PARTICULATE STUDY ON MATERIALS FOR CLEANROOM ASSEMBLY OF SRF CAVITIES*

L. Zhao, T. Reilly,
Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

Abstract

Reducing particulates is an important aspect for cleanroom operation. Knowing that it is impossible to completely eliminate all particulates in a clean room, efforts have been made to prevent particulates from entering SRF cavities during high pressure rinsing (HPR) and assembly. At Jefferson Lab, one practice to achieve this goal has been clamping covers to cavity open flanges during assembly. Several cover materials that have been used are examined and alternative candidate materials are under development. Clamps as a known particulate generator are carefully examined and cleaning efficiency of different methods is studied. Cover tests were done on different cavity flanges, including an LCLS-II beam pipe flange, which helps the selection of cover materials for prototype and production of the project.

BACKGROUND

The battle with field emission has been a long journey for the SRF community [1-3]. Even with newly developed facilities and tools, understanding [4] and controlling [5] particle contamination is still an on-going topic. During HPR and assembly at Jefferson Lab, open ports on cavities are covered to prevent particulates entering clean cavities. The cover material has evolved over time and with projects. For CEBAF cavities (C50 and C100), stainless steel covers with O-ring were used. Screws were used to keep the covers in place. Figure 1 (left and middle) shows two examples of these covers. In recent years, niobium blanks (Fig. 1, right) have been used on various cavity shapes, attached to cavity openings with stainless steel spring clamps. This option is much simpler and less flange dimension dependent than the O-ring design.

Since metal-to-metal contact can generate significant amount of particles, other candidates such as plastic materials are being considered.

EXPERIMENT

Investigation of Plastic Covers

Polyvinylidene fluoride (PVDF) and polytetrafluoroethylene (PTFE) are widely used in ultrapure water industry and semiconductor industry. At Jefferson Lab they are commonly used plastics in cavity processing especially chemical polishing tools, because of their excellent chemical resistance and reasonable mechanical strength. Our search for alternatives started with these two materials.

Figure 1: Stainless steel covers with O-ring (left, middle) and niobium blank (right).

Similar to common plastics, longer time is needed to blow clean PVDF and PTFE with an ionized nitrogen gun compared with metals. Bulk PTFE has only moderate stiffness and low surface friction, which can be a problem when a large force is applied. Other forms of PTFE products are available commercially, such as expanded PTFE (Gore-Tex), which preserves the chemical property but is very stretchable, enabling it to be used as gaskets. PVDF has higher mechanical strength but is less stretchable.

Figure 2 shows particle counts on PVDF covers of different dimensions. The smaller diameter was 70 mm, and the bigger diameter was 140 mm. The surface was lathed. The particle counter was set at 10 seconds/cycle and the flow rate was 1.0 cfm. The horizontal axis is the clean-up time needed for a cover, i.e. how long it took to blow down to zero counts. The vertical axis is the total amount of particles (≥0.3 μm) recorded through the clean-up time of the cover. The two axes are not necessarily functions of each other. Rather, the plot shows two parameters that indicate the cleanliness of a part. Points near the upper right corner indicate the surface has more particles and it takes longer to clean up. Points at lower left corner indicate the surface has fewer particles and it cleans up quickly. Apparently, geometry and dimension also play a role in surface particle counts. For the same surface finish, parts with more corners and holes have larger total counts.

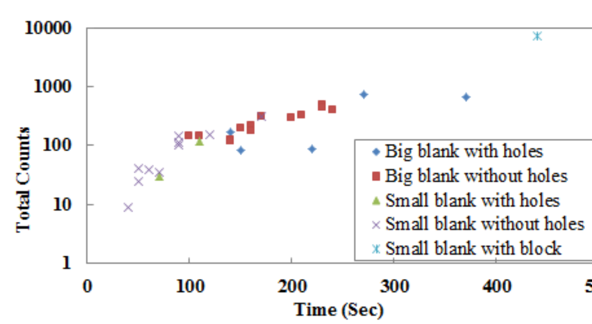

Figure 2: Total particle (≥ 0.3 μm) counts and cleaning-up time on PVDF covers in two diameters and different designs.

PVDF Covers with Different Surface Finish

The machined PVDF surface was difficult to blow clean. Noticing that the as-received manufactured surface

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† lzhao@jlab.org

is very smooth and much lower in particle counts than the machined surface, different surface treatments were tried to smoothen the machined surface. A heat torch was used to melt the top surface layer and remove any small burrs. Sand paper was used for mechanical polishing. Figure 3 shows particle counts on PVDF covers with different surface treatments. Surface melting and mechanical polishing help improve surface particle counts slightly, but still far from the as-manufactured shiny surface.

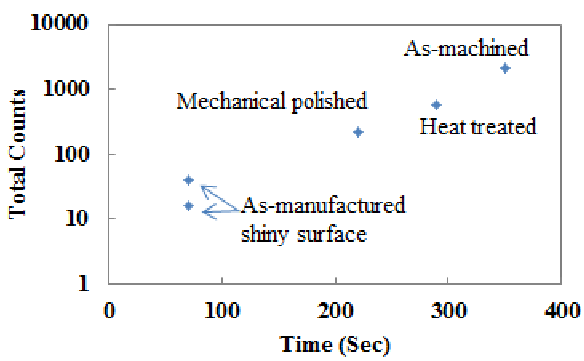

Figure 3: Total particle (≥ 0.3 µm) counts and clean-up time on PVDF covers with different surface finish.

PVDF was less promising for this application due to limited improvement and potential intensive labor required to achieve smooth surface.

Covers Tested on Cavity Flanges

Covers serve to protect cavity sealing surfaces and prevent particles from entering cavities. Our main considerations when choosing a cover are particle counts on the cover itself and the sealing it provides. Several cover materials and combinations were tested on two types of cavity beam pipe flanges.

Seven cover combinations were tested on a C50 beam pipe flange. The results are listed in Table 1. The flange has a flat surface for an indium seal. The cavity flange was cleaned to particle free before testing. A PVC tube was cleaned and clamped onto one beam pipe flange of the cavity. The tube went through inside the cavity beam pipe and reached the other beam pipe flange of the cavity. The stainless steel collection cup of the particle counter went through inside the PVC tube to near the beam pipe flange to be tested. Before testing covers, the particle counter was started and monitored to make sure the background particle count from the setup was zero.

For each cover test, the cover material was first blown clean with ionized nitrogen, and then clamped onto the cavity flange. Particle counts during the clamping indicate the amount of particles generated from the cover material contacting the flange. The connection between the cover and cavity flange was then blown with ionized nitrogen. Particle counts during the blowing indicate the sealing ability of the cover. Then the cover was removed from the flange. Particle counts during the removal also gave us some information on particles accumulated at the contacting surface. Numbers listed in Table 1 are the maximum counts per cycle for each operation described above.

Table 1: Particle (≥ 0.3 µm) counts (maximum count per cycle) during cover tests on C50 type beam pipe flange

Cover type	Clamp cover to cavity flange	Blow connection	Remove cover
PTFE blank	0	4	0
Gore-Tex ring + Nb blank	0	9	0
Nb blank	0	9	1
Gore-Tex ring + polished PVDF	0	12	0
Polished PVDF	28	23	0
Unpolished PVDF	13	34	0
Stainless steel and O-ring	2	74	20

The PTFE blank and niobium blank showed reasonable performance by themselves. PVDF with and without polishing both showed more particle counts. The addition of Gore-Tex gasket between PVDF blank and cavity flange resulted fewer particle counts than using PVDF blank only. Stainless steel with side screws showed the most particle counts.

Similar tests were done with seven different material combinations on another single cell, which has a TESLA design flange with grooved flange surface for an Al-Mg gasket seal. The cavity flange was disassembled in cleanroom, but flange surface and bolt holes did not receive

Table 2: Particle (≥ 0.3 µm) counts (maximum count per cycle) during cover tests on beam pipe flange with TESLA design

Cover type	Clamp cover to cavity flange	Blow connection	Remove cover
Gore-Tex blank (3 mm thick) and Nb blank	0	1	0
Medium Gore-Tex ring (3 mm thick) and Nb blank	0	13	3
Unpolished PVDF blank	0	27	0
Large Gore-Tex ring (1.5 mm thick, with bolt holes) and Nb blank	0	196	7
PTFE blank	0	243	0
Polished PVDF blank (grooved side)	0	307	3
Nb blank	12	474	1

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further cleaning before the cover test. The results are listed in Table 2. Notice that only the thick Gore-Tex gasket and thick Gore-Tex blank combined with niobium blank provided enough protection from particles on this type of flange.

Sliding Between Clamps and Covers

Sliding is still possible when clamp tips touch a metal cover, even when great care is taken to prevent that. To avoid metal-to-metal sliding, commercially available plastic spring clamps and covering stainless steel clamp tips with Vinyl tape have been evaluated. Clamp tips and niobium blank were blown clean before testing. Stainless steel clamps with taped and un-taped tips were slid against a niobium blank, during which time particle counts were measured (Table 3). Particle counts on niobium blanks and clamp tips were also measured before and after sliding (Fig. 4).

Table 3: Particles (≥ 0.3 µm) generated during sliding clamps over niobium blank

Sliding materials	Repeated runs	Maximum count per cycle
Un-taped stainless steel clamp sliding on niobium blank	#1	326
	#2	52
	#3	578
Taped stainless steel clamp sliding on niobium blank	#1	0
	#2	30
	#3	7
Plastic clamp sliding on niobium blank	#1	41

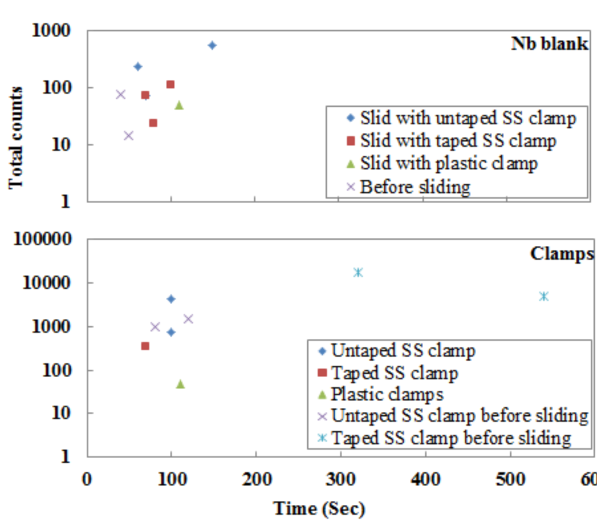

Figure 4: Total particle (≥ 0.3 µm) counts and clean-up time of niobium blank (upper plot) and clamps (lower plot), before and after sliding.

As expected, taped clamps generated fewer particles when sliding over niobium blanks. However, blowing clean taped tips took a longer time once particles were collected on them. Commercially available whole plastic clamps did not show significant advance over stainless steel clamps in particle counts, as shown in Table 3 and Fig. 4. Stainless steel spring clamps are still the choice given no significant advantages found from the other options evaluated.

Cleaning of Clamps

Spring clamps generate particles from metal-to-metal friction on the spring when exercised. Methods of cleaning clamps have been evaluated. Particle counts on the entire clamp including tips and spring area were compared. Wiping with isopropanol alcohol and then ultrapure water did little to help reducing particle counts near the spring area. Ultrasonic cleaning however was very effective removing particles.

SUMMARY AND APPLICATION

The niobium flange cover method currently in use provides reasonable protection against particles. Plastics such as PTFE and PVDF as alternative flange cover materials were investigated. Surface particle count was found to be material dependent and surface finish dependent. Metal was easier to blow clean than plastic. Polished surface was easier to blow clean than rough surface. Among all the tested material combinations, Gore-Tex combined with niobium blanks provided best protection against particles.

Proceeding to application on the LCLS-II prototype cavity string assembly, Gore-Tex gasket combined with mirror finish stainless steel blank were used, as shown in Fig. 5.

Figure 5: Beam pipe cover for LCLS-II prototype cavity string assembly.

Stainless steel clamps used for string cavity assembly are ultrasonically cleaned daily to minimize particle accumulation on them.

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