DEVELOPMENT OF MOVABLE MASK WITH REDUCED-HOM DESIGN FOR KEKB

K. Shibata#, Y. Suetsugu, T. Kageyama, KEK, Tsukuba, Japan

Abstract

At the high energy ring of the KEK B-factory (KEKB), it was found that some bellows near the movable masks were overheated due to the higher order mode (HOM) as increasing the beam current over 900 mA. To cope with this problem, a new mask was designed where the length of ramps beside the mask head was expanded from 30 mm to 400 mm. MAFIA T3 simulations showed that the loss factor for the new long mask was about a half of that for the previous short one. The power of the TE mode, on the other hand, which can easily couple with the bellows through the finger-type RF-shield, was expected to reduce to about 6 percent of that for the short one. During the summer shutdown in 2002, two long masks were installed as a test. In the following run the temperature rise of bellows near the long masks was about 20 percent of those near the short ones and the new design was found to be effective to reduce the HOM. The decrease in the temperature rise was larger than the reduction of the HOM power estimated from the loss factor. This result indicates that the overheating of the bellows is mainly due to the TE mode like HOM rather than the total HOM.

INTRODUCTION

The KEKB is a high-luminosity electron-positron synchrotron collider with asymmetric energies to produce copious B and anti-B mesons for the study on the CP violation [1]. It has two rings, one is the high energy ring for 8 GeV electrons (HER), and the other is the low energy ring for 3.5 GeV positrons (LER). The design beam current of HER and LER are 1.1 A and 2.6 A, respectively, and the luminosity goal is 1×10^{34} $cm^{-2}s^{-1}$ [2]. To achieve such a high luminosity, there are various kinds of devices in the vacuum system of KEKB. A movable mask (or collimator) is one of them to cut off particles escaped from a bunched beam and to reduce background noise in the BELLE detector [3-5]. Sixteen movable masks (eight vertical and eight horizontal type masks) are now installed in each ring. The position of each mask head can be adjusted remotely balancing the background noise in the detector with the beam life time.

In 2002, overheating of bellows just near the vertical masks in HER was found at the beam current higher than 900 mA. This overheating was caused by the HOM which went inside of the bellows through slits between RF-shield fingers of bellows [6]. Some bellows were overheated up to about one hundred degrees and sometimes resulted in vacuum leaks. In order to solve this problem, the vertical movable mask was improved introducing a reduced-HOM design. Here the structure of new mask and the estimation of HOM power are presented in detail.

#kyo.shibata@kek.jp

REDUCED-HOM DESIGN

Structure

Figure 1 shows sketches of the previous short mask and the new long one (vertical type). A mask chamber is a bent chamber and the wall of the chamber has the function as a mask head. Since the cross section of the beam chamber is kept constant, there is no trapped mode at the mask head although the HOM is excited at the mask head where the beam passes off centre of the beam chamber [4]. The position of the mask head can be adjusted by moving the mask chamber with a stroke of ±10 mm around the nominal position. There are bellows with a finger-type RF-shield [6] at the both side of the mask chamber to absorb the motion of the mask chamber.

In order to reduce the power of the HOM generated at the mask head, the length of the ramps beside the mask head was expanded from 30 mm to 400 mm with the same height of 15 mm in the case of the improved long mask. The length of the ramp was limited to 400 mm by the space for installation.

Reduction of Loss factor

To estimate the effect of this new long mask, the loss factor of a vertical mask was calculated by using MAFIA T3 simulation code. The distance from the mask head to the beam and the bunch length were set for 10 mm and 6 mm, respectively. Figure 2 shows the loss factor, k, as a function of the ramp length of the mask head, l. The loss factor decreases rapidly with increasing the ramp length from 30 mm to 100 mm. After that the loss factor decreases gradually with the ramp length. When the ramp length is expanded from 30 mm to 400 mm, the loss

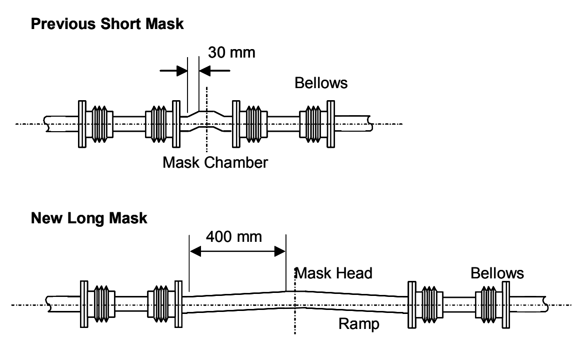

Figure 1: Previous short mask and new long mask. The length of the ramps was expanded from 30 mm to 400 mm.

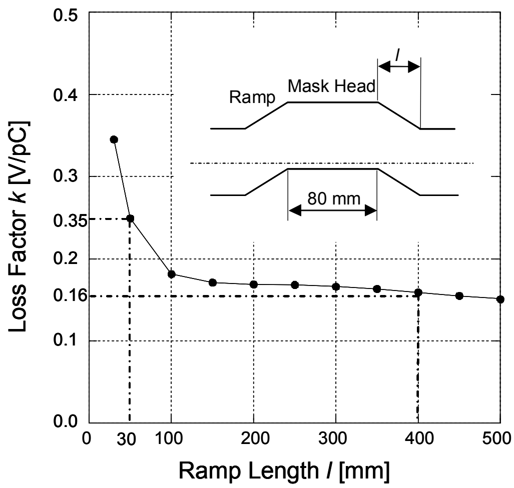

Figure 2: Loss factor, k, of the HER vertical mask as a function of the ramp length, l.

factor is reduced to about 46%. It is, therefore, expected that the temperature rise of the bellows near the mask should reduce to about a half at least. For 1000 mA beam with 1200 bunches, for an example, the power loss should reduce from 2.8 kW to 1.3 kW.

Reduction of TE mode

TE mode can easily couple with the bellows through the slits between RF-shield fingers. (The width and length of the slit are 0.5 mm and 20 mm, respectively [6].) It is, therefore, very important to consider the effect of the TE mode among various modes.

To estimate the power of the TE mode, the magnetic field component B_z, which is parallel to the beam axis, just near the inner wall of the beam duct was calculated. The monitoring point was 100 mm away from the edge of the ramp beside the mask head that is the nearest bellows position.

The results are shown in Fig. 3 as a function of the ramp length, where $<B_z^2>$ is the averaged intensity of B_z^2 for 5 ns after a bunch passed by the monitoring point (about a half of the present bunch spacing) excluding the beam induced field and it represents the power of the TE mode. The averaged intensity, $<B_z^2>$, decreases more drastically than the loss factor (Fig. 2). Comparing the case of 30 mm with 400 mm, $<B_z^2>$ reduces to about 6%. It is, therefore, expected that the temperature rise of the bellows near the masks could reduce to about 1/16.

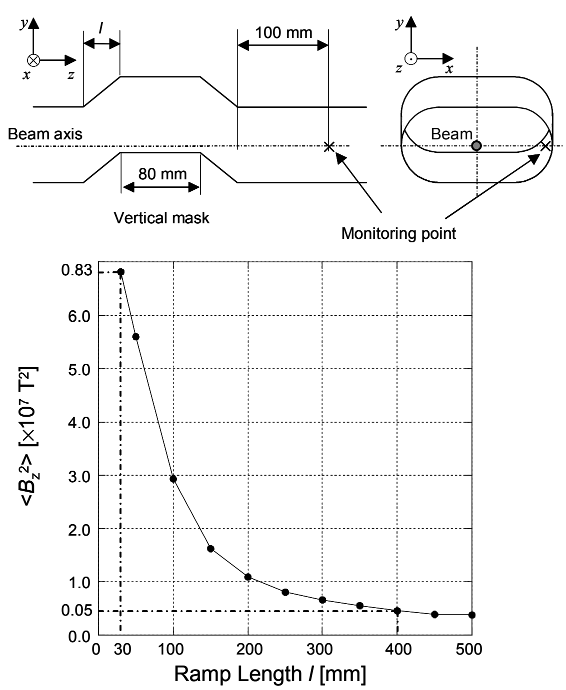

Figure 3: The averaged intensity, $<B_z^2>$, of the HER vertical mask as a function of the ramp length, l. The monitoring point is also indicated in the sketch above.

RESULTS AND DISCUSSIONS

During the summer shutdown in 2002, two long masks were installed in HER as a test and the temperatures of bellows just near the vertical masks were measured. Figure 4 shows the behaviour of temperatures of bellows near new long masks and previous short ones against the beam current. Because of the resonance phenomenon, there are some differences between data. However, it is obvious that the temperature rises of the bellows near the new long masks are smaller than that of the previous ones. When the beam current was 950 mA, the temperature rise reduced to about 20% on average.

The ratios of the temperature rise of the bellows near the long mask to that near the short one are shown in Table 1, where ΔT, ΔT_k and ΔT_B represent the temperature rise obtained by the measurement, expected from k and $<B_z^2>$, respectively. There are some discrepancies between the expectations and the observations. The experimental result is between the expectations.

The expectation from the loss factor k is larger than the

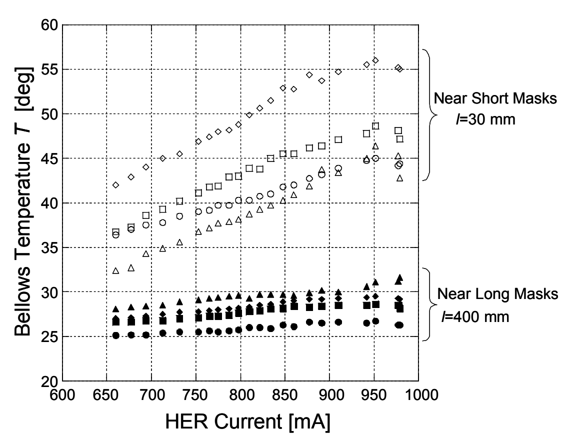

Figure 4: Behaviour of bellows temperature, T, against HER beam current.

Table 1: Reduction of the temperature rise obtained by the measurement and expected from k and B_z.

Expectation from k	$\frac{\Delta T_k \text{ (400 mm)}}{\Delta T_k \text{ (30 mm)}} = 0.46$
Experimental result	$\frac{\Delta T \text{ (400 mm)}}{\Delta T \text{ (30 mm)}} = 0.2$
Expectation from $<B_z^2>$ (full frequencies)	$\frac{\Delta T_B \text{ (400 mm)}}{\Delta T_B \text{ (30 mm)}} = 0.06$
Expectation from $<B_z^2>$ (f > 2 GHz)	$\frac{\Delta T_B \text{ (400 mm)}}{\Delta T_B \text{ (30 mm)}} = 0.2$

experimental result. This difference can be explained by that the effects of both the TE and TM modes were included in the expectation from k. Practically, only the TE mode can go through the RF-shield of bellows and contribute the heating of the bellows. According to the calculation by MAFIA, the reduction of the TE mode is larger than that of the TM mode with increasing the ramp length. The expectation from the loss factor must be underestimated.

On the other hand, the expectation from $<B_z^2>$, that represents the TE mode power, is less than the experimental result. One possible explanation for this difference is that heating of the bellows depends on frequency of the TE mode and all of the TE modes are not responsible for heating of the bellows.

Figure 5 shows the calculated spectrum of B_z for the short mask and the long mask. For the short mask there is a strong HOM around 1.5 GHz. However, the TE modes with low frequencies hardly go through the RF-shield of bellows, because the slits between RF-shield fingers are short compared to the wavelength. For example, taking into account only the TE modes with frequencies higher than 2 GHz, the expectation from $<B_z^2>$ gets close to the observed result (Table 1).

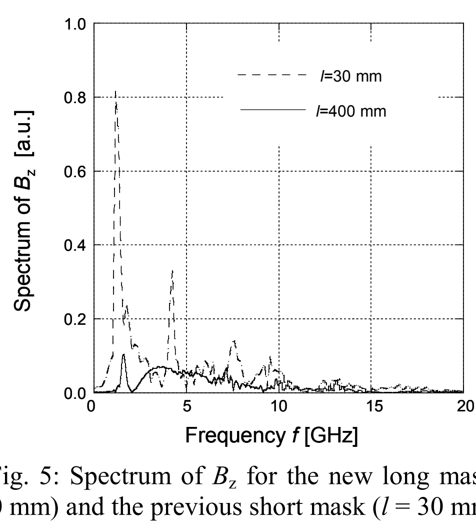

Fig. 5: Spectrum of B_z for the new long mask (l = 400 mm) and the previous short mask (l = 30 mm).

CONCLUSION

In order to suppress the heating of the bellows just near the vertical movable masks in HER, the movable mask with a reduced-HOM design was developed. The length of ramps beside the mask head were expanded from 30 mm to 400 mm. After installation of the new long masks, the temperature rise of the bellows just near the masks reduced to about 20%, and it was confirmed that this new long mask is very effective to reduce the temperature rise of the bellows. Furthermore, from MAFIA T3 simulation it was found that the TE modes with frequencies higher than 2 GHz mainly responsible for heating of the bellows.

During the winter shutdown in 2002-2003, more two long vertical masks were installed in HER. After installation of the new long masks the stored current was increased gradually, and at the beginning of May 2003 it was about 1.1 A for HER (design current [2]). The maximum peak luminosity exceeded the design value and reached 1.03×10^{34} cm^{-2}s^{-1}. Overheating of bellows near the new long masks has not been found. All the short masks in HER will be exchanged for the new long masks during the summer shutdown in 2003.

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