

DEVELOPMENT OF THE H0 DUMP BRANCH DUCT FOR THE ADDITIONAL COLLIMATION SYSTEM IN J-PARC RCS

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Abstract

For the new collimation system at the H0 dump line junction in the J-PARC RCS, we redesigned a new H0 dump branch duct. This new branch duct is made of the two kinds of the stainless steels as follows; SUS316L austenitic stainless steel and SUS430 ferritic stainless steel. In order to verify the material selection, several material testing of SUS430 were carried out with test ducts and the magnetic annealing condition for SUS430 was fixed. Up to now, the new H0 branch duct has been manufactured and its performance is checked. The new collimation system will be assembled with the new H0 dump and another component and be installed at the H0 beam dump line junction from September 2011.

INTRODUCTION

In the J-PARC RCS, the significant beam losses were observed at the H0 dump branch duct and the beam position monitor which was put at the downstream of the H0 branch duct [1]. From the beam study and the particle tracking simulation, we were certain that these beam losses were caused by the scattering of the injecting and circulating beam at the charge stripping foil [2]. These beam losses are special key issues for the 1MW power up scenario of the RCS. In order to localize these beam losses and reduce the residual radioactivity at another injection area, we started to develop a new additional collimation system at the H0 dump line junction [3]. The new additional collimation system consists of various components, and a new H0 dump branch duct is the one of the important components. The design concept of the new H0 dump branch duct was changed from the current branch duct. The material selection was re-examined and then material testing was carried out. In this paper, we report the design of the new H0 dump branch duct and the results of the material testing with the test ducts, and introduce the manufactured new H0 dump branch duct.

REDESIGN OF THE NEW H0 DUMP BRANCH DUCT

The branch ducts in the RCS have the branch structure that is welded two ducts to one flange [4]. One duct is installed inside the septum magnet to pass through the injecting or extracting beam, and the other is installed outside to pass through the circulating beam. Therefore the inside duct is made by the nonmagnetic material. The

outside duct had better be made by the magnetic material to reduce the leakage field from the septum magnet. In the case of the current branch ducts, titanium and electromagnetic stainless steel (EM stainless) were adopted as the nonmagnetic and magnetic materials respectively. This material selection has many advantages, but it requires a high degree of technical skill in the manufacturing process. This branch duct is constructed of several unit ducts which were made with electric beam welding (EBW) in vacuum to suppress machining error and especially to prevent the titanium from being oxidized. Titanium and stainless steel cannot be welded directly. Therefore the branch duct is assembled with the Ti/SUS HIP bonding plate. Moreover, EM stainless is a custom-made material with a high magnetic property and for an ultra high vacuum environment, and then it is very expensive.

On the other hand, the new H0 branch duct for the additional collimation system needs to be replaced with new one every few years. Thus it is necessary to re-examine the material selection and the machining process in terms of the cost. We selected SUS316L as the inside duct material and SUS430 ferritic stainless steel as the outside duct material. In this material selection, the branch duct can be assembled without the HIP bonding plate and welding process can be changed from EBW to laser beam welding (LBW) in air. Not only the material cost but also the machining cost can be saved with this new material selection. The new additional collimation system requires same structural design changes of the new H0 branch duct. Figure 1 shows the schematic diagram of the redesigning new H0 dump branch duct. The outside duct has an additional chamber where the collimator blocks will be installed. The bellows are adopted a stainless steel welded bellow and are welded on the H0 dump duct directly.

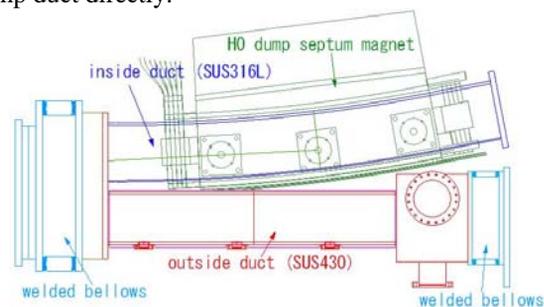


Figure 1: Schematic diagram of the redesigning H0 dump branch duct installed in the H0 dump septum magnet.

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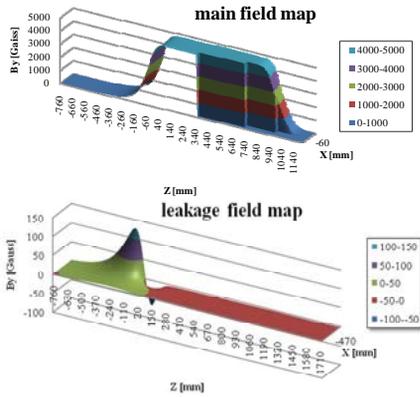


Figure 2: Measured field map of the H0 dump septum magnet without the H0 branch duct.

MATERIAL TESTING FOR SUS430

We selected SUS430 as the outside duct material for the new H0 dump brunch duct, because SUS430 is a ferritic stainless steel which has a magnetic characteristic. But its magnetic characteristic does not provide better performance than EM stainless. On the other hand, SUS430 is not adopted as an ultra high vacuum chamber in general. Therefore, in order to verify that SUS430 is usable as the branch duct, we had tried some material testing of SUS430.

We prepared three test chambers and three test piece rings for the material testing of SUS430. The purposes of the material testing with the test chambers were establishing its manufacturing process, demonstrating the ultra high vacuum chamber made of SUS430, and proving its magnetic shielding ability. The test piece rings were used to measure the magnetization curve of SUS430. Three pairs of test chamber and test piece ring were compared by changing the magnetic annealing condition as follows; one was heated for 4hours at 700degC, another was for 4hours at 850degC, and the other was not heated.

The test chamber is a straight duct of 500mm long and has a rectangular cross section of 60mm by 60mm aperture and of 10mm thickness. Using an electrolytic polishing or a chemical polishing, the surface of SUS430 becomes rough contrary to the surface treatment of the austenitic stainless steel. Thus the surface of the test chambers is only buffed and polished before welding. In the case of the real SUS430 duct of the new brunch duct, the titanium nitride coating process was carried out to suppress secondary electron emission. After welding, the test ducts were annealed in a vacuum furnace.

Figure 2 shows the measured field map of the H0 dump septum magnet without the H0 branch duct. The high leakage field was located at the entrance of the septum magnet and the peak was about 100Gauss. Thus the outside duct of the branch duct was required to reduce about 100Gauss of outer magnetic field. To verify the magnetic shielding ability of the SUS430, the test duct

was installed in the Helmholtz coils and the magnetic field inside the test duct was measured with 1-dimensional Hall probe. A setup of the magnetic field measurement is shown in Fig. 3. The maximum magnetic field of about 85Gauss can be generated by the Helmholtz coils with current of 10A, which is limited by air cooling coils. But it makes little difference to simulate the leakage field of the H0 dump septum magnet. The field measurement results were summarized in Fig. 4. The upper plots the measurement field, and this result indicates all SUS430 test ducts can shield the external magnetic field. The lower shows the field shielding efficiency, which is calculated from the measured fields without test duct. The magnetic annealing can recover the magnetic characteristic of SUS 430, and field shielding efficiency is about 1% with annealing condition at 850degC for 4hours.

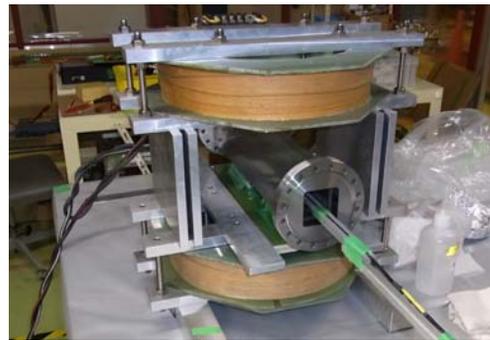


Figure 3: Setup of the magnetic field measurement with the 1-dimensional Hall probe.

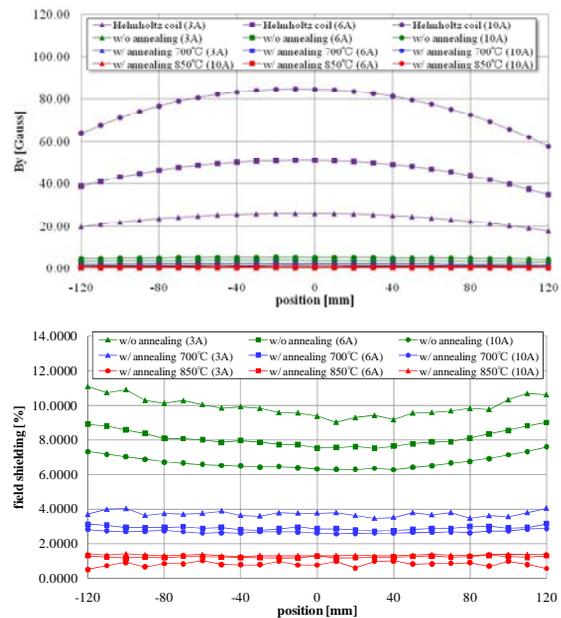


Figure 4: Magnetic field measurement results with SUS430 test duct. Upper plots the measured field, and lower shows the field shielding efficiency.

The test piece ring is 5mm thickness, 35mm internal diameter, and 45mm outer diameter. The magnetization curves were measured with rings as shown in Fig. 5. These results indicate that the magnetic annealing can recover the magnetic characteristic of SUS 430. Figure 6 shows the comparison of the measured permeability with various magnetic materials as follows; SUS430, EM stainless, SS400, and electromagnetic soft iron. SS400 is the rolled steels for general structure. Electromagnetic soft iron has a high degree of magnetic permeability and is adopted as a pole of a magnet in general. From the material testing, SUS430 duct can reduce the leakage field from the H0 dump septum magnet sufficiently. However the magnetic permeability of SUS430 is less than EM stainless significantly. Therefore, in the real new branch duct, an additional shield plate was attached on the outside duct to make sure of field shielding efficiency.

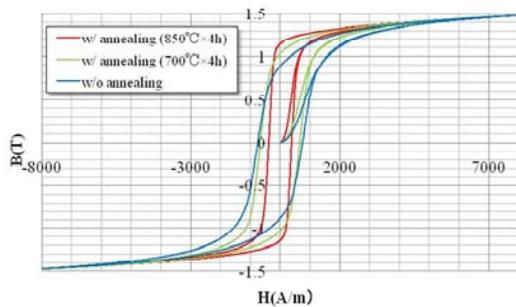


Figure 5: Comparison of the measured magnetization curve with test piece rings.

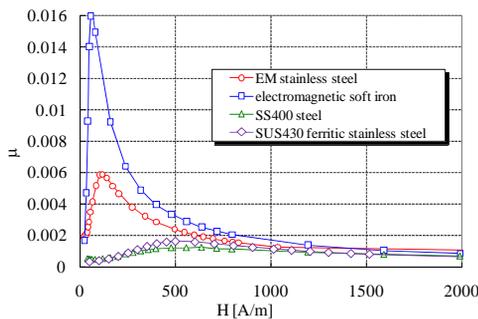


Figure 6: Comparison of the measured permeability with various magnetic materials.

MANUFACTURING OF NEW BRUNCH DUCT

The new H0 dump branch duct has been manufactured as shown in Fig. 7. The outside duct was constructed with three SUS430 ducts. Three ducts were welded with LBW and annealed at 850degC for 4hours in the vacuum furnace. The SUS430 ducts were coated with a thin layer of titanium nitride to suppress secondary electron emission after the magnetic annealing process. And then SUS430 ducts and SUS316L inside duct were assembled

with TIG welding. After assembling, the additional shield plates made with EM steel were attached on the branch duct. The upper photo in Fig. 7 shows the naked new H0 branch duct, and the lower is the duct mounting with the additional shielding plates.

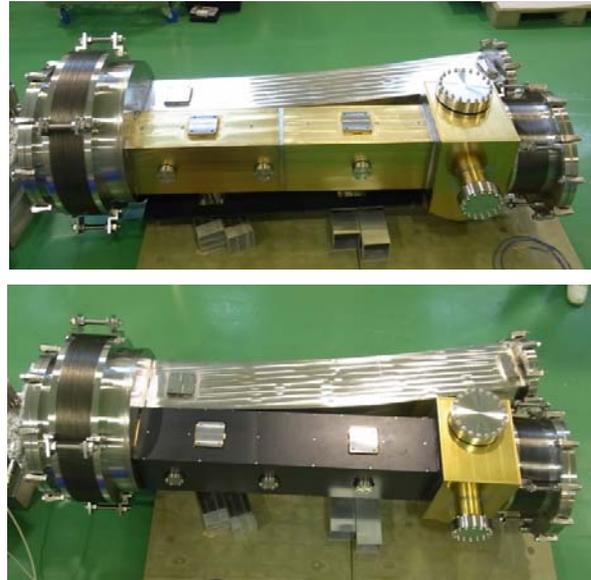


Figure 7: Photos of the new H0 dump branch duct. Upper is the naked branch duct, and lower is the duct mounting with the additional shielding plates.

SUMMARY

We redesigned the new H0 dump branch duct, which is one important component of the new collimation system against the foil scattering beam loss. The new branch duct was adopted SUS430 as the magnetic material to reduce the leakage field from the H0 dump septum magnet. In order to verify the material selection, material testing of SUS430 was carried out. As a result, he magnetic annealing can recover the magnetic characteristic of SUS 430 and field shielding efficiency is about 1% with annealing condition at 850degC for 4hours. Now, the new H0 branch duct has been manufactured and its performance is checked.

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