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SPECIAL ALUMINUM GASKET SEALING OF NON-CIRCULAR PROFILE FLANGES FOR THE ACCELERATOR UHV SYSTEMS

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Abstract

Most of the beam ducts for the accelerators are not regularly the circular profile. Unfortunately, the conflat (CF-) flanges and the gaskets with non-circular profile were not commercially available. Besides, additional RF-contact bridges between the flanges must be built in for mitigating the impedance from the flange-gaps. In this study, various types of the aluminum (Al-) gaskets designed for the non-circular profile Al-flanges for the accelerator ultrahigh vacuum (UHV) systems are introduced. The surface of the Al-flange is flat to accommodate the special Al-gasket with knife edges for the sealing. Both the flange and gasket are manufactured by the oil-free Ethanol-CNC-machining process that any non-circular profile, e.g. rectangular, race-track, key-hole, etc., flanges can be precisely produced. The inner diameters of the gasket just suit those of the flanges that the impedance from the gap is significantly reduced. The flanges and gaskets after oil-free machining can be assembled immediately without any chemical cleaning. The experimental results for the as-mentioned non-circular profile Al-flanges reveal the UHV quality at pressure < 20 nPa after vacuum baking.

INTRODUCTION

The profile of the beam ducts for the accelerators, to accommodate the dynamic aperture of the beam, is not regularly the circular profile. However, the traditional standard conflat (CF-) flanges produced by the lathing are only in circular profile. Then the additional RF-bridge components have to be built in between the flanges and along the edge of beam duct to form the same profile for conducting the image current and mitigating the impedance from the flange-gaps. The system of the CF-flanges assembled with the RF-bridge becomes more complicated and non-reliable. The better way to produce the non-circular flange is to reverse the sealing mechanism from the CF-flanges, i.e. sealed by the metallic O-ring. The gasket with the diamond-shape profile as the metallic O-ring sealing for the UHV systems had been developed by Rufer and Unterlerchner around 1970's [1] which lately named "LEP-type joints" were applied for the LEP accelerator at CERN successfully in 1990 [2]. Afterwards, other applications of the diamond-profile gaskets for the INDUS-2 in 2008 [3] and for the TPS in 2012 [4] and 2018 [5] were reported. However, the profiles of those diamond-profile gaskets were still in circular-shape and machined by the lathing process only.

In this study, various types of the aluminum (Al) diamond-edge (DE-) gaskets, with knife edges on both sides for the sealing, designed for the non-circular profile Al-flanges for the accelerator ultrahigh vacuum (UHV) systems are introduced. The surface of the Al-flange is flat to accommodate the Al DE-gasket with the same profile. Both the flange and gasket are manufactured by CNC-machining process that the profile of non-circular shape can be precisely produced. In case of the beam duct for the accelerators, the inner diameters of the gasket just suit those of the flanges not only performs the leak-tight but also mitigates the RF-impedance from the gap. The assemblies of the non-circular profile Al-flanges with the DE-gasket sealing can be applied for many Al UHV systems with high reliabilities. The non-circular Al-flanges and the DE-gaskets can be assembled immediately without any further cleaning if they are made by the oil-free ethanol machining process, which generates a clean surface oxide layer with much lower outgassing rate [6]. By the way, the ethanol CNC machining process also benefit the afterwards re-machining for the assembly of the Al vacuum chambers and flanges. The design concept and the development results for the non-circular profile Al-flanges will be described in the following sections

DESIGN CONCEPT

Since both the Al-flanges and the gaskets with the non-circular profile must be made by the CNC machining, therefore the concept of the sealing via the flat surface on the Al-flange accommodating the Al DE-gasket with knife edges is feasible. Figure 1 depicts an example of the rectangular flange, gasket, and the cross section view of the flange sealing. The materials for the Al-flange and the Al-gasket are typically the A6061T651 and the A1050O aluminum alloys, respectively. The gasket is soft with respected to the flange, that the tightening-torque for depressing the knife edges to the leak-tight is about 80 kg cm. The surface roughness (Ra) of the flange after CNC machining is typically under 0.8 micron. Then the gasket can be re-used by applying higher tightening-torque on the surface of smaller roughness. The CNC-machining benefits the free-trajectory that any non-circular profile, e.g. rectangular, race-track, key-hole, etc., flanges can be precisely produced. The curvature of profile for the gasket is larger than 3 mm in general. The inner diameters of both the gasket and the flange are easily machined that the impedance from the gap is significantly reduced. The knife-edges on both sides of the DE-gasket were machined to 90° triangular edge that forms a profile of so called diamond-shape. The outside diameter of the gasket is about 0.1 ~ 0.2 mm smaller than the inner diameter of flat sealing surface of the flange.

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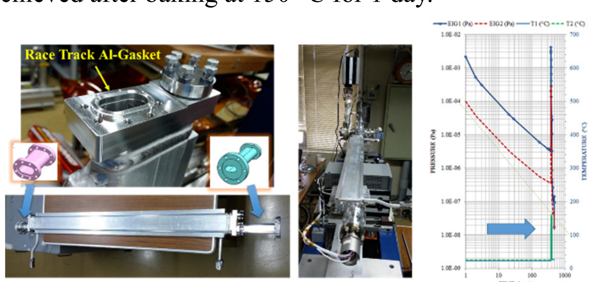
(a) (b) (c)

Figure 1: Drawings of the (a) Rectangular flange, (b) gasket, and (c) cross section view of the flange sealing with DE-gasket.

DEVELOPMENT OF THE DE-GASKETS

Flange and DE-gasket with Race-track Profile

A 1 m long aluminum extruded chamber (dummy chamber for the TPS) with inner aperture of race-track shape, 20 mm in height and 68 mm in width, was prepared for the UHV test. The chamber was cleaned with nitric acid followed by the ozonized water rinsing. The special non-circular adapter flanges on both ends were produced by oil-free ethanol CNC machining which can be directly welded on the Al-chamber without further cleaning. The two special flanges, race-track shape of 14 mm × 28 mm and round shape of 14 mm in diameter, were directed machined on the adapter flange. Those flanges to be sealed with the concentric same profile DE-gaskets are flat. Figure 2(a) shows the pictures of the Al-chamber and the gaskets. The plot of pumping-down curve is shown in Fig. 2(b) in which the arrow indicates the ultimate pressure of < 15 nPa (0.11 nTorr) has been achieved after baking at 150 °C for 1 day.



(a) (b)

Figure 2: Pictures of (a) the 1 m Al-chamber and the race-track DE-gasket, and (b) pumping down curve in which the arrow indicates the ultimate pressure.

Flange and DE-gasket with Key-hole Profile

The typical aluminum extruded chamber for the insertion device, e.g. EPU for the TPS, possessed an inner aperture of key-hole shape with 8 mm × 68 mm beam duct and 16 mm × 40 mm ante-chamber for NEG strip and a long pumping slot of 5 mm in height linked in between. The assembly of traditional Al CF-flanges requests a large machined reducer flange to transfer the different profile of flanges from the EPU chamber to the adjacent beam ducts, as shown in Figs. 3(a) and 3(b). The new designed Al reducer flange with key-hole profile and DE-gaskets, as shown in Fig. 3(c), were machined for the UHV test. Figure 4(a) and 4(b) depicts the pictures of the Al-flanges and DE-gaskets as well as the assembly test vacuum system, respectively. The pumping-down curve in Fig. 4(c) shows the arrow indicates the ultimate pressure of 7 nPa (0.05 nTorr) were achieved after vacuum baking at 150 °C for 1 day.

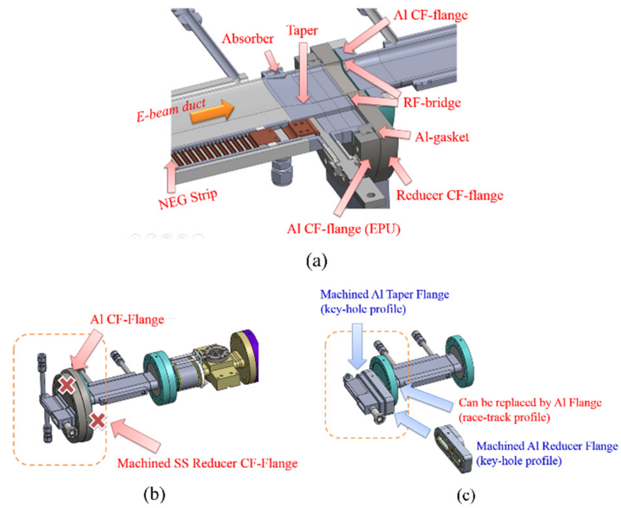


Figure 3: Drawings of the EPU-chamber and adjacent beam duct of (a) cross section view, (b) Al and Reducer CF-flanges, and (c) Machined Al Reducer flange with key-hole profile.

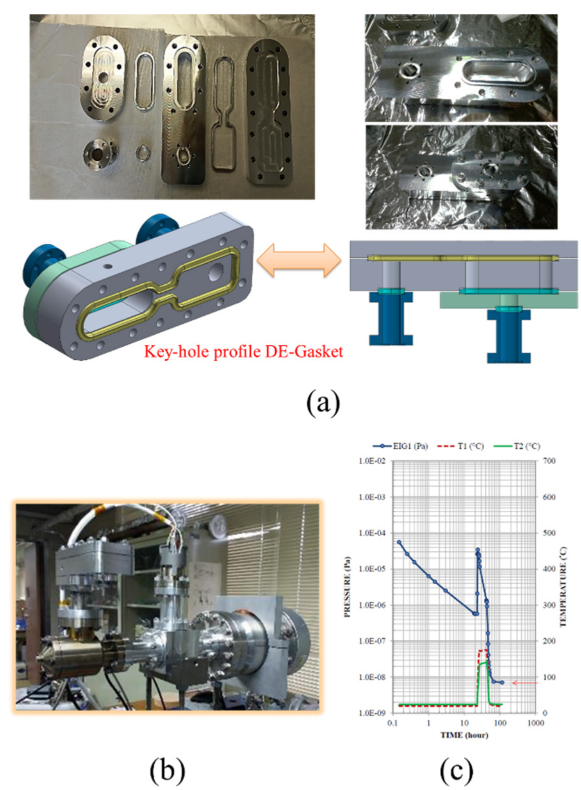


Figure 4: Pictures of (a) the Al reducer flanges with the key-hole profile DE-gasket, (b) assembly test UHV system for the key-hole Al-flanges, and (c) pumping down curve in which the arrow indicates the ultimate pressure.

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CONCLUSION

The special designed Al DE-gaskets developed for the non-circular profile Al-flanges have been produced for the applications of the accelerator UHV systems. The knife edges of the DE-gasket were depressed to the tight-sealing by the flat surface of the Al-flanges. Both the Al flange and DE-gasket, made of A6061T651 and A1050O aluminum alloys respectively, were produced by the oil-free ethanol CNC machining that no further chemical cleaning is necessary. The dimension of the inner shape of the DE-gasket can be the same as that of the Al-flanges for the accelerator beam duct that the impedance from the gap of the flanges is mitigated. The torque for tightening the Al-flanges sealed with the DE-gaskets is typically about 80 kg cm. The DE-gasket can be re-used few more times if apply more tightening-torque and on the surface with surface roughness (Ra) < 0.8 μm. The DE-gaskets for the non-circular profile Al-flanges including the race-track shape and the key-hole shape have been tested and achieved the ultimate pressure of 15 nPa and 7 nPa, respectively, after vacuum baking at 150 °C for 1 day. Besides the great UHV features, the reliability of the assemblies of non-circular Al-flange and DE-gasket is much higher than that of the traditional CF-flanges which provides the circular profile only. The development of the special Al DE-gaskets for the non-circular profile Al-flanges of larger size, higher aspect ratio, tilt-angles of the diamond-profile edges, the sizes of the bolts and the corresponding tightening-torques, etc. will be continued in the near future.

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