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Technical Note for ILD beam pipe

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Abstract

Parasitic loss, mechanical strength and vacuum pressure profiles are evaluated for the present ILD beam pipe made of beryllium, and the technical problems are discussed.

1. Parasitic Loss

The loss factor (*k*) was calculated for a model of ILD beam pipe as shown in Fig. 1 (axisymmetrical 2D). Due to the limited memory size, the *k* for bunches with bunch lengths (σ_z) of 2, 3, 6 and 9 mm were estimated first, and then that for σ_z = 0.3 mm was extrapolated using these results [1]. The calculated values were almost in inverse proportion to σ_z. Since the apertures at both ends of the model in Fig.1 were different, the calculated *k* depended on the direction of passing beam. Therefore, the loss factors were calculated for each passing direction, and they were added finally. The obtained *k* was that for two beams as a result, i.e. for electron and positron beams. The *k* for σ_z = 0.3 mm was finally estimated to be $6–7\times10^{13}$ VC^{-1} for two beams. The estimated *k* was almost the same as those presented by H. Yamamoto [2] and A. Novokhatski [3]. The parasitic loss in the beam pipe is then 20–24 W (= $k\times q\times I$ = $k\times q^2\times N_b\times f$), where the bunch charge (*q*), the number of bunch (N_b) and the repetition rate (*f*) were assumed to be 3.2 nC, 6600 bunches and 5 Hz, respectively (LowP option). Air cooling will be enough to take the power away.

Since the beam pipe has a cavity structure as shown in Fig. 1, various modes are trapped in it. The intensity of magnetic fields of a typical trapped mode in the beam pipe is presented in Fig. 2, where the resonant frequency is approximately 800 MHz (TM mode). Although some part of the excited higher order modes (HOM) can run away from the cone region, the parasitic loss will be mainly dissipated on the inner surface in this region, as indicated in the figure.

2. Vacuum Pressure Profile

The vacuum pressure profiles in the ILD beam pipe was calculated assuming a constant thermal gas desorption rate. Any gas desorptions other than the thermal gas desorption, such as the photodesorption due to irradiated photons, were not considered here. Unfortunately, the gas desorption rate from beryllium has not been reported so far. Therefore, the gas desorption rate of aluminum was assumed here as the first approximation [1]: The assumed gas desorption rates for H_2 and CO were 2×10^{-7} and 2×10^{-8} $Pam^3s^{-1}m^{-2}$, respectively. These values are for those without *in situ* baking and after 4 days' evacuation. The chamber, however, should be baked before the assembling. A vacuum pump was located at approximately 3.3 m from the collision point. The pumps were assumed to have effective pumping speeds of 0.72 and 0.12 m^3s^{-1} for H_2 and CO, respectively (conductances of pumping ports of 1.1 and 0.3 m^3s^{-1} were also assumed for H_2 and CO, respectively). The results are shown in Fig. 3 (a) and (b). The pressures of approximately 1×10^{-6} and 6×10^{-7} Pa were obtained for H_2 and CO, respectively. The pressure on the order of 1×10^{-6} Pa can be achieved for these gas desorption rates [4].

The effective pumping speed was strongly limited by the conductance of small pipe at just back side of the cone region. If further lower pressure is required and any *in situ* baking of beam pipe is not allowed, an extra vacuum pump should be prepared in the cone region [1]. In any way, the gas desorption rate of beryllium has to be measured using a test chamber in order to obtain the more realistic pressure.

3. Mechanical Strength

The mechanical strength of the beam pipe was also estimated using a model as shown in Fig. 1. The beryllium has an elastic modulus of 275 GPa, and the Poisson ratio of 0.3. The thickness of beam pipe was written down in Fig. 1. The atmospheric pressure of 1.0×10^5 Pa was applied from outside. The collision point was fixed in the calculation. The model was elastic and axisymmetrical 2D, and no buckling was taken into account here. The deformation and the stress (von Mises stress) are presented in Fig. 4(a) and (b), respectively, where the deformation was exaggerated for convenience. The maximum deformation was approximately 30 μm. The maximum stress was approximately 7.5×10^7 Pa, which is much smaller than the yield strength of beryllium, 2.6×10^8 Pa [5].

However, note here that beryllium oxide has a high toxicity, especially to the lung, as is well known. Therefore, the welding of beryllium by TiG or electron beam (EB) is usually avoided, and the vacuum brazing has been widely used. Thus the beam pipe will experience a high temperature, 800–900 °C, during the brazing process. The beryllium pipe should be annealed at this high temperature, and the mechanical strength will weaken. The yield strength of beryllium at 650 °C is, for example, approximately 9×10^7 Pa [5], which is almost the same as that of the estimated maximum stress. The method of joining beryllium should be considered carefully. Any measures to enforce the structural strength will be required if vacuum brazing is adopted.

4. Issues to be investigated

(1) How to install the beam pipe into the detector. How to support the beam pipe. Don’t we need bellows or flanges near to the collision point?

(2) Measurement of thermal gas desorption rate from beryllium. An experiment to measure it using a test chamber is necessary. New pumping port should be prepared in the cone region depending on the result.

(3) Checking of other sources of the gas desorption, such as photons, electros and ions.

(4) R&D on the method of joining beryllium. The cutting and welding of beryllium requires careful consideration. Furthermore, the manufacturer that can treat beryllium should be limited.

References

[1] Y. Suetsugu, “Preliminary design studies on ILD vacuum pipes”, TILC08, Tohoku Univ., March 2–7, 2008.

[2] H. Yamamoto, “HOM Heating”, IRENG'07, SLAC, September 17–21, 2007.

[3] A. Novokhatski, “IR wake fields and HOM absorbers”, IRENG'07, SLAC, September 17–21, 2007.

[4] L. Keller, “Vacuum Requirements”, IRENG'07, SLAC, September 17–21, 2007.

[5] ASM International, “Properties and Selection: Nonferrous Alloys and Special-Purpose Materials”, Metals Handbook, 10th edition, Vol. 2, 1990.

Figure Captions

Fig. 1 Calculation model of the present ILD beam pipe.

Fig. 2 Example of trapped modes (TM mode) in the beam pipe, where the azimuthal components of magnetic field was represented in contour.

Fig. 3 Pressure profile for (a) H_2 and (b) CO in the beam pipe.

Fig. 4 (a) Deformation and (b) von Mises stress of the beam pipe under atmospheric pressure.

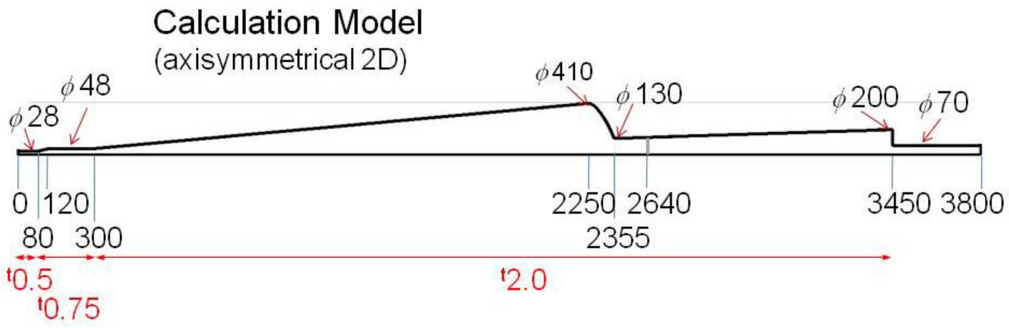


Fig. 1

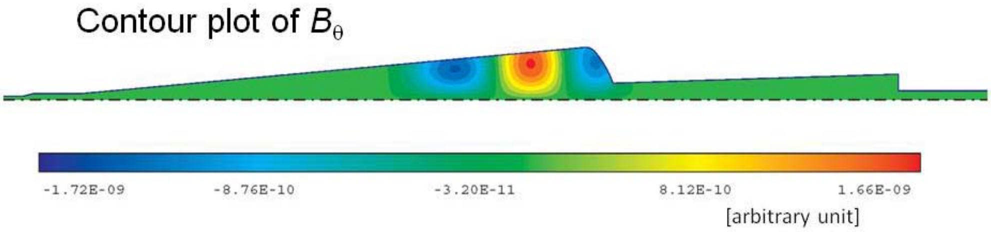


Fig. 2

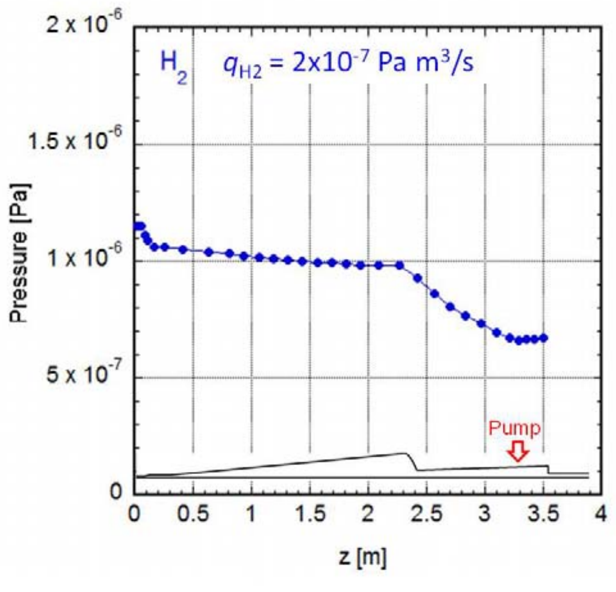


Fig. 3(a)

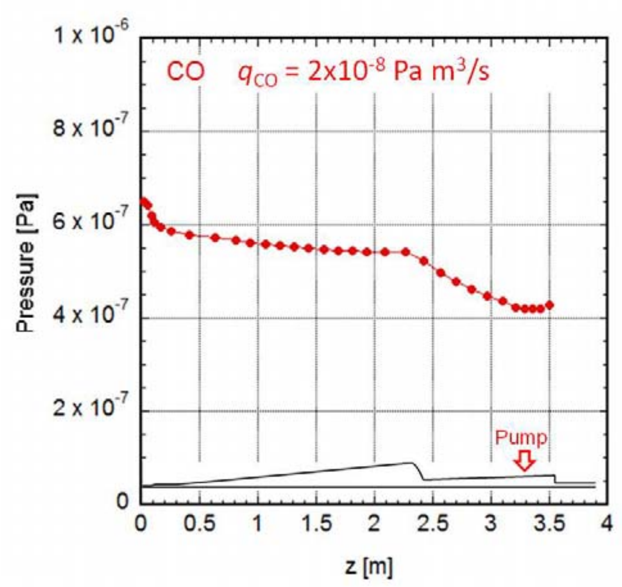
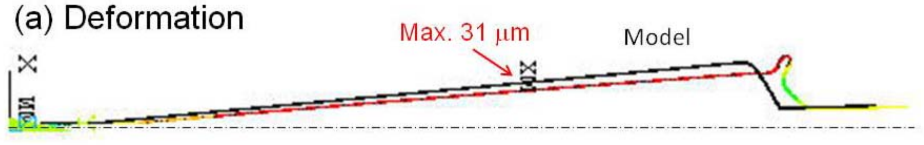


Fig. 3(b)

(a) Deformation



(b) Von Mises Stress

Fig. 4