DEVELOPMENT OF A RADIAL COMPRESSED SEAL AND ITS REMOTE HANDLING DEVICES

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Abstract

This paper reports the design of a radial compressed seal and its remote handling flange used in the NP-hall of J-PARC. This facility will be handled a high intensity proton beam of $3x10^{14}$ppp accelerated by 50GeV. The power of a primary proton beam will be about 100 times greater than the currently slow extraction facility at KEK 12GeV-PS. The radial seal ordinary used as the seal of high viscous fluid was developed as a new flange system for a connection of vacuum beam pipes. Presently two flange devices were developed by each fastening mechanisms. The sealing capacity of the connecting device is reached with $<10^{-10}$ Pa.m^3/sec.

1. INTRODUCTION

The High Energy Accelerator Research Organization (KEK) and the Japan Atomic Energy Research Institute (JAERI) is jointly constructed the High Intensity Proton Accelerator Facility (J-PARC) in Tokai, Japan [1]. The facility of this project will be planed the counter experimental hall called the NP-hall for nuclear physics and high-energy particle physics. The primary proton beam will be extracted out to the NP-hall as slow extraction mode with 0.7s pulse width, 3.27s cycle. This NP-hall has been designed to handle a primary proton beam of up to $3x10^{14}$ ppp (protons per pulse). The power of a beam line of the NP-hall will be 750 kW; it is about 100 times greater than the currently slow extraction line of the north counter hall at KEK 12GeV-PS. Therefore the development of new technology for handling a high intensity beams is absolutely required. Especially in order to prevent beam line loss less than a few W /m, the vacuum pipes for a beam transport will become large aperture such as about a 300mm diameter. According to a large aperture pipe, a large connection flange is needed. The existing devices of a flange connection was a Conflate flange, a V-band coupling with an elastomer rubber and a metal O-rig, and the pillow seal flange, etc.

That flanges which uses with a bolts-nuts is most popular, many industrial standards was employed in the accelerator facilities. But these flange devices have many bolt parts, to need much time for a fasten work, and it must fasten by hands.

Although the V-band coupling of these devices has the flange of large size, the fastening compressed ability to generate by a belt is small, and it does not have for a metal seal with radiation hard. The remotely fasten device of a V-retainer as evaluated a V-band belt was developed in the north counter hall at January 1990 [2,3].

From the PSI (Paul Scherrer Institute, Switzerland), we had technology supplied and the pillow seal flange without bolts and nuts was installed a beam line of the north counter hall [4]. The pillow seal device is sealed by a metallic baggy therefore this is given a scratch damage on the surface of a metallic baggy. Also as for a sealing capacity, a few 10^{-7} Pa.m^3/sec are a limit.

The presently a radial compressed sealing was used a high viscosity fluid, for example a water connection. The flange device by using of a radial seal has a need of a socket and a plug flange. Therefore the flange use scarcely for a vacuumed beam line. However, a radial seal flange can realize the large flange by small fastens power, and there is some possibility that a sealing capacity is also obtained enough.

2. DESIGN CONSIDERATION

2.1 Design Requirements

The beam line components such as magnets, vacuum pipes and beam monitors are required to work under very high radiation environments and will have very strong residual radioactivity. Maintenance of these equipments must be carried out against very high radiation. Therefore the most important character is that it must never break. However, in the case of need, maintenance should be carried out quickly from distant location. For example, the residual radiation on a primary beam line will be over 170 Sv/hr surrounding the production target after a normal operation period (a half year) [5]. The connecting devices itself is more radioactive, to install and evacuation in remoteness and a short time for maintenance work. Therefore a seal material with getting scratch damage and corroding by an oxidized gas is expected a disposable materials. The quantity of an air

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leak has an influence in a beam line loss, therefore better than small leak rate of vacuum connections <1x10^{-8} Pa.m^3/sec of He.

2.2 Radial Seal

The radial seal is compressed a sealing ring for radial direction of a beam line. The radial seal is one of metal seal is based on the plastic deformation of a lining of greater ductility than the materials surrounding it. The radial seal is possibility of internal and external compression. Internal compression expands the inner diameter of the seal. External compression reduces the outer diameter. The cross section of a radial seal structure seal is shown in Fig.1.

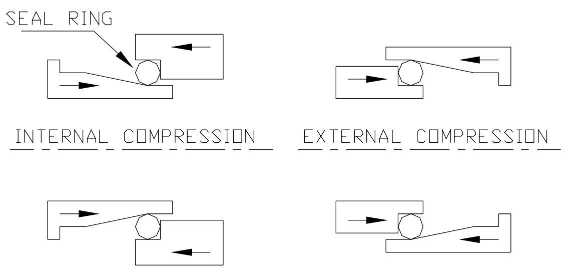

Figure 1: The cross section of a plug and socket

A left figure is the seal flange of a taper plug type with an internal compression and usually moves a taper side. The right figure is a case of a taper socket flange. And both types in which an opposite flange of a taper side carries out movable can be exceptionally considered.

The radial seal has the following excellent characters.

1. Tightening force required the 1/10 of an axial compression flange.
2. The plug and socket flange have self-guide function, with large tolerance of a centres of both axes.
3. It is easy to install.
4. The seal material is a disposable.

On the other side, the weak points are as follows.

1. The plug and socket flange is necessary.
2. The tightening stroke is long.
3. An air leak may be cause between the different materials such as a seal and a flange in heat expansion.
4. The lubrication on taper surface is essential.

The cross-sectional form of the seal material used for figure 2 is shown. The type-A of figure 2 is usual axial type seal section form. Pressing carries out a seal from right and left by the parallel plane. The type-B, C and D were prepared for radial seals. Each seal is a lack of different angle and especially the outer cover of type-D is carrying out overlap structure. The sizes of a seal ring used for the R&D are a 210mm of an inner diameter, and a thickness of 4mm. The size use is actually expected to be is about 300mm in a diameter of an effective inner aperture. The spring coil which puts in a ring tube was made of a SUS304 is used for the core material, and a skin covers with an aluminium alloy A1050 over an outside. The compressed force is expected a 60 % of an axial seal, such as 0.54mm for 4mm thickness. When a taper angle is set to 1/10, it is presumed that the compression force of an axis direction is required a 21daN/cm for this size.

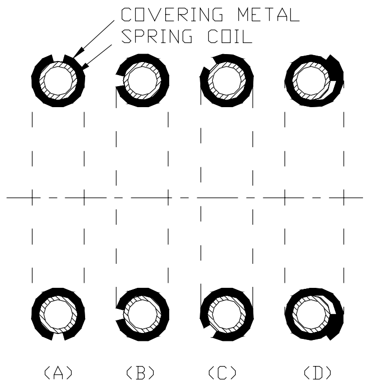

Figure 2: The cross-sectional forms of each seals

The relation of the compression force and a seal capacity performance was checked in figure 3. The seal performance to expect with 1x10^{-8} Pa.m^3/sec was reached by compression force smaller in early stage. And the marginal value was observed about 1x10^{-9} Pa.m^3/sec in this case. However it is the seal capacity performance, which can also fully use this for our beam line.

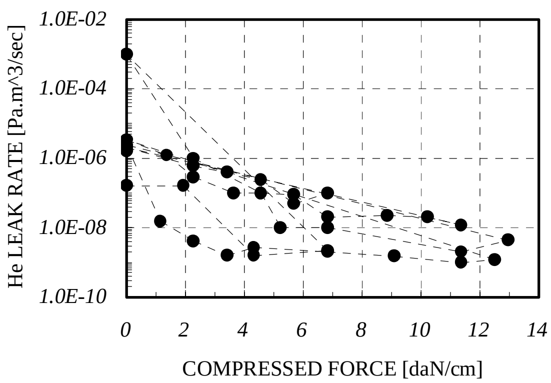

Figure 3: The compression power and a leak rate

3. EXTERNAL COMPRESSION

3.1 Taper socket flange

First radial seal device of a taper socket type was developed at March 2003. The asymmetry for flanges of weak point of the radial seal is settled that to insert and the plug-plug or the socket-socket flange expand between fixed flanges as pillow seal. Here is a figure that shows in figure 4. The dotted line of right and left in a figure 4 assumes the situation where it was installed into the magnet. The reason for having chosen both taper socket types is that it is inside a compressed taper that is easy given a scratch damage. It is easy to install a seal ring and is based also on the reason, which can be carried out outside of a beam line with the extended equipment of centre. The picture of the device is shown in figure 5.

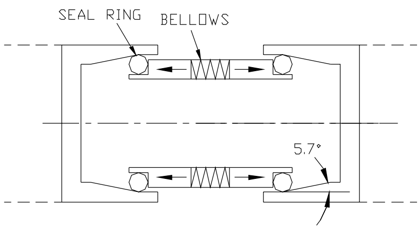

Figure 4: The concept of external compression

Figure 5: Outside view of the taper sockets device

The result of the experiment was that the sealing capacity is 1×10^{-8} Pa.m^3/sec. The seal capacity of the metal seal ring is about 1×10^{-9} Pa.m^3/sec of marginal performance. One explanation for an insufficient of seal capacity may be that external compression is not uniformity without lubrication. Moreover, because of the trace left behind to the seal ring, the seal line by which a seal ring and a taper socket have touched moved in a snaky circle line.

4. INTERNAL COMPRESSION

Although it thought that there was no difference performance from the compression method so much at the beginning of development, by the above result, the seal capacity performance of an internal compression (a taper plug) and an external compression (a taper socket) was compared using the same size sealing in figure 6.

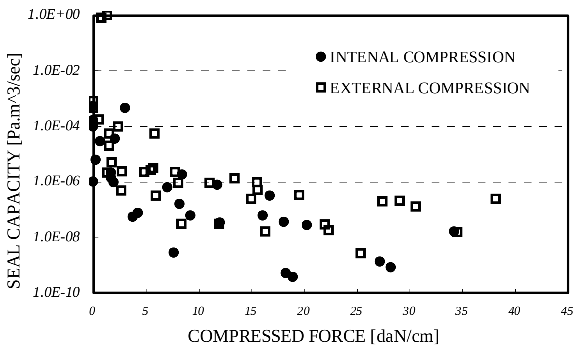

Figure 6: The seal capacity performance of an internal taper and an external taper was compared.

The seal capacity of the taper plug type is slightly good than the taper socket type. The taper plug type to which a seal ring can extend this outside is considered.

At present, the remote flange device of the taper plug type is under development, the picture is shown in figure7. And now its performance is checked.

Figure 7: Outside view of the taper plug device (Internal compression)

5. SUMMARY

The radial seal for a connecting device of high viscosity fluid technology was established to sufficient use for a future vacuum-connecting flange for handling a high intensity beam. The radial seal flange of large diameter is carried out an airtight by small tighten force. A metal seal ring of internal compression is carried out a high seal capacity with a few 10^{-10} Pa.m^3/sec.

6. ACKNOWLEDGMENT

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