IMPROVEMENTS OF THE CHARGE EXCHANGE SYSTEM AT THE 3GEV RCS IN J-PARC

Masahiro Yoshimoto*, Osamu Takeda, Masato Kawase, Yoshio Yamazaki, Michikazu Kinsho, JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken, JAPAN
Yoshio Saito
KEK/J-PARC, Tsukuba, Ibaraki-Ken, JAPAN
Zensaburo Kabeya
Mitsubishi Heavy Industries Ltd, Nagoya, JAPAN

Abstract

At the 3GeV RCS (Rapid Cycling Synchrotron) in J-PARC (Japan Proton Accelerator Research Complex), the scheme of H- charge exchange injection using stripping foils is adopted. The charge exchange system is composed of three stripping foil devices. The 1st stripping foil device, which converts the H- beam from the 181MeV LINAC into the H+ beam, can replace the broken foil with new one in vacuum remotely and automatically. In September 2007, mechanical trouble with the 1st stripping foil device had occurred just before the RCS beam commissioning was started. The magnetic coupling of the transfer rod had been decoupled and the transfer rod had been broken which was caught in the vacuum gate valve. We studied the trouble cause, re-examined the structural design and the material selection, and then verified the specification from endurance tests with sample pieces. Then the improved device was installed in the ring in summer 2008.

INTRODUCTION

The RCS has three stripping foils for the beam injection [1]. The H^- beam from the LINAC is injected into the RCS ring and the charge is changed from H^- to H^+ with a 1st charge stripping foil. But it is difficult for the H^- beam to be charge exchanged perfectly at the thin foil, and the H^- and H^0 beam are occurred exiguously. In order to control the H^- and H^0 beam, there are two more stripping foils installed downstream of the 1st foil. At the 2nd and 3rd foil, the H^- beam and H^0 beam are exchanged to the H^+ beam again respectively. These beams including the two types of H^+ beams passes through the dump line and directs to the H0-dump.

These stripping foils are the Hybrid type thick Boron-doped Carbon (HBC) stripping foil, which was developed by Sugai group in KEK [2]. The 1st stripping foil is a double-layered HBC foil to reduce the pin holes risk, and its total thickness is 200 μg/cm^2 to achieve the charge exchange efficiency of 99.7%. The 2nd and 3rd stripping foils are also double-layered HBC foils and each total thickness is 500 μg/cm^2.

In order to realize the beam injection scheme with the charge stripping foils, we developed the charge exchange system. The charge exchange system is composed of three stripping foil devices as shown in Fig. 1. The 1st stripping foil device can adjust the horizontal and vertical position depended on the beam injection point respectively, and can replace the broken foil with new one in vacuum remotely and automatically. The 2nd and 3rd stripping foil devices adjust only each horizontal position and don't have an automatic foil exchange system, because the irradiated beam current diminishes in comparison with the 1st stripping foil.

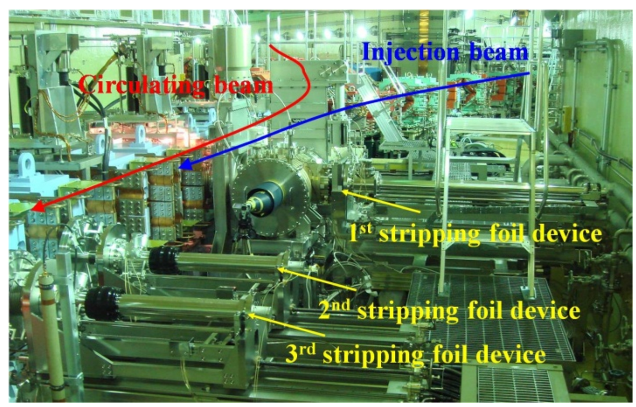

Figure 1: Charge exchange system in J-PARC RCS.

CHARGE EXCHANGE SYSTEM

1st charge stripping foil device

Fig.2 shows the schematic diagram of the 1st stripping foil device. The 1st stripping foil device was required to replace the broken foil with new one in vacuum remotely and automatically. Thus the horizontal moving distance is about 1500mm long. But the bellows mechanism is too big to fit in the tunnel of the injection area, and then we developed the foil moving system with a new type of transfer rod (TR1) [3]. The vertical moving distance is +/-10mm long for the adjustment of the beam irradiation spot at the foil. Then the flexible bellows was adopted and the TR1 itself was lifted up or down. The stripping foil was mounted on the foil holder. The foil holders with the spare stripping foils were stored on the holder storage rack. The maximum holder numbers stored on the rack is 15 frames. Then the beam operation can be carried on for two weeks, even if the stripping foil is broken every day. The TR1 has a holder clamp mechanism, which can catch

*E-mail address: yoshimoto.masahiro@jaea.go.j

or release the foil holder in the vacuum chamber remotely.

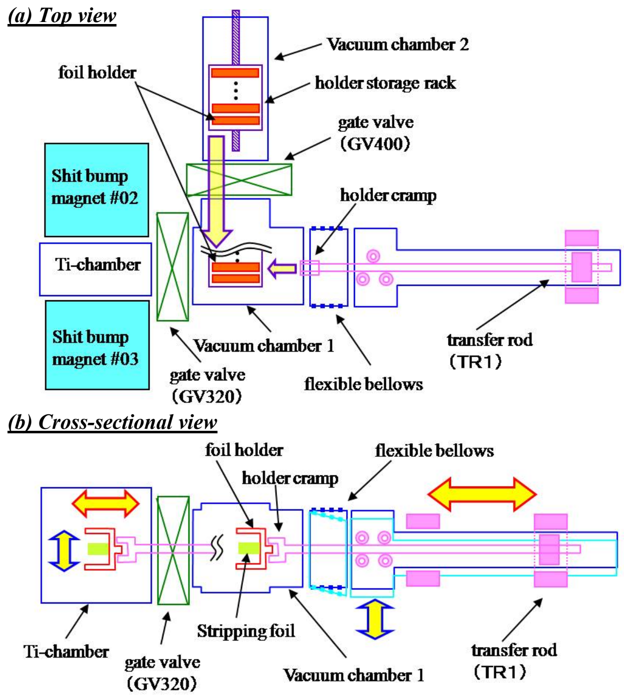

Figure 2: Schematic diagrams of the 1st stripping foil device. (a) shows the top view and (b) shows the cross-sectional view.

Mechanical trouble

In September 2007, mechanical trouble with the 1st stripping foil device had occurred just before the RCS beam commissioning was started. The magnetic coupling of the TR1 had been decoupled and the TR1 had been broken which was caught in the vacuum gate valve like a guillotine. When we had investigated the cause of the mechanical trouble, the abrasion marks were found on both the TR1 and bearing rollers which supported the TR1. In the original design, the minimum distance of the bearing rollers is 148mm long, and the maximum load on the bearing rollers was 558N. The outer diameter of the bearing roller was ϕ20mm and the crowning radius was R10mm, therefore the maximum surface pressure was 2100MPa. It was negative surface pressure because the stainless steel (SUS304) bearing roller was adopted and the material of the TR1 was the stainless steel (SUS316L) too. In this trouble case, the TR1 had joined on the bearing roller because the same materials were pressed with higher pressure than its sufficient load capacity in vacuum during a long time. Even if the magnetic coupling of the TR1 was decoupled, the interlock safety system should protect from the guillotine-like trouble. But there were no sensors to detect the TR1 decoupling in the original design. In the improvement of the 1st stripping foil device, the following factors were taken into account: (1) the structural design for reduction of the surface pressure was re-examined, (2) the material selection against the metal joining was started over, and (3) the interlock system for the machine safety was upgraded.

1ST STRIPPING FOIL DEVICE IMPROVEMENT

Transfer rod

In order to reduce the surface pressure on the TR1, we re-examined the structural design as follow. At first, the distance of the bearing rollers should be lengthened, and large bearing rollers were adopted. Because the large bearing rollers took up a lot of room in the vacuum chamber, the shaft shape of the TR1 was modified from a square-shaped pipe to T-shape bar. And it was aimed to lighten the weight of the TR1 in parallel. The re-examined structural design parameters were summarized in table 1, and the schematic diagram of the improved TR1 was shown in Fig. 3.

Table 1: Structural design parameters

	Original	Improvement
Weight of TR1	8.55 kg	7.57 kg
Weigh of holder cramp	1.7 kg	1.4 kg
Distance between rollers	148 mm	200 mm
Load on roller	558 N	205 N
Outer diameter of roller	ϕ20 mm	ϕ50 mm
Crowning radius	R10 mm	R30 mm
Surface pressure	2100 MPa	446 MPa

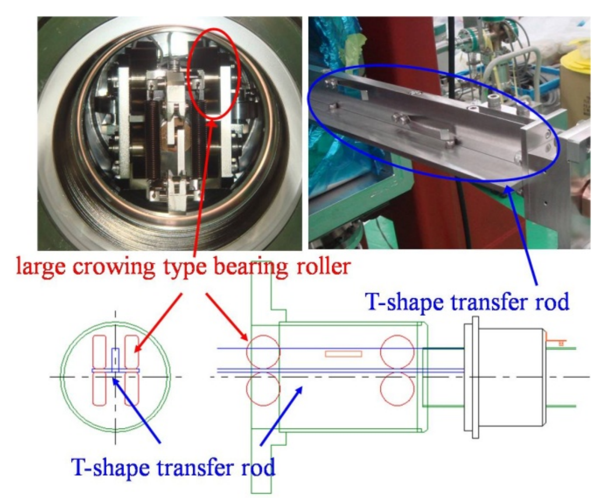

Figure 3: Photographs and schematic diagram of the TR1 and the bearing rollers.

Materials of the TR1 and the bearing rollers should be selected in considering the surface-hardness for sufficient load capacity. Some available materials were selected and we verified the specification from endurance tests with the sample pieces. Table 2 shows the results of the material selection.

Table 2: Material selection

	Original	Improvement
TR1	SUS316L	SUS304N2-X
Bearing rollers	SUS304	Quenched SUS440C

Foil holder clamping

The holder clamp mechanism should be reviewed in terms of accuracy and certainty that the clamp can catch or release the heavy target, for example the quarts plate mounted on the foil holder. Fig. 4 shows the new clamp mechanism. Non magnetic heat resisting INCONEL X750 springs were replaced. The holder clamp has two arms with frame slot and the width of the frame slot was narrowed down from 3.5 mm to 3.1 mm. The both two arms can be moved up and down, and catch hold of both the upside and the downside of the foil holder. The dowel-pins are attached to the clamp arms, and the pin-punches are punched out in the holder frame. The dowel-pins not only keep the good accuracy of the holder location but also lock the holder frame stability.

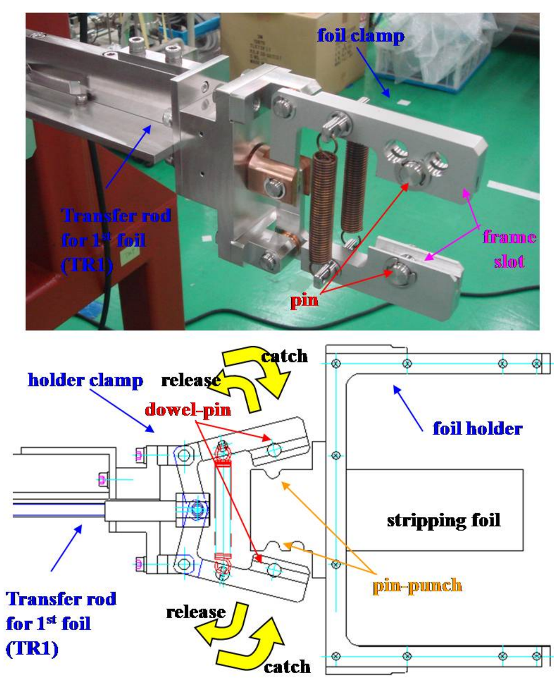

Figure 4: Photograph and schematic diagram of the holder clamp mechanism.

Interlock safety system

To upgrade the interlock safety system, especially to protect the guillotine-like trouble, three limit switches in vacuum and a contactless magnetic sensor were added to the 1st stripping foil device. Fig. 5 shows the additional interlock system. The limit switches were consisted of the leaf springs and contact-bars, and they can check the following operable TR1 position: centre injection position, paint injection position, and TR1 home position. The sensor consists of a permanent magnet bottom set on the inner ring of the TR1 magnetic coupling and a reed switch set on the outer ring. Thus the sensor can detect the decoupling of the TR1 directly.

The control system of the 1st stripping foil device was modified to upgrade the interlock safety system [4]. The vacuum gate valve can be operated on condition that the TR1 is returned to the home position and the limit switch signal turns on. And then if the contactless magnetic sensor detects the decoupling of the TR1, all processes are stopped forcibly and any operation cannot be executed until the magnetic coupling is retrieved.

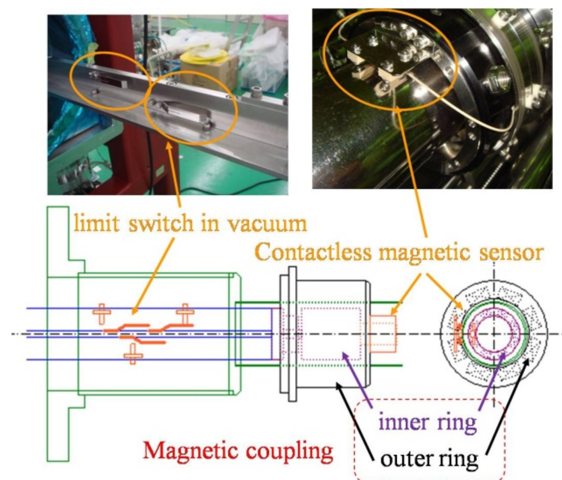

Figure 5: Photographs and schematic diagram of the limit switches in vacuum and a contactless magnetic sensor.

OUTLOOK

We studied the cause of the guillotine-like trouble, re-examined the structural design the material selection, and then improved the charge exchange system. As a result, the 1st stripping foil can be replaced remotely and the various RCS beam studies using the different kind of the stripping foils can be carried out [5].

Now, an additional booth to take out the irradiated foils from the vacuum chamber safely is developed and it will be installed in this summer.

REFERENCES

[1] M. Yoshimoto et. al., Proceedings of EPAC06 (2006) 1765-1797.

[2] I.Sugai, et. al., Nucl. Inst. and Meth. A561(2006) 16-23.

[3] Y. Takeda et. al., Nucl. Inst. And Meth. A590 (2008) 213-220.

[4] M. Kawase et. al., in this proceedings.

[5] M. Yoshimoto et. al., in this proceedings.