cavity structure

Simulation code: Analyst

Analyst is a software package for the design of various microwave devices. It supports two-dimensional and three-dimensional for mode analysis and multipacting study. Typical multipacting oscillations can be obtained by tracking electrons emitted from the surface of the RF cavity.

Numerical Setup

Type ISE #1~3 have no port, therefore 10 degree sector model can be used for time saving instead of full three dimensional tracking. Typically maximum mesh size on surface is 0.2mm and 40000 elements are used. It is rather coarse grid, therefore the peak field has big error but enough to see qualitative behaviour and close to the limit of one personal computer for the multipacting analysis. The yield function which determines the secondary electron emission is chosen as

$$Yield = C_0 C_1^2 \frac{x}{C_2} Exp\left[-C_3 \sqrt{\frac{x}{c_2}}\right], \qquad (1)$$

where x is the impact energy in unit of eV and (c0,c1,c2,c3) is (1.3, 2.72, 600, 2.0) for the standard Niobium surface. The electrons emit with 2eV starting energy and are traced with time step of 10 degree phase of the RF period during 50 RF periods. If the electron survived during 10~25 impacts, it is regarded as a resonant electron.

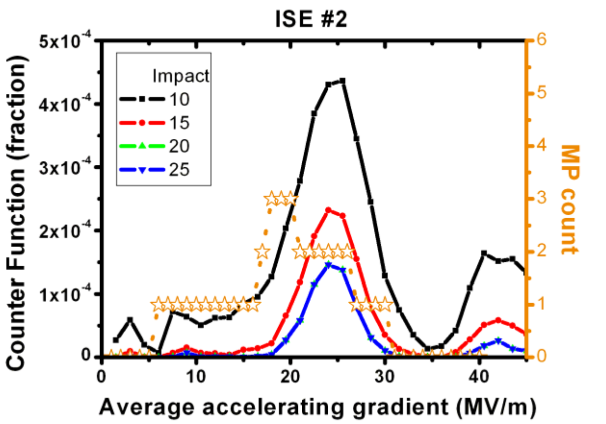

Figure 2: Fractional counter function and observed multipacting effect in ISE #2.

Simulation Result

The counter function is a basic tool to describe the multipacting effect. It is defined as the number of resonant particle orbits and the fractional counter function is the ratio to the total number of the primary particle emissions.

Figure 2 shows the counter function as a function of the average accelerating gradient with several minimum impact options in ISE #2. The multipacting occurs in 20-30MV/m and above 40MV/m. As the minimum impact required for the resonant decision increases, the number of the corresponding particles are reduced, especially in lower field region. The counter function looks saturated at the impact 20 which is the default value in Analyst version 10.0 patch 3.

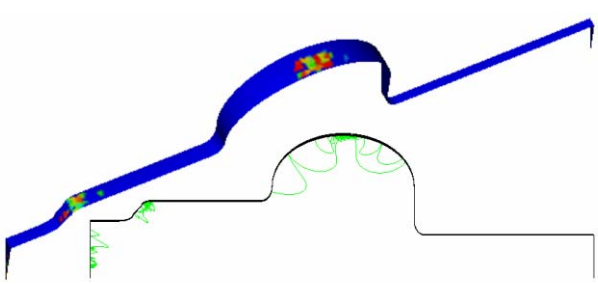

Figure 3: In ISE #2, maximum yield on surface and several electrons trace at E_{acc}= 6 MV/m with 10 minimum impacts. The traces near the equator resemble one point resonance.

orbit.

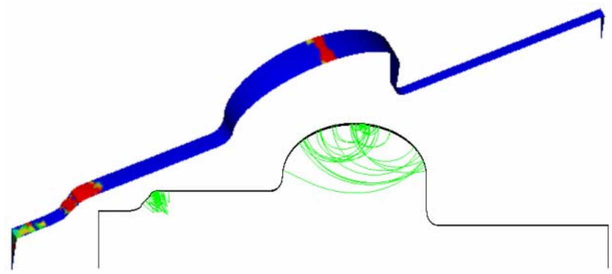

Figure 4: In ISE #2, maximum yield on surface and several electrons trace at E_{acc}= 21 MV/m. Two point resonance orbits are formed near equator.

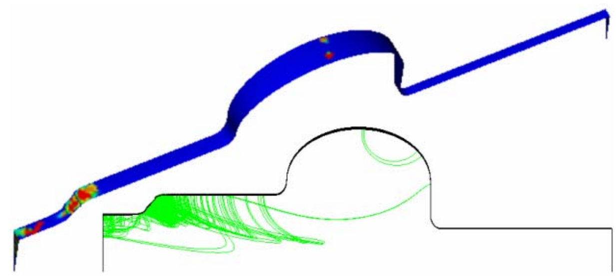

Figure 5: In ISE #2, maximum yield on surface and several electrons trace at E_{acc}= 42 MV/m. Heavy multipacting occurred in step.

As field strength increases, different parts contribute to counter function. Trace of some electrons and maximum yield on surface mesh are shown in Figure 3-5. Maximum yield map shows the multipacting position and we can suppose that it is similar with the temperature map [3]. At 6MV/m one point like multipacting near equator appears as Figure 3 but very weak below 20MV/m. Above 20MV/m there are relatively small effect in the step and two point multipacting near equator [4]. Due to the asymmetric structure highly colliding zone (red) is slightly shifted from the equator which is welding position. If two regions are separated enough, yield function of the welding part is not important. In ISE #1, there is a narrower peak and no effect in pipe, so no more peaks above 30MV/m up to 45MV/m, as shown in Figure 6. The peak center is shifted to higher field and weaker in ISE #3, as shown in Figure 7. The shift-up of center can be explained by lower magnetic field near equator. The shape of the cavity affects the multipacting highly [5].

EXPERIMENT

During increase input power to excite Ichiro end cavities, the multipacting can be recognized from the typical noise pattern in power profile and the radiation detector. In repeated measurement the cavity conditions are not same and the multipacting occurrences are different. Therefore the statistical description is obtained as plotted as stars in Figure 2, 6 and 7. This method does not require the special device but shows rough estimation. It is agreed that there is the multipacting in the range of 20-30MV/m but not understood that high peak at 18MV/m in ISE #1, #2. That field is the condition of two point resonance [6]. But it is much stronger than simulation.

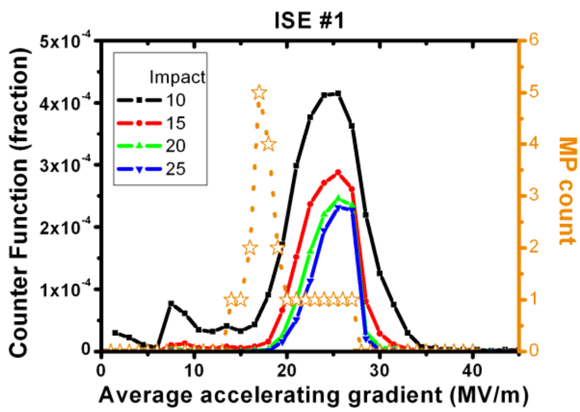

Figure 6: Fractional counter function and observed multipacting effect in ISE #1

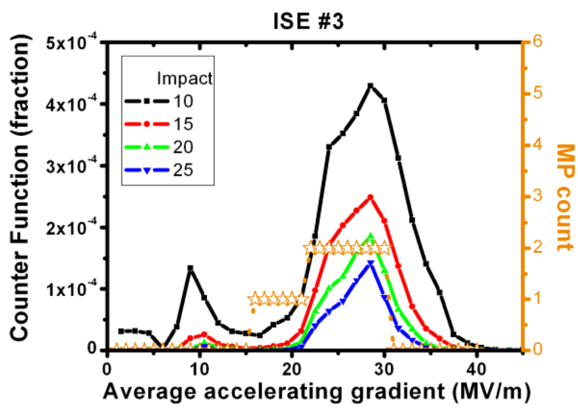

Figure 7: Fractional counter function and observed multipacting effect in ISE #3.

SUMMARY

The multipacting effect in Ichiro end cavities were studied numerically by tracking code and observed in the experiment. The step in the pipe is strong source and two point resonance occurred at the equator in the range of the average accelerating gradient 20-30MV/m. ISE #3 which has smaller pipe and 3mm smaller equator, shows weaker effect and center shift-up. It is agreed with the experiment but strong effect at 18MV/m is not shown in the simulation. It should be investigated more. Further study for accurate description of the multipacting is needed.

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