ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPAL031

DEVELOPMENT OF VERTICAL ELECTROPOLISHING FACILITY FOR NB 9-CELL CAVITY

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Abstract

Our Nb accelerating cavity vertical electropolishing (VEP) facility development group which was led by KEK started single-cell VEP facility development from 2014. This is based on KEK's over 10-year horizontal electropolishing (HEP) techniques and Marui's over 30-year stainless steel electropolishing techniques. We have reported results of Nb cavity VEP with Ninja cathode so far. In order to achieve international linear collider (ILC) construction, it is said that cost reduction and productivity improvement are necessary, however in case of 9-cell cavity, uniform inner surface polishing is difficult, as well known to predecessors. In this article, we will report the first report of VEP facility development from initial mock-up to improvement for Nb 9-cell cavity.

REGARDING ELECTROPOLISHING 4M

Our 9-cell VEP development points are based upon know-how gained in over 30 years of experience with stainless steel electropolishing. In contrast with HEP, which has an over 15-year track record with Nb material, our development of a VEP system started from scratch. We began by laying out the basic points of electropolishing. The following points are essential in achieving uniform electropolishing. 1) Basic Elements a) Agitation of the sample b) Management of the EP solution flow c) Management of the current d) Build optimal cathodes for target material. The above 4 items may be called the 4M of electropolishing. 2) Why are the 4M necessary? Based on our many years of experience, unlike electroplating, electropolishing work requires a viscous film and viscous layer. 3) We hypothesized that a satisfactory electropolishing cannot be achieved without creating a viscous film in the initial stages of the electropolishing. But this viscous layer also becomes a factor in the flow of hydrogen bubbles. If this viscous layer is not controlled, the optimal electropolishing goal cannot be achieved. It is for that reason that we summarized the 4M of electropolishing based on our years of experience in the industry. With the formation and workings of this viscous layer in mind, and based on the 4M of electropolishing, our researchers undertook development of the 9C VEP.

OBSERVATION OF SACLAY, DESY, CORNELL, JLAB, AND INVESTIGATION INTO VEP POSSIBILITY

In 2011, I read about Japan's ILC in the newspaper. At that point, our company had about 25 years of experience in electropolishing, but we knew nothing about Nb cavities. They had experience electropolishing stainless steel, and aluminum but it was the first time I'd heard of the alloy Niobium. As a provider of electropolishing services, I was interested, so I contacted KEK, the originator of the newspaper article, and asked if I could visit them and observe.

They had experience doing electropolishing of stainless steel accelerator cavities as at J-PARC. Observing their on-site Nb cavity electropolishing made us very interested, and we suggested doing collaborative research with KEK's Dr. Hayano. Afterwards, we became curious about the state of affairs with electropolishing overseas, and so with the introductions from Dr. Hayano, we visited France's Saclay, Germany's DESY, Italy's Zanon, America's Cornell, and America's JLab. All of the places we visited were using the HEP (Horizontal Electropolishing System) introduced by KEK. As an electropolishing provider, when I learned this fact, I had many questions: Was the distance between the cathodes proper? How was the circulation of the electropolishing solution? Was it really the best for this new shape to use horizontal electropolishing?

My first impression was that if it were me, I would want to do the electropolishing of this kind of target using a vertical process. This was due to my experience in electropolishing the inner surface of stainless steel S-shaped and U-shaped valves. But it wasn't until I first did electropolishing on a single Nb cell that I realized that my 25 years of experience with stainless steel couldn't be directly applied.

PRODUCTION OF THE NINJA CATHODE BASED ON STAINLESS STEEL CAVITY RESERCH

In 2013, when we first began to experiment, we were able to borrow a transparent resin model of a 9-cell cavity. Using that model, we first looked into the issues of the EP solution flow and cathode shape [1]. As an electropolishing company, we are very exacting about maintaining a uniform distance between the target sample and the

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cathode. We knew that in order to adjust to the inner shape of the cavity, we would need a cathode that could be retracted when it was inserted, and then unfolded after insertion. In particular, we used the idea of a mesh conveyer belt for the opening and closing part, and after repeated trial and error, we succeeded in a design that could maintain the flow of electricity [1]. Figure 1 shows photos of the newspaper article and stainless steel cavities (dumbbell, single cell, 9-cell).

Figure 1: Photos of the newspaper article and stainless steel cavities (dumbbell, single cell, 9-cell).

PURCHASE OF SINGLE CELL FROM RI AND VEP OF NIOBIUM

Using a stainless-steel dumbbell, single cell, 9-cell, we were able to do uniform electropolishing of the interior surface with the Ninja Cathode using the same electropolishing methods we'd been accustomed to up to that point. But we had no experience yet using niobium. So we purchased a single cell made of niobium from the company we had visited, RI. As expected, doing EP with the EP solution made for Niobium specs was more difficult, and potentially dangerous than EP for stainless steel, and we learned the importance of safety measures.

BORROWING OF NIOBIUM 9-CELL FROM KEK

After gaining confidence by carrying out tests over and over with the single cell [1]-[3], we borrowed a 9C cavity from KEK for the next stage. Now we thought we were finally ready to try the real thing, and we had been electropolishing niobium for 3 consecutive years. So, we began to build our first dedicated VEP setup #1 specifically for use with a 9C niobium cavity [4][5]. The main features we built into this #1 9C VEP setup were: (1) The ability to reverse the flow of the EP solution is something we learned from our experience with pipes and other stainless-steel parts. (2) We thought that it would be a simple matter to switch to using the Ninja cathode, but unlike electropolishing of stainless-steel, with niobium, a large amount of hydrogen gas is created when the current is flowing, so we were unable to achieve a uniform electropolishing. So, we did a series of experiments to try to explain the cause of the asymmetry [6]. Although we had experienced this also with stainless-steel, the importance of swiftly removing the hydrogen gas during electropolishing was once again made very clear. Furthermore, during the EP tests with the single niobium cell, we saw an effect from the hydrogen bubble trail, so we deduced that the reason for the lack of asymmetry was due to the viscous layer. We realized that, in a lengthy electropolishing process, removal of the hydrogen gas bubble flow, and temporary removal of the viscous layer on the cavity surface was difficult.

CONFIRMATION OF PROBLEMS IN ABOVE

Regarding the asymmetric electropolishing, we flowed EP solution not only from the bottom of the 9C VEP to the top, but also from the top to the bottom. At this time, the hydrogen gas remaining inside flowed to the top. We tried to solve the problem by changing the flow of the EP solution. This was a method we'd used when doing EP on stainless-steel long pipes and curved pipes and had solved the problem by changing the flow direction. Although we attempted to use this method, we saw asymmetric removal in the upper 4-5 cells on the order of 4-5 times the polishing amount. As compared to stainless-steel EP, we believe the amount of hydrogen gas produced with Nb material EP was 3-5 times greater. We felt that simply changing the direction of the EP solution flow was not going to be sufficient to manage the hydrogen gas.

As mentioned above, it would also be difficult to temporarily eliminate the viscous layer.

FIRST PRODUCTION AND IMPLEMENTATION OF THE VEP SETUP

Figure 2 shows photos of a niobium single cell cavity, a niobium 9-cell cavity, a first type VEP setup used for this confirmation, and Marui-KEK member.

PROBLEMS WITH MANUAL EP SOLUTION FLOW CONTROL

With the initial 9C VEP setup, we experienced difficulty when operating all valves manually for the control. However, in terms of the overall scheme, the design of the VEP layout demonstrated that all aspects performed their roles sufficiently. But for automatic control, the manual valves were no good.

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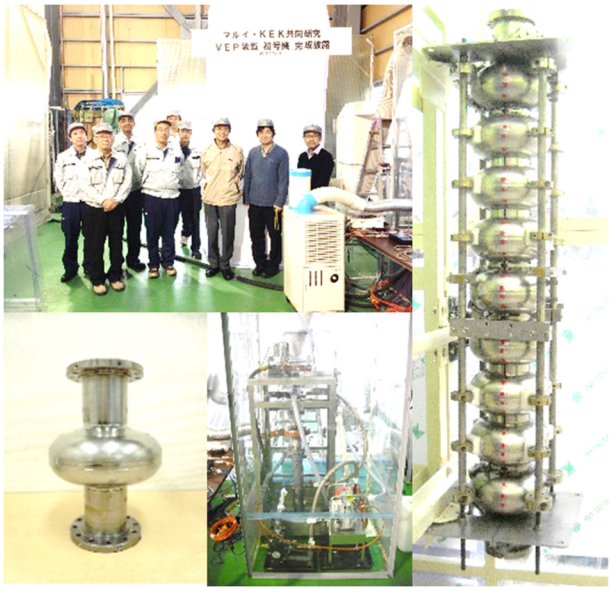

Figure 2: Photos of a niobium single cell cavity, a niobium 9-cell cavity, a first type VEP setup used for this confirmation, and Marui-KEK member.

CREATION OF IMPROVED VEP SETUP VER 1 WITH ELECTRIC SWITCHING CONTROL SETUP THANKS TO COLLABORATION WITH TWO IWATE COMPANIES: HIGASHI-NIHON KIDENKAIHATSU, AND WING

Automatic valve switching of EP solution influx and flow, and post-EP water wash, allowed us to do electronically controlled 2-3 valve switching operation, and so were able to do testing much more quickly. Also, it's necessary to externally control the increase in temperature of the 9C cavities during EP, so we installed an electronically-controlled shower-type water chiller system in the improved version of the system thanks to the cooperation of both Higashi-Nihon Kidenkaihatsu and Wing. Figure 3 shows a photo of the member of Marui, Higashi-Nihon Kidenkaihatsu and Wing.

Figure 3: A photo of the member of Marui, Higashi-Nihon Kidenkaihatsu and Wing.

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