APPLICATION OF MO SEALING FOR SRF CAVITIES

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Abstract

H. Matsumoto in KEK and his collaborator M. Ohotsuka have developed MO sealing for normal conducting high peak power RF wave-guide. This is impedance free sealing. We have applied this sealing to SRF cavity instead of indium sealing. We used pure aluminium gasket as the sealing material. We had a difficulty on the titanium flange but finally succeeded to demonstrate its leak tightness in super-fluid Helium. In this paper, we will report the R&D results.

INTRODUCTION

The concept of the seal so call MO seal has originally come from the S-band accelerator design at DESY [1]. H.Matsumoto and M.Ohotsuka have successfully realized it for C-band high peak power RF/vacuum system [2]. In 2006, we studied this seal as an elemental technology R&D for the SRF cold vacuum seal and successfully confirmed to be leak tight in the super-fluid Helium [1]. Since then, we are developing to use it for wider areas in the SRF cavity because this has many advantages compared to the currently used seals: RF zero impedance, easy cavity assembly, cost saving, and so on.

MO SEAL

The original MO flange and its seal are shown in Fig.1. The features are: 1) the gasket is bitten at the inner square flange edge, which makes vacuum leak less sensitive about scratches on the gasket surface, 2) the seal is gap-less contacting tightly flanges/gasket/flange, which produces RF zero impedance, 3) the flange has nock-pins for the gasket not to move during assembly and this also helps as a guider for easy assembly, 4) the gasket is less expensive compared to Indium seal or other gaskets currently used in SRF field. The feature 2) looks like the ICF seal, which has a knife-edge but has a gap between flanges. MO seal is better structure for RF shielding than ICF design.

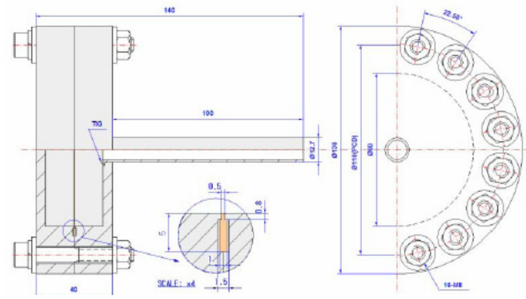


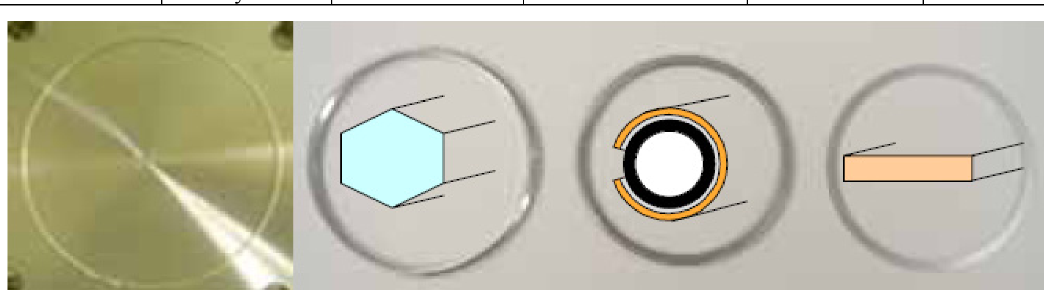
Fig.1 The Original MO seal design by H.Matsumoto.

Comparison of gaskets

Table 1 compares the currently used seals with SRF cavity vacuum seal. Fig.2 shows the gasket shapes and materials. Indium wire sealing has been successfully used reliably in super-fluid Helium for a long time, however the difficulty is in removing the gasket due to the sticky adhesion, which is a potential of Indium contamination. So in the TESLA R&D, DESY successfully developed so called "Diamond seal". Its seal material is aluminium alloy and the cross-section is a hexagon seen in Fig.2. Due to the complicated shape, the cost is rather high. Higher tightening torque is needed compared with others. KEK STF-baseline group uses Indium plated U-tight seal. This seal structure is very complicated and extremely expensive. MO seal has a simple gasket like ICF one. The material should be less expensive. So this seal should be cheapest. The tightening torque should be similar to Indium wire seal if used a soft material like pure Aluminium.

Table 1: Comparison of the features

Sealing Types	Easy handling	Tightening torque [Pam]	Gasket material	Cost [$]/a 90ϕ seal	Demerits
In wire	Complicated	15	Pure Indium	24	In contamination
DESY Diamond	Easy	30	Aluminium alloy	30	High toque
In plated U-tight seal	Easy	15	SUS+In plating	120	Expensive
MO seal	Easy	15	Pure Aluminium	5	Flange masking on chem.



Indium wire sealing DESY "Diamond gasket" In plated U-tight seal MO seal (Al or Cu)

Fig.2 Currently used SRF cavity sealing

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MODIFICATION OF DESIGN AND MATRIALS

We have modified the original MO flange design to be more suitable for SRF cavity. New MO flange design is shown in Fig.3. The modifications are:

1) Flange/gasket/flange contact to flange/flange contact,
2) Small holes are made on inside of flange against the air pocket,
3) Flange material from SUS316L to Titanium,
4) Bolt material from SUS to Aluminium alloy,
5) Flange face-to face contact at the outer flange to a small gap,
6) Gasket material from copper to pure Aluminium.

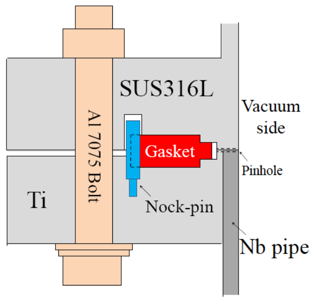

Fig.3: Modified MO flange. The size is not scaled.

The modification 1 is the biggest change. Our flange of SRF cavity is electron beam welded Titanium flange outside of a Niobium tube 2.8mm thick, of which Vickers hardness is about 50. If applied the original design, the Niobium edge will yield to the gasket. So we designed to machine the square edge on the Titanium flange side. This design change has an advantage and a disadvantage. The advantage is less particle contamination from gasket during flange tightening because the gasket is hidden from the SRF surface. Disadvantage is an air pocket. To eliminate this problem we make small holes penetrating to the SRF surface (Modification 2).

A big concern in the SRF application of MO seal is thermal expansion coefficients among the different materials. Table 2 summarize the thermal shrinkage coefficients from 300K to 10K. Titanium (Ti) has a very small shrinkage. Its Vickers hardness is about 140Hv and hard enough on well annealed Copper (~40Hv) or pure Aluminium (~30Hv), which are a candidate of seal gasket material. The price is not so expensive as Niobium. Titanium is easily EBW welded on Niobium pipe. From these reasons, we have chosen Titanium as the flange material (Modification 3).

Table 2: Measured shrinkage coefficients* on our concerned materials in this R&D

Materials	Shrinkage (dL/L) 300-10K
SUS 304	2.83E-3
SUS 316L	2.96E-3
Cu	3.26E-3
Al 1050 (pure Al)	3.93E-3**
Al 7075	3.89E-3**
Ti	1.47E-3
Nb	1.53E-3

* This work has been done by the collaboration with KEK and NIMS leaded by K.Tsuchiya. The details will be published somewhere.
** 300-77.4K, calculated from Aluminium Handbook, Japan

In this R&D, the big challenge is how to compensate the shrinkages between flanges and gasket. Modification 4 and 5 are to fix this problem. Niobium gasket might be best choice from shrinkage point of view but it is costly. So far we are testing pure Aluminium as the seal gasket. By the cooling down from 300K to 4.2K, the bitten Aluminium gasket part (0.5mm @ RT) shrinks by 2□m. If outsides of the flanges keep contacting, the shrinkage of Aluminium gasket could not be compensated. Choice of Aluminium alloy bolt is by this reason. If there has a gap (Modification 5) and bolts with high thermal expansion coefficient are use, Aluminium gasket shrinkage will be compensated. Modification 6 is to reduce the tightening torque for women to be workable in this field.

PRINCIPLE PROOF EXPERIMENTS

We have made principle proof experiments first. Fig.4 illustrates our detection system of superfluid-leak. The method is the same as M.G. Rao's one [3].

Experimental Method

MO flange is bolt tightened with another one locating bottom of the test stand. Inside of the flanges is evacuated by a helium leak detector. After that, the object is cooled by liquid helium, and filled up some level. The liquid helium is pumped down lower than 38.4 Torr (2.17K) to produce He-II. During the cooling down, high sensitive Q-mass detector also measures the helium partial pressure. When no leak happens, the object is exposed to the He-II environment (20-10 Torr) for three hours closing off both gate valve at the cryostat Top flange and head valve of the He leak detector. After warmed up to 300K, opening the gate valve first, the helium partial pressure is measured by the high sensitive Q-mass, then the amount of helium gas contained in the line is measured by the He leak detector. The signal from the helium-leak detector is integrated and calculated as the leak rate.

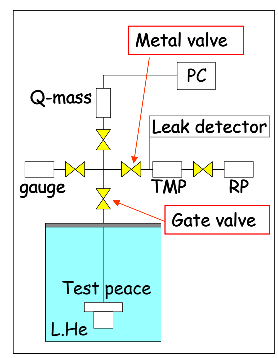

Fig.4: High sensitive cold leak test system at KEK

Results of the Principal proof experiments

Fig.5 shows the summary of the principal proof experiments. In these experiments, the aluminium gasket cleaning, indium plating on gasket, annealing (350°C, 3hr in vacuum), and bolt material dependence are investigated. The first and second results in Fig.5 are on cleaning, which is done used the same BCP (30 sec) acid for SRF niobium cavities. When no etching is done, the probability of leaking is 80% with 5 tests. Cleaning is very essential.

Indium plating by 7-15μm improves the reliability up to 100% but it is too expensive so far.

Annealing of gasket (350°C for 3hrs in vacuum) makes the material softer. Hardness of the pure Aluminium gasket usually becomes around 30Hv, which improves the leak rate by a magnitude of 2.

Using Aluminium alloy bolts instead of SUS304 ones improves the leak rate by a magnitude of 2.

Thus, we can conclude that the best way is to anneal gasket first, clean it by BCP acid, then tighten with Aluminium alloy bolts. Table 3 shows the result of 5 times tests by the best way. Averaged He leak rate was (2.8±3.0) E-12 Atm cc/sec.

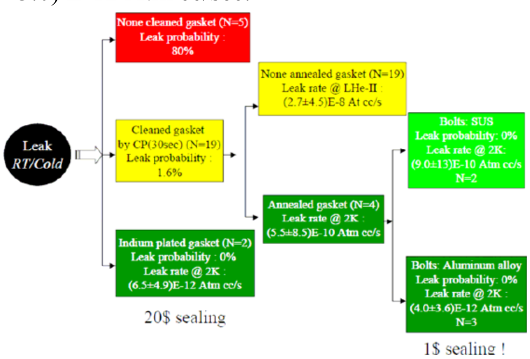

Fig: 5 Summary of the principle proof experiments

As MO seals locate outside of the helium vessel in the cryomodule, the leak tightness with superfluid helium is most serious at vertical test.

Table 3: Summary of the reducible test of the best way

Test No.	Leak Rate [Atmcc/sec]	Bitten Thickness [mm]
1	5.1E-12	0.504±0.004
2	2.3E-12	0.505±0.004
3	1.5E-12	0.507±0.006
4	1.2E-12	0.504±0.004
5	1.0E-12	0.501±0.004
Average	(2.8±3.0)E-12	

TEST RESULTS ON SINGLE CELL CAVITIES

We made vertical test the MO seal with 1.3GHz single cell cavities. One is on MO flange welded to the input coupler. The other is on MO flange used as Top flange. Fig.6 shows the Top flange case. In both tests, PLL feed back system was worked very stable for 3 hours exposing to He-II environment. Fig. 7 shows an example of successful vertical tests on the MO input flange case.

Fig.6: MO seal test with single cell cavity.

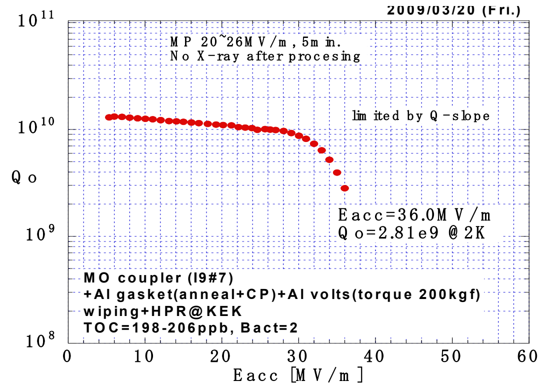

Fig.7: An example of successful vertical test using MO seal.

SMALL PROBLEMS

Small leaks after warm up

The vertical tests were no problem on the MO seal but a small leak was observed after warmed up to room temperature. The leak rate was 5E-11~7E-6 Atm cc/s. This might be that the annealed pure Aluminium gasket is too soft. The hardness of the gasket is Hv=27. Annealed copper gasket is Hv=40. We will try Copper gasket next.

Ti flange corrosion during BCP

Another problem is corrosion of the flange., Titanium flange is often corroded by the BCP/EP acid vapour during the process. When the gasket bitten area of the flange is corroded, it often makes a cold leak. Fig. 8 shows an example of the corrosion. The blushing by 3M Scotch Brite usually works but is worried particle contamination. We have to develop a better masking against the acid vapours.

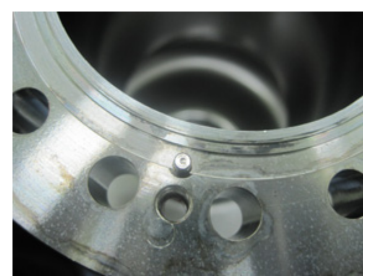

Fig.8: Titanium flange corrosion during BCP

SUMMARY

MO seal is under development for the SRF cavity. If it has succeeded, it will bring a big advantage to the SRF cavity technology on cavity performance and cost. So far it has been confirmed the MO seal works in the vertical test with super-liquid helium but happens a small leak after warm up. For the establishment of this technology, still R&D is needed, especially gasket material. Copper gasket will be tested very soon.

REFERENCES

[1] H. Matsumoto et al., EPAC06 proc., pp.753-755, MOPLS085
[2] H.Matsomoto et al., PAC97, Proc. pp.530-532.
[3] M. G. Rao, J. Vac. Sci. Thechnol. A(114)Jul/Aug 1993, pp.1598-1601.