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DEVELOPMENT OF AUTOMATIC CLEANING AND ASSEMBLY SYSTEMS IN CLEAN ROOM AT KEK

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Abstract

At KEK, new clean work systems including vertical auto cleaning system, replacement system between blank flange and bellows, and robot arm have been developed and installed since 2020 under the collaboration between Japan and France. The main purpose is unmanned and dust-free operation in clean room to avoid performance degradation with field emission in vertical test and cryomodule test. The vertical auto cleaning system and the replacement system between blank flange and bellows have been operated successfully in 2021-2022. Currently, clean work studies related to auto cleaning and assembly is under progress by combining the blank-bellows replacement system and a robot arm. In this report, the recent status of clean works at KEK will be presented.

INTRODUCTION

In recent years, as superconducting accelerators have become larger and larger, assembly work in clean rooms has become increasingly important. A typical clean room operation is the cleaning of cavities, input power couplers and vacuum components using an ionized gun. The cleaned parts are installed into the cavity one after another, and finally the cavity string assembly is completed and taken out of the clean room to finish. This cleaning work using the ionized gun is quite hard work, depending on the degree of contamination of the object, and requires high quality, as care must be taken to prevent dust from entering the cavity. Therefore, it makes sense to automate these tasks, which are difficult to maintain quality when performed by humans, using a robot arm.

Since 2020, KEK has been developing an automatic cleaning and assembly system for use in clean room operations under Japan-France cooperation. IRFU/CEA has already started their activities on the use of robotics in their clean room several years ago [1, 2].

The following three items have been developed: 1) a vertical automatic cleaning system for vertical test, 2) a replacement system between blanks and bellows for cavity string assembly, and 3) a robot arm system for automation. Of these, 1) is a prototype and fits only for cavity assembly for vertical test, while 2) and 3) are to be used in combination and are intended for cavity string assembly to install into cryomodule. We are currently conducting studies for each of these situations, which will be described in turn in the following chapters.

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A VERTICAL AUTOMATIC CLEANING SYSTEM FOR VERTICAL TEST

The automatic vertical cleaning system was developed as a prototype automatic cleaning system to reduce the burden of the cleaning process during the assembly of the vertical test of the cavity. Instead of using a robot arm, the system uses a manipulator to enable horizontal and vertical swing oscillation in addition to R, θ, and Z-direction movements. However, only two patterns of simultaneous movement are possible: R-θ and R-Z planes. The typical speed is about several centimeters per second for safety. In the case of movement in the R-θ plane, the dust monitoring system counts the number of dusts as it moves in a circle, then returns to the origin along the same trajectory, and so on. The dust diameters that can be detected are 0.1 mm and 0.3 mm. R-Z plane operation is basically the same, although since it cannot move simultaneously in the θ direction, it must continue to clean the same angular location.

After various improvements and trajectory development since the commissioning test in March 2021, the system is now available as an automatic cleaning system. However, the ionized gun itself, which was selected for the first time at KEK, turned out to be a dust source, and in the end, 0.1 mm of dust was never eliminated. Figure 1 shows the vertical automatic cleaning system with an installed cavity. Figure 2 shows the developed trajectory on CAD and the dust trend during automatic cleaning.

A REPLACEMENT SYSTEM BETWEEN BLANKS AND BELLOWS FOR CAVITY STRING ASSEMBLY

The blank and bellows replacement auxiliary system is designed to replace the blank and bellows beam pipe attached to the flange of the cavity without direct hand contact, which is done during cavity string assembly. It can also be used as a training kit for practicing cavity string assembly procedures, consisting of two dummy cavities and three dummy bellows, with filters on the flanges at both ends for gas introduction. The dummy bellows also has a dust monitoring port, which leads to a dust monitoring system. The dust monitor used in this case is a SOLAIR1100LD, which can detect simultaneously six dust diameters from 0.1 mm to 1.0 mm. During cavity string assembly, 0.1 MPa nitrogen gas through pneumatic lines is introduced as backflow from both ends of the cavity. However, in this study, the gas pressure through pneumatic line was increased as a trial. The results showed that there was no problem at 0.15 MPa, although many dusts penetrated through the filter when the pressure exceeded 0.2 MPa.

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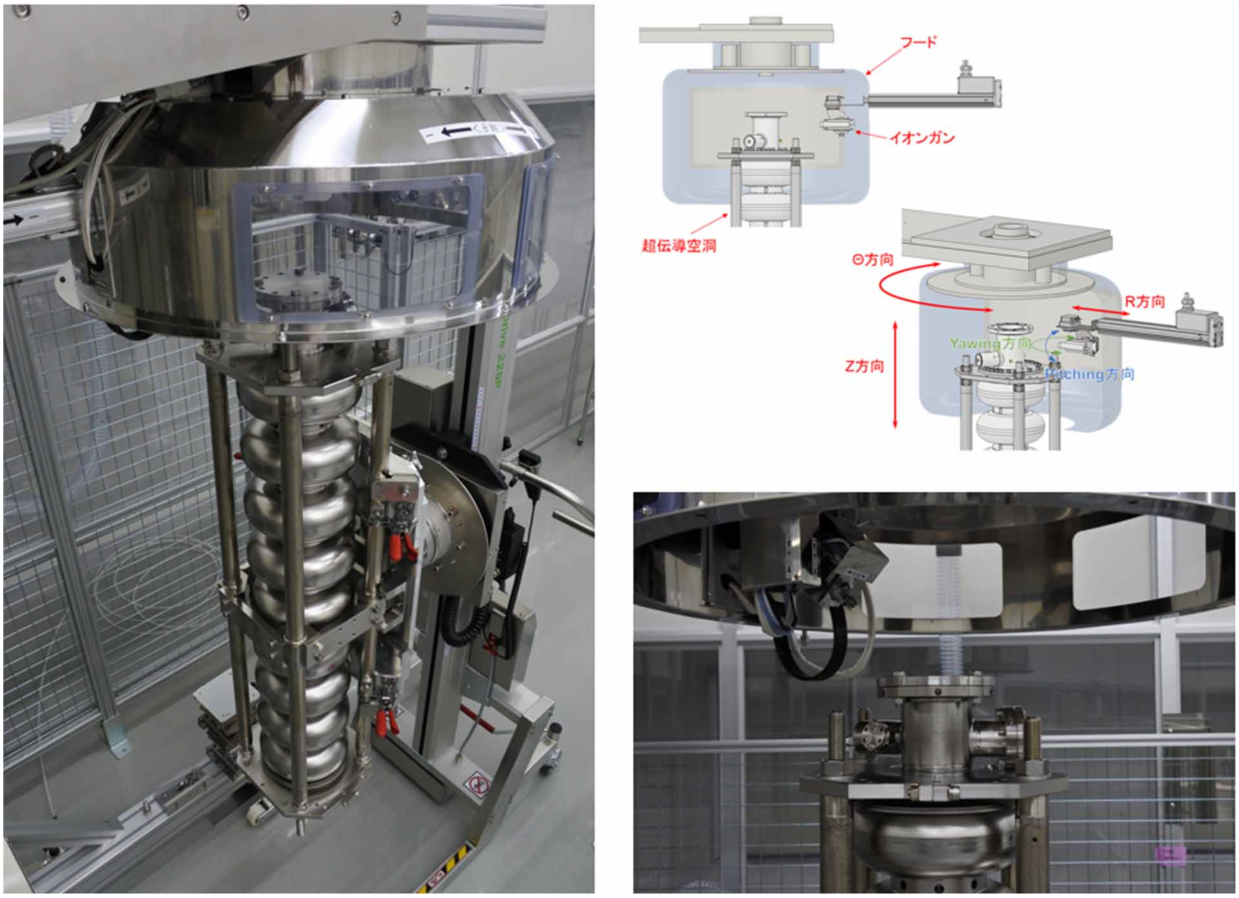

Figure 1: Vertical automatic cleaning system with an installed 9-cell cavity.

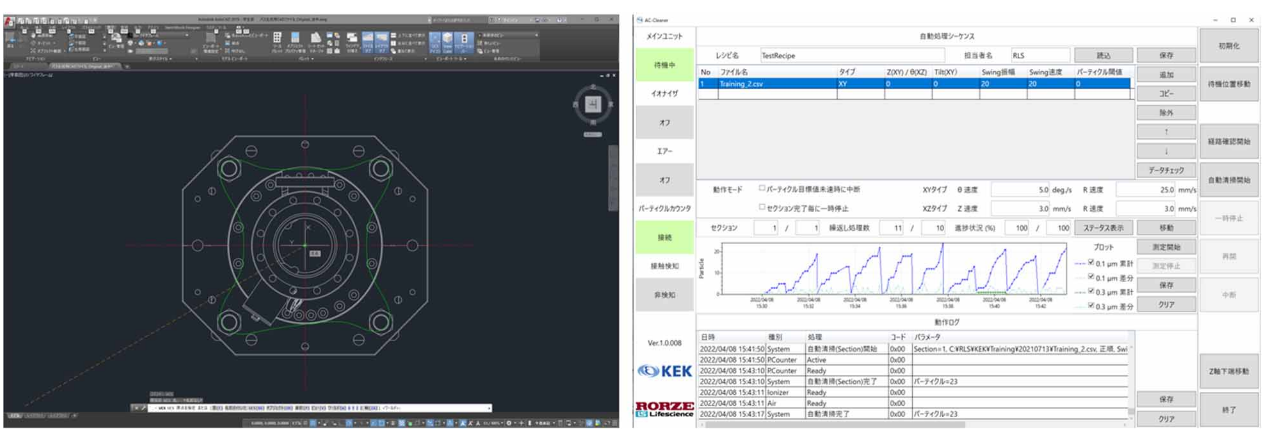

Figure 2: Trajectory of ionized gun developed on CAD (left), and trend of number of dusts with 0.1 μm during auto-cleaning (right).

Therefore, it seems that it would be better to use the filter at 0.15 MPa or lower. This system will also be used in combination with a robot arm system described later in this study for automatic cleaning and assembly. Figure 3 shows the replacement system between blanks and bellows, and a dust monitoring system connected to the dummy bellows.

A ROBOT ARM SYSTEM FOR STUDY OF AUTO-CLEANING/ASSEMBLY IN ISO4 CLEAN ROOM

In anticipation of cavity string assembly to be performed in the future, KEK has been performing automatic cleaning and assembly using a robot arm system installed in December 2022. This has also been done in combination with a blank bellows replacement system, as mentioned earlier.

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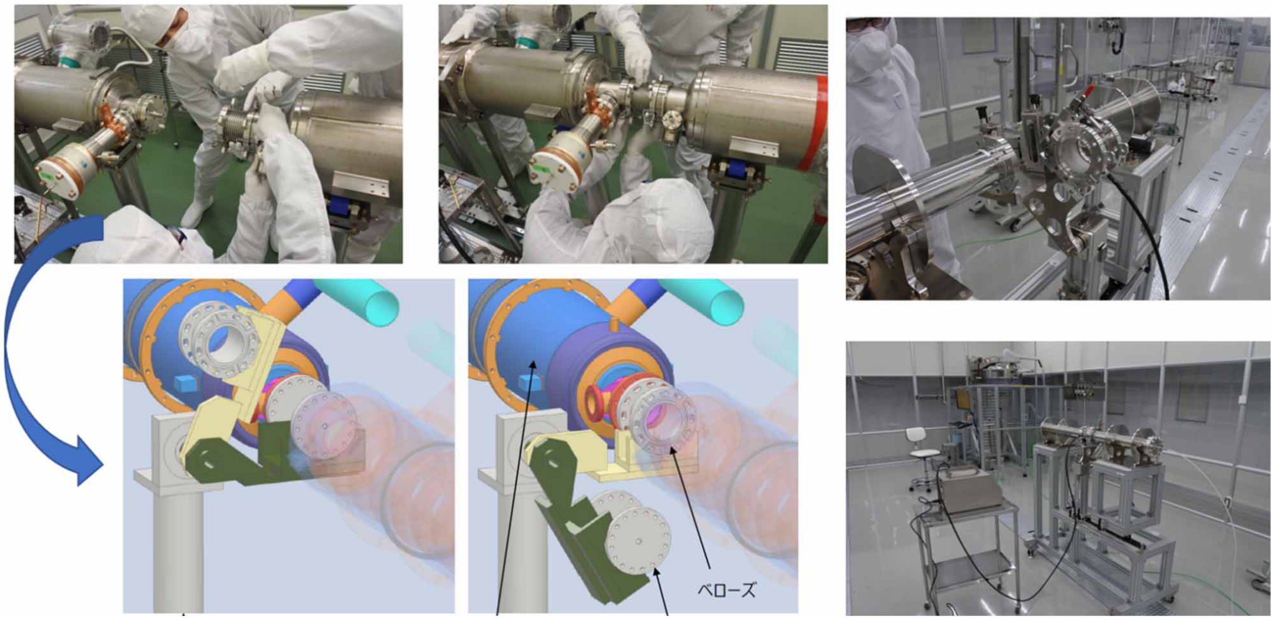

Figure 3: Replacement system between blanks and bellows developed for cavity string assembly.

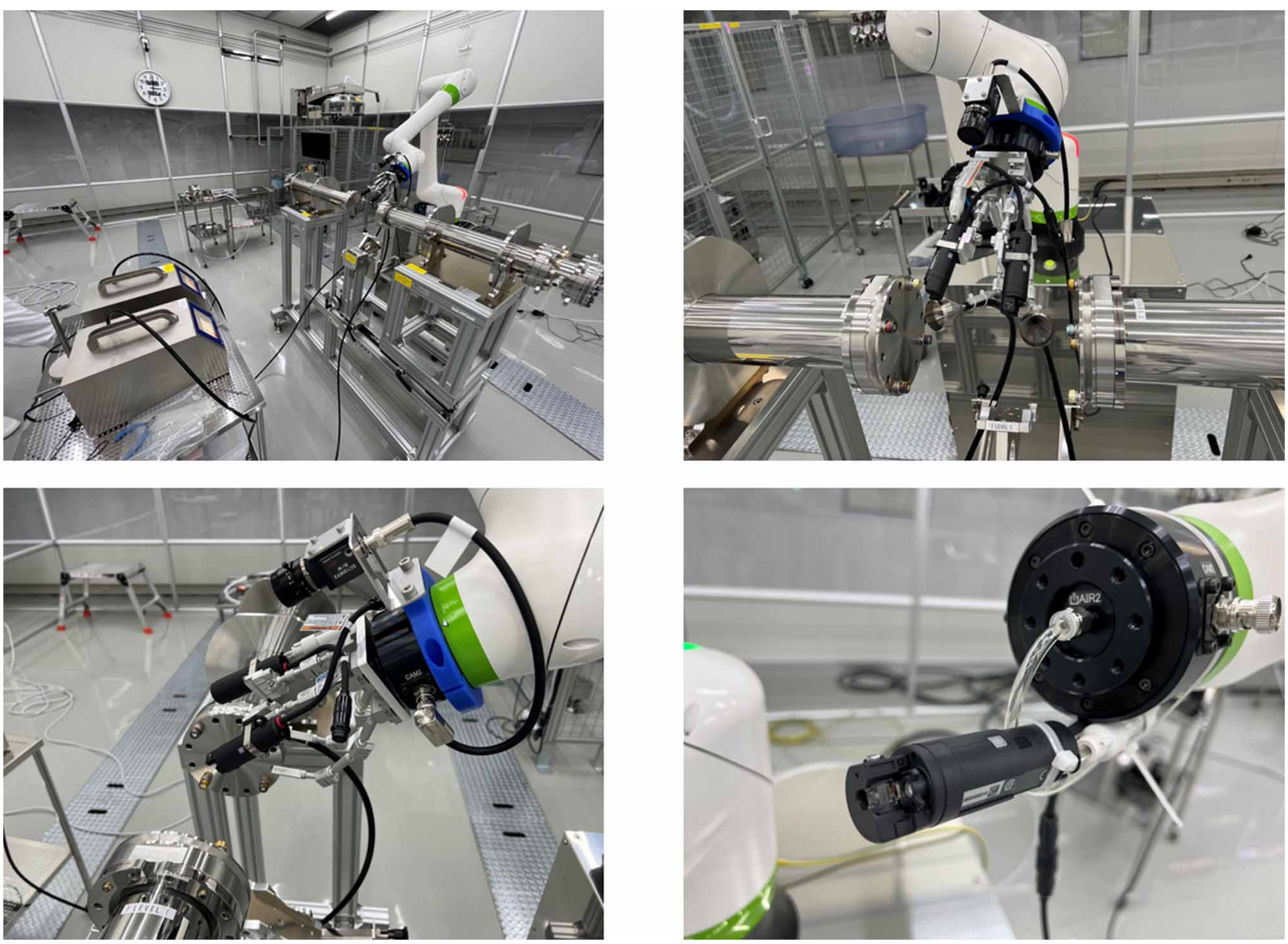

Figure 4: Demonstration of auto-cleaning by a robot arm with multi-ionized guns.

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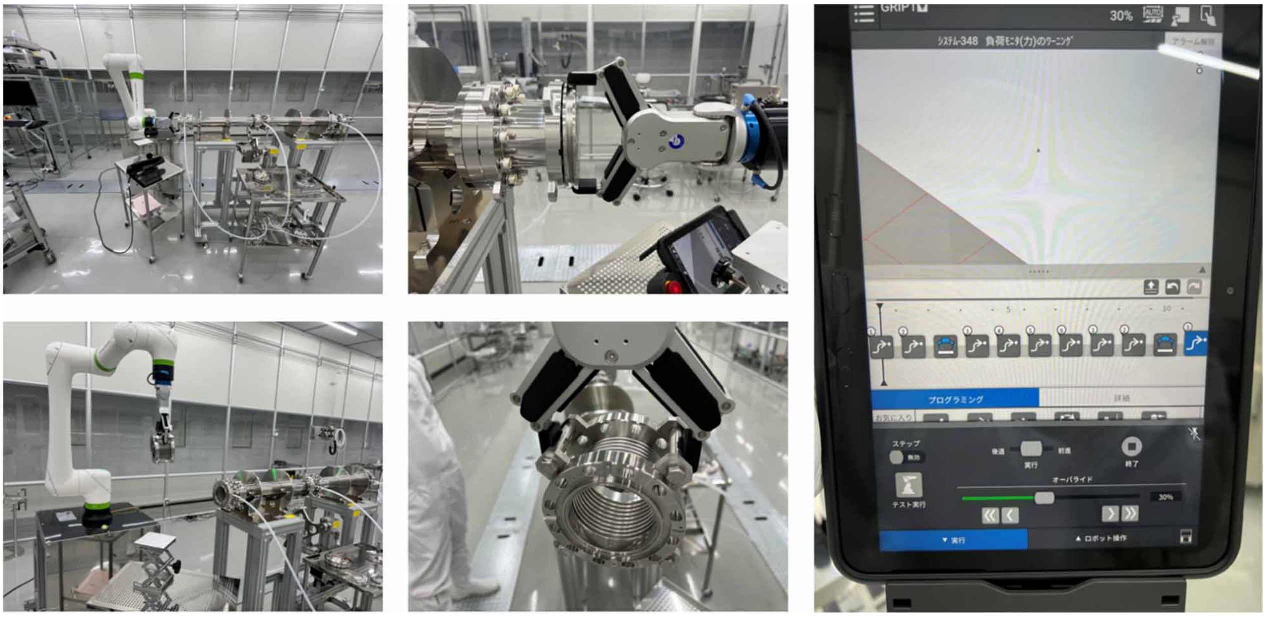

Figure 5: Demonstration of auto-assembly for a blank flange and a connection bellows by a robot arm including program developed on the control panel.

The robot arm is capable of teaching trajectories by direct teaching. A hand is attached to the end of the robot arm, which can be equipped with two sets of ionized guns and dust monitor nozzles. This is because automatic cleaning with multiple ionized guns is envisioned for the future. The test run of automatic cleaning of the cavity flange was successfully done with no dusts detected. The next step is to have the robot arm hold a blank flange with a slightly stronger hand and try to attach it to the cavity flange. This was also done well, and the alignment adjustment at the flange's alignment point was carefully done.

We will now proceed to automatic installation of bellows between two cavities. Remote control of the ionized gun and dust monitor is also underway, and in the future the robot arm will be remotely controlled as part of a comprehensive system.

Figure 4 shows the demonstration of auto-cleaning by a robot arm with multi-ionized guns. Figure 5 shows the demonstration of auto-assembly for blank and connecting bellows by a robot arm, and the program developed on the control panel.

FUTURE PLAN

Our future plans include:

1. construction of a remote system including ionized gun, dust monitor, and robot arm introduction of a second robot arm
2. study of automatic cleaning and assembly using real cavities including input power couplers
3. full automation and unmanned operation in clean room

Finally, we want to use them for large SRF accelerator project in future, like ILC.

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