Nb/SUS JOINT OF HELIUM VESSEL BASE PLATE FOR SRF CAVITY DRESSING

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Abstract

Different material joint is a key issue for dressing of the SRF cavity. So far the baseline design of ILC is to use titanium helium vessel, however, it will make very complicate procedure from high vessel regulation code point of view. If material is changed to stainless steel from the titanium at the place close to cavity, the regulation control should be much more relaxed. We have developed the joint method niobium and stainless steel applying HIP technology, and demonstrated it to work fine in the STF0.5 experiment. The result is presented in this paper.

MATERIAL OF THE MODULE-INTEGRATION

Material Configuration of the ILC Base Line Cold-Mass

A conceptual design of the ILC cryomodule is shown in Fig.1. Eight cavities will be hung by a helium gas return pipe with 300mm diameter. In the baseline design, the used materials are: 1) niobium for cavity, 2) niobium-titanium alloy (NbTi) for cavity beam pipe flange, 3) titanium (Ti) for helium vessel, 4) titanium (Ti) for 2K helium liquid supply line, 5) stainless steel (SUS316L@JIS and others) for Helium gas return pipe.

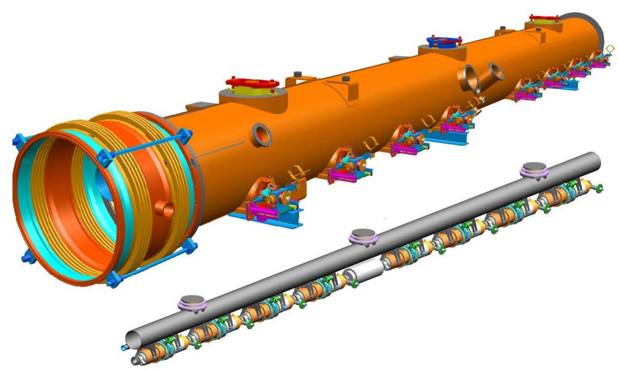

Figure 1: ILC cryomodule.

Titanium has similar thermal expansion coefficient with niobium and a light material. Titanium is easy to welding to niobium by electron beam welding (EBW).

However, titanium is very difficult to weld with stainless steel. Fig.2 illustrates the material configuration on the ILC baseline test facility, which is under construction at STF in KEK. In this configuration, a material transformer from titanium to stainless steel is needed somewhere between the gas return pipe and 2K

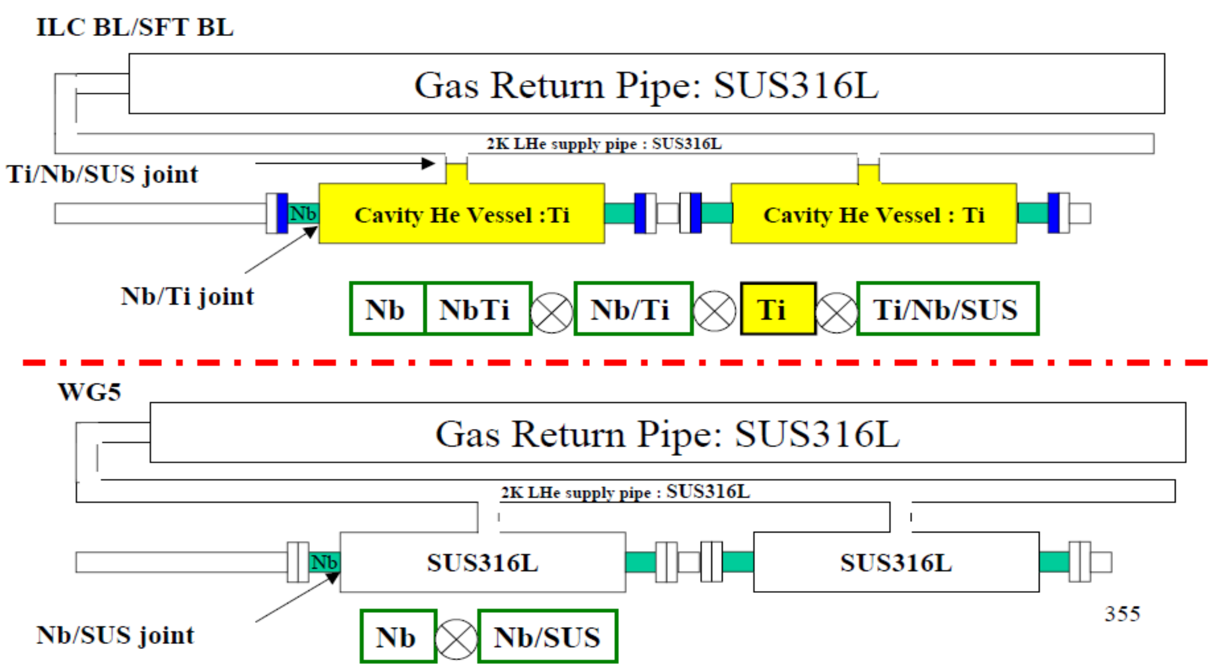

Figure 2: Materials for cryomodule integration.

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helium liquid supply line. Flange connection is one possible way but cold leak is worried at the sealing for the future ILC machine. Thermal cycles of the machine and long-term operation more likely produce the cold leak. When it happens, people will get panic in such a huge machine. So usually welding is preferred than flange connection, but reliable welding technology has not been developed yet for Ti/stainless steel.

Titanium is quite new material to use at cryogenic temperature and expensive. From safety point of view, one must not use inexperienced new material so much for such a huge machine like ILC. High-pressure safety regulation is another issue, which every country has his own. Titanium is not allowed at the temperature below 4.2K in the Japanese regulation so far. We would need special permission from the government, which is quite similar to niobium. This process is very much time consuming and more likely disturbs the construction schedule so much. This regulation controls different material joints either. As seen in Fig.1, in the baseline scheme high-pressure regulation concerns niobium and titanium themselves, in addition different material joints niobium/titanium and titanium/stainless. It is too much. Of course we hope the regulation could be more comfortable for the international construction with ILC but it is still a big issue to be considered.

Proposal of Stainless Steel Helium Vessel

If chosen the stainless steel helium vessel, this situation can be more relaxed. Stainless steel is a well-established material at cryogenic temperature. Already LHC has used it for their superconducting magnet helium liquid tank at 2K in such a huge circumference of 27km. As seen in Fig.2, the concerned issues are only two: niobium itself and Nb/SUS joint. The treatment of the high-pressure vessel safety regulation should become very much relaxed.

However, there is a reason why they did not choose stainless steel. The thermal expansion coefficient of stainless steel is larger a factor 3 than that of niobium. When niobium cavity is cooled down, helium vessel shrinks more than the cavity. So one has to be careful for the cavity not to have stress from the helium vessel and not to be detuned in the worst case. Usually helium vessel has a bellow and a mechanical tuner. This thermal stress effect could be controlled by the tuner operation during the cool down [1].

The other reason is we have not yet reliable welding method between niobium and stainless steel. Explosive bonding is a candidate technology but very difficult to apply pipes. Brazing has been to use in Jlab but it still weak to convince the high-pressure regulation. One has to control well the solder follow into the gaps in this technology. Here proposed Nb/SUS joint by HIP can produce perfect contact between the different material surfaces directly or through an insulator. If successfully developed the reliable Nb/SUS joint method, it will bring lots of benefit on cryogenics and change the situation so much.

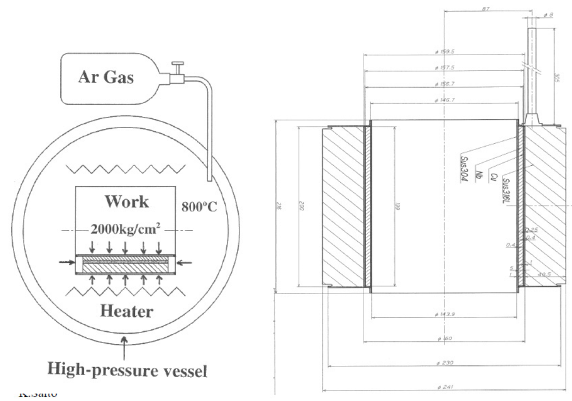

Figure 3: HIP bonding method.

DEVELOPMENT OF NB/SUS JOINT TECHNOLOGY

Here our proposed method is much reliable about the different material bonding and much more suitable for mass-production like ILC.

Nb/SUS joint by HIP

We have developed Nb/SUS joint using hot iso-static pressing (HIP) technology [2]. Fig.3 shows an example how to make the helium base-plate by this technology. We prepare four tubes: a innermost steel tube to protect niobium tube from Argon gas exposure during HIP process, a niobium tube, a copper tube as insulator, and outermost thick stainless tube. We put these four tubes together. End caps are welded at the both ends of this four-folded tube. The body is evacuated with baking around 250^{O}C. After the evacuation, it is finally chipped the pipe off and the gaps between tubes are kept under vacuum. One can use electron beam welding for the canning.

The body is put in a furnace and pressurized by heated Argon gas. The furnace is held for several hours at a pressure about 1000-2000kg/cm^2 and at a temperature 800-1000^{O}C. Niobium and stainless steel don't bond each other, but copper has a good bonding property with the both. In this duration, the copper becomes very soft and moves any gaps between the niobium tube and the

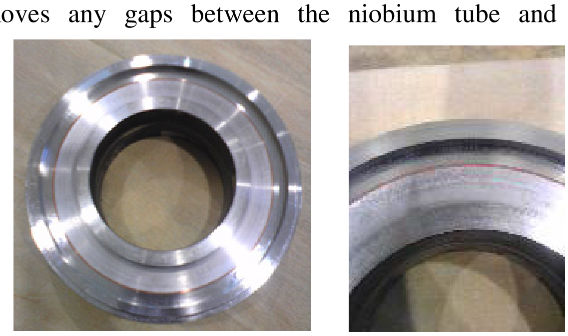

Figure 4: A machined roughly helium base-plate (left). The picture zoomed around the insulated copper area (right).

stainless steel tube. Thus one can obtain a very firmly bonded Nb/SUS joint. After cooling the furnace, one takes out the body and slices it at any size, which he wants.

Making the helium base-plate, we sliced it off about 25mm long and remove off the inside steel using lathe and take off some parts up to the niobium appears, which is a part of cavity beam pipe. One example is shown in Fig.4.

For a mass-production, one can put many bodies in a big HIP furnace, which is already under commercial service in several HIP companies. So this technology is very suitable for the mass-production.

Cold Leak Check

After machining the sliced part roughly, we make cold leak test first on the Nb/SUS bonding area. The method is very similar to that by M.G.Rao.at JLAB [3]. Our cold leak test system is illustrated in Fig.5. An example of cold tested base-plate is presented in Fig.6. In this case two pieces are tested at the same time (Fig.6 left). Our concern is the copper area. The chamber is TIG welded to the evacuation line at the top pipe (see Fig.6 right). The body is hanged cryo-stand and inserted into cryostat. Liquid He-II fills the inside of the cylinder. As seen Fig.5, we have a high sensitive residual gas analyser (RGA) on the top plate of the cryostat, which detects He partial pressure.

After confirmed leak tight during pumping down from 760 to ~10 torr, we close the gate valve located at top plate of the cryostat and stay for 3 hour at ~10 torr. Then we warm up the body room temperature for one night by heating. Next morning we open the gate valve and measure the collected helium gas in the closed line. This is an integrated method. The sensitivity is 1000 times higher than the usual leak checking method.

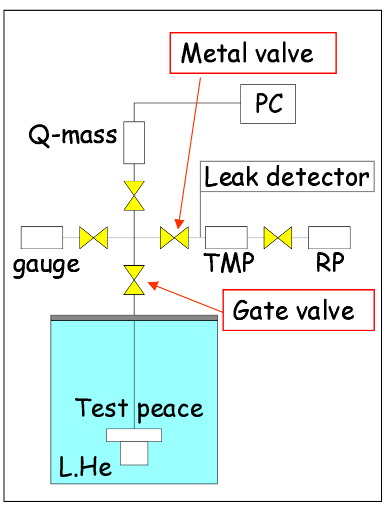

Figure 5: High sensitive cold leak test system at KEK.

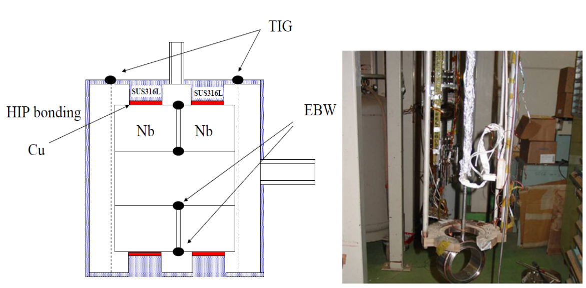

Figure 6: An example of cold leak tested base-plates. The left is welded pieces; the right after TIG welded pieces on the cold leak test line.

Welding of the Base-Plates

After we confirmed the leak, we machine the pieces to complete the correct size and weld on the end group by EBW. Fig.7 shows after welding the base-plate on end half caps. Beam pipes are EBW welded on the both helium base-plates and completed the end groups. Further more, these end groups are welded on the dumbbells and a 9-cell cavity is completed.

Figure 7: The welded base-plate on end group.

Cavity Dressing

Helium vessel is finally dressed on the cavity, which is made of stainless steel as seen in Fig.8. TIg welding is used in this dressing. After that it is installed into STF Cryomodule.

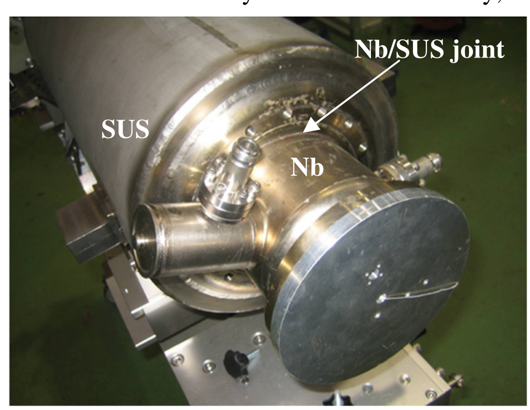

Figure 8: The cavity dressed helium vessel.

TEST IN THE STF0.5 PROGRAM

STF0.5 Program

Two groups are developing cavity package at KEK: STF baseline and ILC alternative. So far entrance of the STF tunnel is too small to bring in a full ILC module. The original program of STF was that each group install 4 cavities for each half cryomodule (Module #A and #B), which can install 4 cavities maximum, then combine into one full module in the STF tunnel, then make high power test at 2K. However, both groups delayed the schedule and KEK decided to test one cavity package each first:

Wrong Suspicious of the Vacuum Leaking Point

Once, we connected both cryomodule in the STF tunnel but a vacuum leak was found around our cold mass. They suspected first our Nb/SUS joint at the helium base-plate. Really the leaking place was closed to the joint, however to point out the leaking place exactly was difficult. Finally we took out our cavity package from the module and made leak check in detail. However, any vacuum was found in our cavity package. During this leak test, we made thermal shocks 4 times by liquid nitrogen and the cavity package was still leak tight. Finally we reassembled the package into the cryomodule. Meanwhile the baseline group successfully finished high power test for their one cavity package at STF. Following their test, we also successfully test our cavity package.

Successful Demonstration of the Leak Tightness

Our STP0.5 test started from end of January 2008 and finished end of March 20008. Our helium vessel made of stainless steel shrinks 3.2mm from room temperature to 4.2K while the cavity shrinks only 1mm. We have to take careful cooling down from room temperature to about 4.2K not to load too much stress on the cavity. First at 250K, we operated the motor tuning system and made pre-load on the helium vessel, which adjusted the helium vessel length longer by 0.5mm expanding the bellows. The similar processes took place at 200K, 145K, and 84K. Totally the helium vessel length was prolonged by 4mm longer in this cooling down. We believe this careful cooling down process contributed to our successful STF0.5 experiment result.

During the high power tests, we never observed cold vacuum leak or vacuum leak in the horizontal cryostat vacuum chamber. After warming up the cryomodule, we never see the vacuum problem. We have successfully demonstrated the cold leak tightness on the Nb/SUS jointed helium base-plates.

SUMMARY

In this paper we proposed to use stainless steel for the helium vessel of the ILC cavity, which will make the system more reliable safety point of view and relaxes the time-consuming high-pressure regulation process.

To use the Stainless steel, we have to develop reliable Nb/SUS joint. We explained how to make such a joint by using HIP technology. Finally we have demonstrated in the STF0.5 experiment that our Nb/SUS joint works fine.

REFERENCES

[1] K.Saito et al., “High Power Test Results of LL Cavity Package in STF0.5 Program at KEK”, Proc. of the 14th SRF Workshop, TUPPO023,

[2] H.Inoue and K.Saito et al., “HIP bonding between Niobium / Copper / Stainless steel Material”, Proc. of the 2nd Superconducting Linear Accelerator Meeting in Japan, 27-28 May, 1999, KEK, Japan, in Japanese, pp.148-152.

[3] M.R.Gao,”High sensitivity He adsorption leak detection method”, J. Vac. Technol. A 11(4), Jul/Aug 1993. pp. 1598-1601.