MULTIPACTING SIMULATION OF THE DEMOUNTABLE DAMPED CAVITY*

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Abstract

We have designed Demountable Damped Cavity (DDC) as an ILC R&D. DDC has an axial symmetric structure which consist the coaxial waveguide HOM coupler and absorber at the end of beampipe. It has also demountable structure. This structure is expected to bring better cavity performance. However, DDC have many parallel faced surfaces and the multipacting might be a concerned issue. We have simulated MP in DDC by using the CST-Studio which is commercial program. The results showed MP could be not serious issue. In this paper we will report the detail of simulation results.

INTRODUCTION

We are developing the Demountable Damped Cavity (DDC) as R&D of ILC main linac (Fig.1) [1]. There are three features in DDC. One is the axial symmetry structure, which will eliminate the beam kick effect in the TESLA type HOM coupler. The second is the coaxial waveguide coupling in the I.D.80mm beampipe, which makes easy to draw out HOMs since the coupling efficiency between the cavity and HOM damper becomes better. However this couples with fundamental mode strongly. So we put choke cavity at the head of the waveguide to reflect this mode. Fig.2 shows the field distribution. Circles are magnetic fields and arrows are electric fields. The third feature is the demountable structure of the end group based on zero impedance MO flange between cavity cell and choke cavity. This structure makes easy to clean the end group.

We will establish the elemental technology of DDC with single cell first, and then prove it with 9-cell. The cavity shape of DDC is same as ICHIRO end cell which is designed for ILC ACD cavity. However, choke structure might cause multipacting (MP) easily. MP sometimes limits the cavity performance. To understand the behaviour of MP in DDC, we simulated it by using the CST-studio [3].

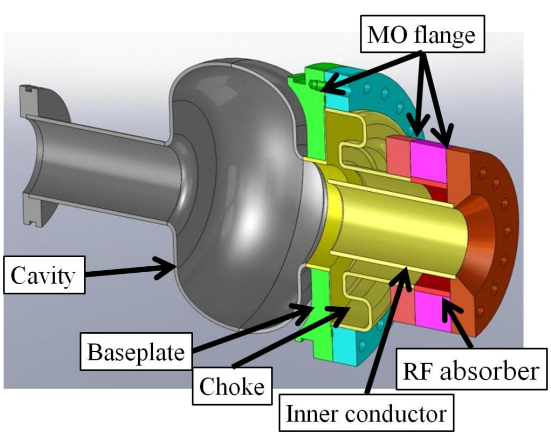

Figure 1: The design of the DDC.

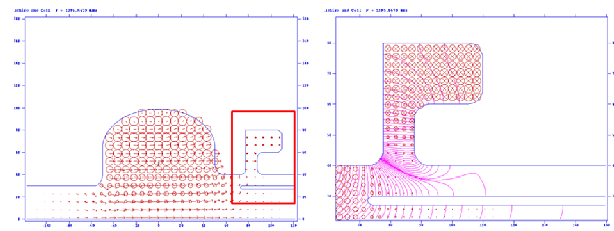

Figure 2: RF field in DDC (Left), expand red frame (Right).

MP SIMULATION OF THE DDC

MP is caused in the following processes. 1) Primary electrons are generated by X-rays generated by field emitted electrons or cosmic rays, etc. 2) Those are accelerated by the RF field and bombard cavity RF surfaces. 3) If secondary emission coefficient of cavity surface is larger than 1, secondary electrons are emitted more from the surface. 4) Those become the seeds of next MP process and repeat amplification. 5) Finally these amplified secondary electrons make big RF loading resulting in the limitation of gradient.

Secondary Electron Yield

The frequency of MP is determined by the secondary electron yield (SEY) of metal surface and the accelerating gradient in the cavity. In the CST-studio, SEY is defined by the Furman model [4]. In this model, SEY is the total of three secondary electron emission (SEE) mechanisms as following equations (fig.3): A) True secondary electron emission (True SEE), B) Re-diffused electron emission (Rd SEE), C) Elastic electron emission (El SEE). True SEE is the secondary electron (not primary electron) directly kicked out from metal surface by the primary electrons. Rd SEE is the emitted primary electron lost energy by multi-scattering in the metal. El SEE is the primary electron itself reflected at the surface by both of elastic and inelastic process. The yields of each SEY are given by following equations.

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$$\delta_{Ture}(E_{primary}) = \frac{\delta_{ts,\max}\left(s\frac{E_{primary}}{E_{ts}}\right)}{s-1+\left(E_{primary}/E_{ts}\right)^{s}} \tag{1}$$

$$\delta_{\mathrm{Rd}}(E_{primary}) = P_{rd,\inf}\left\{1-\exp\left(-\left(\frac{E_{primary}}{E_{rd}}\right)^{r}\right)\right\} \tag{2}$$

$$\delta_{El}(E_{primary}) = P_{el,\inf} + (P_{el} - P_{el,prim}) \times \exp\left(-\frac{\left|E_{primary} - E_{el}\right|^{p}}{pW^{p}}\right) \tag{3}$$

In those equations, deltas are the yields, s gives a span of the True SEY peak. E_{ts} is the energy of initial electrons at SEY peak, $P_{Rd,inf}$ is a Rd SEY at infinity primary energy, r is a slope of Rd SEY, E_{rd} is a starting energy to rise Rd SEY, P_{el} is a El SEY at infinity of primary energy, $P_{el,inf}$ is a gap of El SEY between 0eV to infinity energy, p and W are slopes of El SEY, E_{el} is a starting energy to rise El SEY, respectively. In this paper, we fixed these parameters as; $\delta_{ts,max}$=2.0, s=1.5, E_{ts}=500, $P_{rd,inf}$=0.2 and $P_{el,inf}$=0.02. Each yield of SEE and the total yield are plotted in Fig. 4 as a function of the initial energy of primary electrons. Here one can see the main contributions are True SEE and Rd SEE.

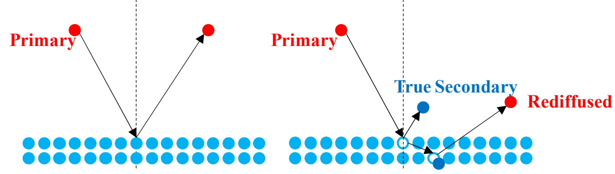

Figure 3: Phenomenon of True SEE and Rediffused SEE (Left) and Elastic SEE (Right).

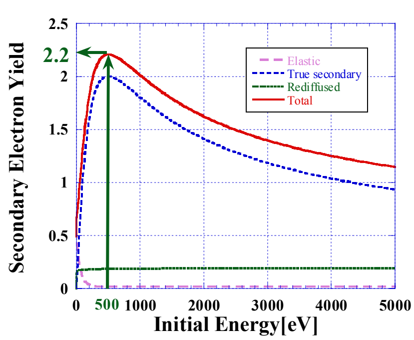

Figure 4: SEY curves used for the MP simulation.

Procedure of the MP Simulation

In MP simulation of DDC, we first calculate the RF field in the structure, and set the primary electrons where are emitted from the cavity cell or choke cavity, or inner conductor, which are shown in Fig.5. MP simulation starts with initial conditions, RF phase and amplitude of the RF field. In this paper, we change RF phase from 0 to 360 degree and amplitude of the RF field from 1to 50 MV/m.

The simulation tracks orbits of individual electrons every time. If MP starts, the number of MP electrons increases exponentially with time as Fig.7, and it can be fitted by Eq. (4)

$$Y = A \cdot \exp(t/\tau) \tag{4}$$

Here A is the number of primary electrons, and named counter function. τ is the rising time of the MP. 1/τ is zero means no MP happens. Special attention should be paid to the rising time because it determines the seriousness of MP.

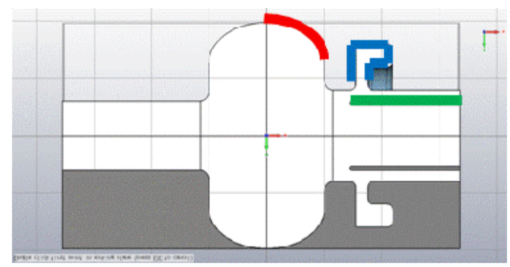

Figure 5: The positions where emitted primary particles from: cavity (red), choke cavity (blue) and the inner conductor (green).

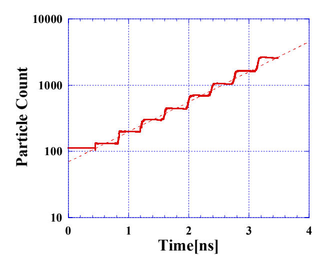

Figure 6: Example of increasing particle counts when MP is occurred.

MP Simulation of the ICHIRO Single Cell Cavity

We checked first the validity of this MP simulation using the ICHIRO single cell cavity (IS) which has ICHIRO center cell shape and I.D.60mm beampipes (Fig.7). In the result of the simulation (Fig.8), the rising time rises at Eacc=18MV/m and decreases from about 30MV/m. The rising time depends on the SEY, smaller SEY correspond to smaller SEY. If the SEY becomes smaller by RF processing, the MP is getting to be suppressed. This simulation, however, does not include such a dynamics process. Fig.9 shows the frequency of MP vs. gradient summarized from the vertical test (VT) results on IS cavities [5]. MP typically happened at 18 to 26MV/m at the VT of IS cavities. MP starting from 18MV/m is consistent with this simulation. Big difference over than 30MV/m is considered as that niobium cavity surface could be cleaned by the MP process and result in reduced SEY, but our simulation does not include such a dynamic process. So our simulation is consistent with experimental result.

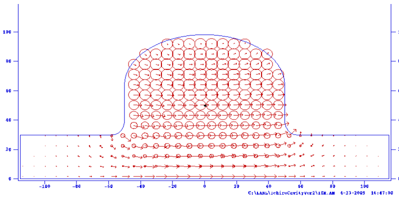

Figure 7: IS shape.

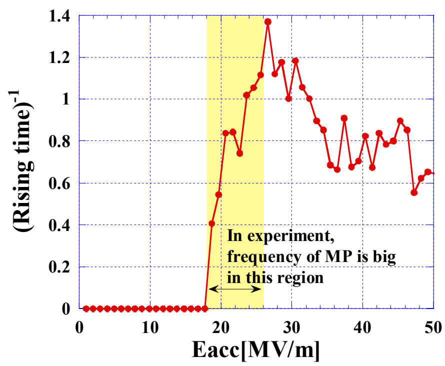

Figure 8: Result of MP simulation on IS.

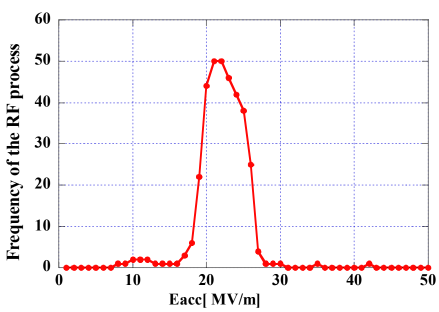

Figure 9: Frequency of the RF process on IS [5].

Results of the MP Simulation of the DDC

As seen in Fig.10, which traces MP orbits, MP is localized at high magnetic field area (see Fig.2). MP could not couple between the sections; cavity cell, choke cavity, coaxial waveguide. Therefore, MP simulations are done in individual section.

Figure 11 shows the results of the MP simulation for the each section of the DDC. Each dots in the graph present MP rising times in three sections; cavity cell (red), choke (blue) and coaxial waveguide (green). Main contribution is the cavity cell. MP in cavity like ICHIRO center cell can process out in experiments. The results also show the MP in the end group; choke and coaxial waveguide could be not so serious.

SUMMARY

The DDC design has been finished. We simulated MP on the DDC. We firstly simulated on the Ichiro single Cell (center cell) and confirmed the validity of the simulation, comparing to experimental result. It has been found out that the MP in the choke cavity is not so serious.

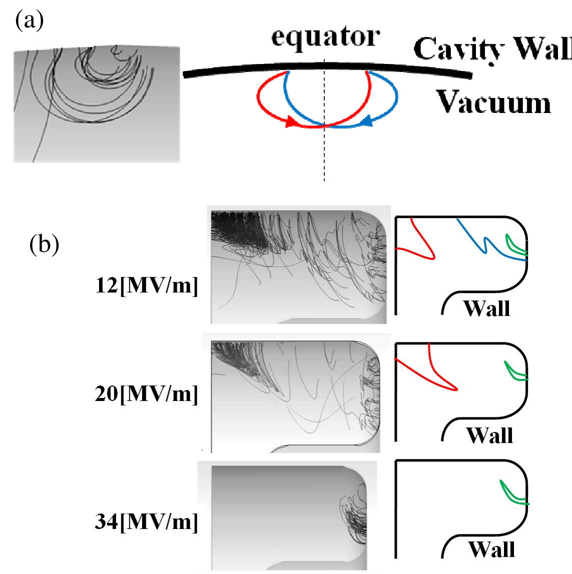

Figure 10: MP orbit in (a) cavity cell and (b) choke cavity.

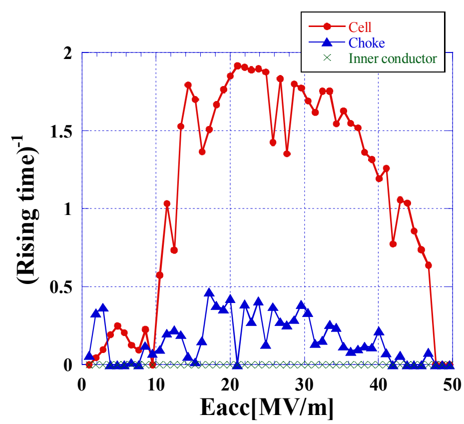

Figure 11: Result of MP simulation on DDC.

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