

DESIGN AND MANUFACTURE OF TPS BPM DIAMOND-EDGE GASKET

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Abstract

The TPS vacuum chamber is machined free of oil; the material (A6061T651) has Brinell hardness 95 kg/mm². A beam position monitor (BPM) is installed in the bending chambers, B1 and B2, and the straight chambers, S3 and S4. A diamond-edge gasket is chosen to seal between the BPM flanges (SS316L) and the vacuum chamber (A6061T651). Ease of manufacture, modest cost and small clamping force are three main advantages of this gasket (material A1050H14, hardness 32 kg/mm²); its surface roughness is well controlled under 0.8 μm because a worse surface roughness would likely generate a radial leak. Based on differences of thermal expansion between stainless steel and aluminium, SS304 set screws, nuts and washers were chosen to provide an axial sealing force. The sealing ability of this diamond-edge gasket is reliable through tens of baking-out tests. The pre-torque should be sufficient to cause plastic deformation of the diamond-edge gasket and re-torque after baking to 150 °C for 24 h; then cooling to 23 °C is important to prevent leakage resulting from a loss of torque that typically occurs about 110 °C. This article presents the concepts of the diamond-edge design and the operations for the practical assembly in a TPS 1/24 cell.

INTRODUCTION

Gaskets of many types are widely used; the first pertinent question is which type is suitable for TPS BPM assembly. The chamber is made of aluminium; to avoid harm to the chamber, the material of the gasket must be less hard than Al. [1] As the screw holes are located in the Al chamber, a small torque for sealing is preferable. For accelerator Indus-2, diamond-edge gaskets were proposed, and experiments were undertaken to exercise gaskets of this type between stainless steel and aluminium flanges. [2] A diamond-edge gasket is claimed to have a small sealing force, to be readily machined and of modest cost. Those attributes fit the TPS BPM gasket requirements, but we made a few changes for the TPS BPM gaskets -- the angle, geometry, and material of the diamond-edge gasket.

MATERIAL HARDNESS

A soft material is commonly applied for gaskets because it might fill the imperfections between hard mating surfaces, such as a TPS aluminium chamber (A6061T651) [3] (Fig. 1) and a BPM flange (SS316L); the Brinell hardnesses are 95 and 217 kg/mm² respectively. To avoid damage to the A6061T651 chamber that is subject to an

axial sealing force, A1050H14 was first considered. Material A1050 has a ductility advantage, being softer than A6061T651; its Brinell hardness is 32 kg/mm². Table 1 lists the hardness of the three parts. Definitely no damage would be incurred to the chamber, as A1050H14 is softer than A6061T651.

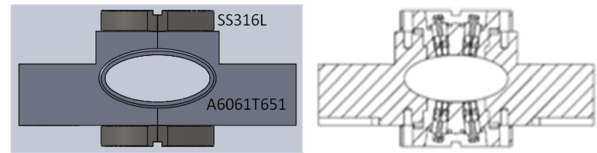


Figure 1: Structure of the TPS BPM flange and BPM beam duct.

Table 1: Brinell Hardness of TPS BPM Parts

	Material	Brinell Hardness
BPM flange	SS316L	217 kg/mm ²
BPM block	A6061T651	95 kg/mm ²
BPM gasket	A1050H14	32 kg/mm ²

DIAMOND-EDGE GASKET

Different from the Indus-2 design with angles 45°-90°-45° for the diamond-edge, angles 70°-90°-20° are designed for the TPS BPM diamond-edge gasket, illustrated in Fig.2. The reason to adopt 70°-90°-20° is to avoid sharp angles and to perform asymmetry deformation. Depending on the experimental data, a diamond-edge gasket of this type requires only 40 kg-cm to achieve a rate of leakage less than 2x10⁻⁹ mbar L/s. When the torque is initially applied to the gasket, the peak of the gasket tends to become flat; on a microscopic scale, fragments of the gasket flow into the valley of the flange surface (Fig.3). Of two main paths for leakage, one is radial and the other is circumferential [4]. As the torque is increased to a standard value, full sealing becomes achieved, but the roughness is proved to affect the seal quality [5]. As excess roughness would basically fail to attain full sealing, the roughness of all seal parts is carefully machined, with the roughness controlled to be less than 0.8 μm.

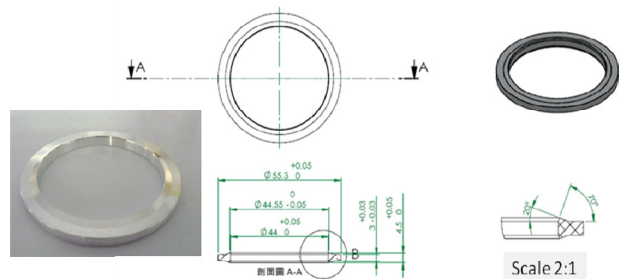


Figure 2: Structure of a TPS BPM diamond-edge gasket.

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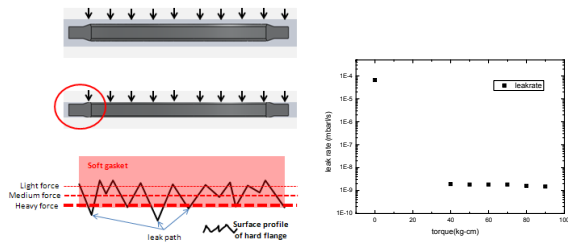


Figure 3: left, surface sealing philosophy; right, rate of leakage vs torque of a diamond-edge gasket.

STEPS FOR SEALING

Although torque 40 kg cm suffices for sealing, we take 70 kg cm as a norm to seal the BPM. A smaller torque has a risk that vibrations would loosen the nut and cause a leak. Fig. 4 shows the prepared tools and parts. Before sealing, we inspect a gasket under a microscope to ensure that no dust and ragged edge exists thereon. The steps for a diamond-edge gasket seal are also described in Fig. 4. The gap of the two flanges without gasket is 3.8 mm, and the gasket thickness is 4.5 mm. Before torque is applied to the gasket, the gap is about 0.7 mm; after torque 70 kg cm is applied to the gasket, the gap becomes 0.2~0.3 mm.



Figure 4: Pictures describing steps for sealing with a diamond-edge gasket.

HEIGHT VERSUS TORQUE

Figure 5 shows a relation between height and torque. Of six lines each is composed of seven points; each point indicates the torque increased another 10 kg cm, at which the change of height is recorded. For the best fitted line with all points, its slope is $0.0060 \text{ mm kg}^{-1} \text{ cm}^{-1}$. When the point at 40 kg cm is omitted, the slope of the line becomes $0.008 \text{ mm kg}^{-1} \text{ cm}^{-1}$. The correlation coefficient of the fitted line in Fig. 7 is greater than that for the line in Fig. 6. The main deviation seems to arise from the first point of the torque, which might be attributed to an abrupt increase of torque from 0 to 40 kg cm.

BAKING RESULTS

TPS BPM gasket has to pass a baking test, 150 °C for 24 h and cooling to 23 °C. On cooling 110 °C, a leak was discovered because of loss of torque. Hence the nuts must

be fastened every 10 °C until the temperature is 50 °C. When this baking and cooling cycle was repeated several times, the diamond-edge gasket proved reliable, even through tens of cycles baking and cooling, but the loosening of nuts during cooling is a difficult problem that increasing the torque to 90 kg cm or greater might alleviate. We did not test a torque greater than 80 kg cm because the screw holes are in the A6061T651 chamber; a large torque might damage the chamber

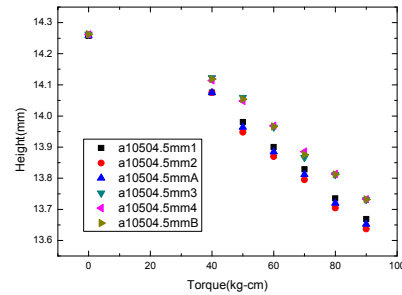


Figure 5: Compressibility of a diamond-edge gasket.

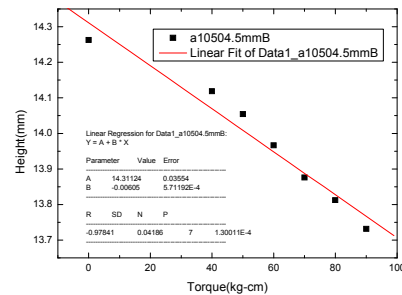


Figure 6: Best fitted line with all measured points.

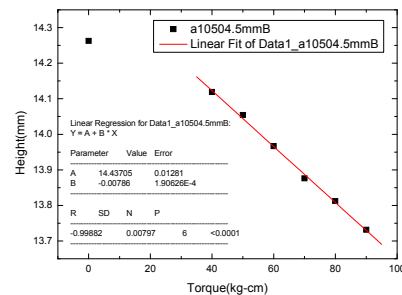


Figure 7: Best fitted line without the first point.

MICROSCOPIC IMAGES

Before and after sealing, surface images were recorded to test whether damage exists on the sealing surfaces (Fig. 8). The pointed end of the used gasket was compressed and turned flat (Fig.9). To test the uniformity of the axial force, a pressure sheet was used to estimate how isotropic was the distribution of the load. The magnitude of the load was deduced from the shades of colour (Fig. 10).

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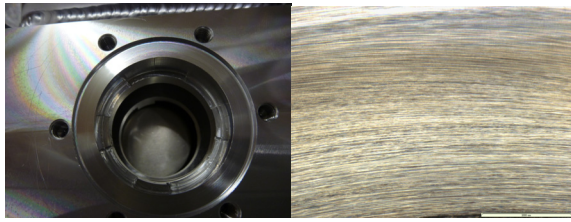


Figure 8: Machined surface of a BPM beam duct for a diamond-edge gasket.

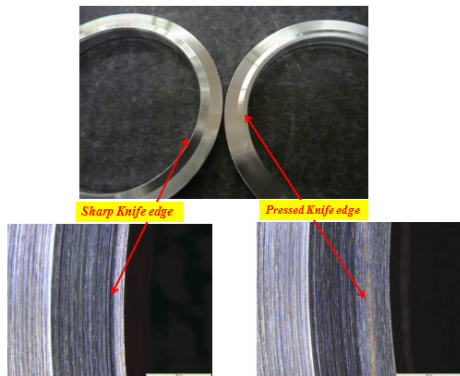


Figure 9: Diamond-edge gasket before and after sealing.



Figure 10: distribution of load on the peak of the diamond-edge gasket.

SUMMARY

Diamond-edge gaskets (material A1050H14) are used for the TPS BPM. Its small sealing torque is attractive and its machining is simple. Equivalent torques on nuts and the quality of the surface roughness are important parameters; these two factors determine whether BPM can be sealed to an ultra high vacuum. From the compression curve of a diamond-edge gasket, material A1050H14 is soft; the slope is believed to be related to geometry (not discussed herein). The designed height of the diamond-edge gasket must fit the gap and is intended to leave 0.2-0.3 mm to be compressed to prevent leakage after baking.

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