STATUS AND PROGRESS OF THE J-PARC 3-GEV RCS

M. Kinsho[#], J-PARC, KEK&JAEA, Tokai-mura, Naka-gun, Ibaraki-ken, 319-1195, Japan

Abstract

The J-PARC 3-GeV rapid cycling synchrotron (RCS) has been operated for the neutron and MLF users program from December 23rd, 2008. The RCS operations not only in support of the MLF but also were providing beam for the MR user program. In parallel we are challenging to realize higher beam power operations with better stability. Before scheduled maintenance last summer beam power was limited by the front end of about 20 kW, after that maintenance the RCS has been operated the beam power of more than 100 kW for MLF users. After beam deliver operation to the MR and MLF, while the priority has been given to their beam tuning, the RCS also continues further beam studies toward higher beam intensity. On December 7th, 2009, the RCS achieved the beam power of more than 300kW to the neutron production target with 25Hz.

INTRODUCTION

The J-PARC 3-GeV rapid cycling synchrotron (RCS) is located in a 348 m long tunnel and will provide proton beam to a high power neutron spallation target as well as to the 50 GeV Main Ring (MR). The RCS beam commissioning in September, 2007 and we accelerated the 181 MeV beam injected from the linac to the designed beam energy of 3 GeV via the RCS, and extracted it to the beam transport to the muon and neutron production targets on October 31st, 2007 [1][2]. The RCS has been operated for the neutron and MLF users program and beam was delivered to the MR for the successful commissioning of first acceleration to 30 GeV and first slow extracted beam to the hadron experimental hall [3].

The RCS has been operated for the neutron and MLF users program from December 23rd, 2008. The RCS operations not only in support of the MLF but also were providing beam for the MR user program (Haron experiment and/or Neutrino experiment). In parallel we are challenging to realize higher beam power operations with better stability [4].

This paper concentrates itself on the J-PARC RCS status and progress for this one year, including the discussion on the issues of the high-power and stable operation.

RCS STATUS

The RCS has been operated for the neutron and MLF users program from December 23rd, 2008. The RCS operations not only in support of the MLF but also were providing beam for the MR user program. In parallel we are challenging to realize higher beam power operations with better stability. Achieved parameters of the RCS are summarized at table 1.

[#]kinsho.michikazu@jaea.go.jp

Table 1: Summary of achieved parameters of RCS

Parameter	Unit	Design	Achieved to data
Injection energy	MeV	400	181
Output energy	GeV	3	3
Number of bunches		2	2
Repetition	Hz	25	25
Output power	kW	1000	120*
Particles/bunch		4.2×10^{13}	5.0×10^{12}*
Injection scheme (painting)		Transverse & longitudinal	Transverse & longitudinal
Tune excursion during acceleration		<0.005	~0.025
COD	mm	<1	<1 with BBA
Chromaticity		0 ~ 20ms w/AC p.s.	at injection w/DC p.s.
Stability of extracted beam orbit	mm	<±1 atQX3	~±0.5 atQX3
Beam emittance (un-normalized in full)	πmm mrad	54 for MR, 81 for MLF	~30[x]/30[y] for 120kW measured

*Consecutive 300 kW (for 1 hour) operations at 25 Hz were well demonstrated.

Before scheduled maintenance last summer beam power was limited by the front end of about 20 kW, after that maintenance the RCS has been operated the beam power of more than 100 kW for MLF users. After beam deliver operation to the MR and MLF, while the priority has been given to their beam tuning, the RCS also continues further beam studies toward higher beam intensity. On December 7th, 2009, the RCS achieved the beam power of more than 300kW to the neutron production target with 25Hz.

ISSUES

In order to realize a high performance accelerator for users which are the MFL and the MR. The RCS has mainly three kinds of issues for high power beam as follows, (1) stable operation for users, (2) reduction of beam losses in the case of high power operation, and (3) realizing of good beam quality for the MR injection.

(1) Stable operation

The availability was ~92.4 % for the total operation time of 842.3hours by January 2010. The cause of beam stop from the RCS is mainly the rf cavity trouble due to shunt impedance drop and the trouble of power supply of the extraction kicker at present.

The shunt impedance variations of the rf cavities operated in the RCS is shown in fig. 1. This measurement has been performed since August, 2008. Ten cavities (#1~#10) have been operated since October 2007 and an additional one cavity (#11) was operated from November 2008. On January 2009, the shunt impedance of the rf cavity #7 suddenly became small, and this cavity had to be run with two gaps (normally with three gaps) until damaged MA cores to be replaced new ones on March. The cause of the shunt impedance reduction was severe damage of MA cores installed in the rf cavity. We call this kind of severe damage "buckling". Since there were only three new cores, we replaced the three damaged cores of cavity #7 and re-install it in the ring at the end of March. Same cavity (#7) was failed due to impedance drop on January this year. This cavity has already replaced to a new cavity with all new cores in this March. The fail of another cavity (#4) occurred due to impedance drop on June 2009. This was disassembled and buckled MA cores were replaced in the 2009 summer shutdown. When the fail of the cavity due to impedance drop was happened the cavity had to be run with only two gaps to reduce the shutdown time of the accelerator.

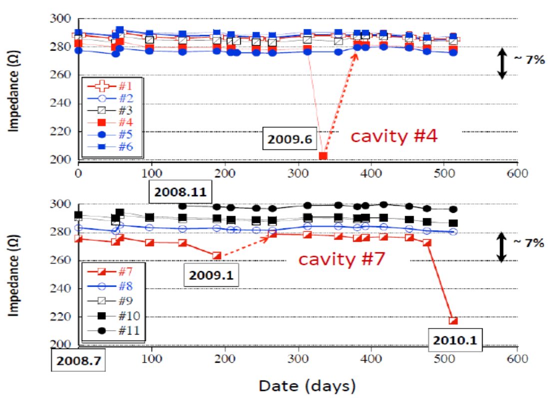

Figure 1: The shunt impedance variations of the rf cavities operated in the RCS. Ten cavities (#1~#10) have been operated since October 2007, and the cavity #11 was operated from November 2008

We disassembled 5 cavities (#3, #4, #5, #6, and #7) to investigate the damage of MA cores. It was found 25 cores were buckled out of a total of 90 cores, but 23 of them have no change in shunt impedance excluding cores at cavity #4 and #7. The cause of the buckling of the core was still under investigation, however, it was statistically found that one of the cause of the buckling was in the manufacturing process of epoxy resin impregnation into the core [5]. We carefully observe the status of the cavity and investigate for the cause of the degradation of MA cores.

The dominant part of troubles (~32.5hours) in the last user operation (January 2010) was caused by the power supplies of the extraction kickers. Eight extraction kicker magnets are installed in the RCS and each magnet is operated by one power supply with 2 thyratrons. Since thyratron is gaseous discharge switching device, it often make misfire or self-breakdown in several hours at present. However this problem has been steadily improved as deepen understanding of the system and the conditioning method of thyratrons [6].

(2) Reduction of beam losses

Beam loss distribution throughout the ring were measured in the case of 120 kW MLF-user operations and 300 kW high power operation shown in fig. 2. There were 4 high loss areas which were collimator, arc-1, extraction, and injection areas in the RCS. Beam losses at collimator area are not so serious because this result goes according to plan and radiation shield of collimator has been taken account of these beam losses [7].

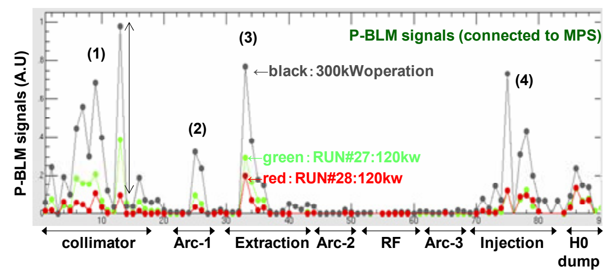

Figure 2: Beam loss distribution throughout the ring in the case of 120 kW MLF-user operations and 300 kW high power operation. Horizontal axis shows the position of beam loss monitors and vertical one is the loss monitor signal normalized the biggest one.

Beam losses at the arc area were observed missing-bend cells with dispersion peak. Figure 3 shows residual activation at arc section-1 and extraction area, and picture of beam loss monitor placed close to the extraction septum chamber. These activations were measured with contact on the vacuum chamber after 6hours from beam operation stop. User operation was carried out for 2-weeks with 120 kW and high power operation of 300 kW-1hour was performed. Beam losses at the arc area made about 40 μSv/h activations with that operation conditions. Since these losses took place at the middle of the acceleration and also sensitive for the tune variation and longitudinal painting, and chromatic correction was done only at injection period with DC power supply, it was found these losses came from the chromatic tune spread. It should be expected to be reduced by full chromatic correction with AC power supply which would be placed in this summer maintenance period.

It was found that there were big loss points at extraction area in fig. 2, however the residual activation of this area was not so high. We have been investigated what was the cause of this beam loss, it was found the beam loss monitor (BLM) was set close to vacuum chamber of the septum magnet and loss beam just hit this point (shown in fig. 3). There were big beam losses at the injection area in fig.2, especially at the branch to the injection dump and at QFM entrance after the stripping foil. Figure 4 shows residual activation at injection area. These activations were measured with contact on the vacuum chamber after

6hours from beam operation stop. User operation was carried out for 2-weeks with 120 kW and high power operation of 300 kW-1hour was performed. The residual activation became about 1.5 mSv/h with this beam operation. This beam loss becomes high under 300 kW user operations, and the activation of the components is estimated at about 3~5 mSv/h after weeks user operation with 300 kW. Since this value is very big for hands-on maintenance of components, continuous operation with 300 kW is difficult for MLF-users without reduction of the losses. On the other hand, since only 4.5 % beam of extracted beam from the RCS is used for the MR, it is possible to deliver 300 kW beam to the MR with 25 Hz switching operation for the MLF and the MR

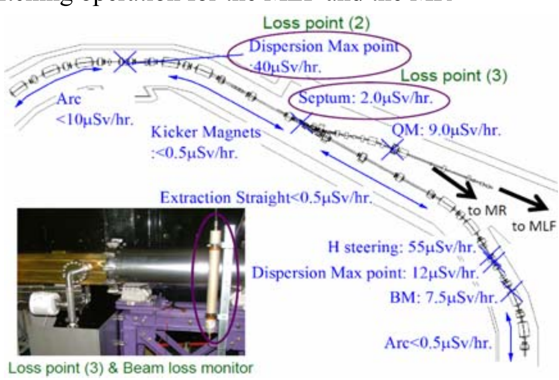

Figure 3: Residual activation at arc section-1 and extraction area, and picture of beam loss monitor placed close to the extraction septum chamber. These activations were measured with contact on the vacuum chamber after 6hours from beam operation stop. User operation was carried out for 2-weeks with 120 kW and high power operation of 300 kW-1hour was performed.

Since the beam loss was proportional to the number of the stripping foil hits from beam studies and simulations, it was concluded that the large angle events with Coulomb scattering made a hot spot at the H0 branch and the entrance of QFM [8][9]. In order to reduce these beam loss, the number of foil hits should be reduced by transverse painting injection and by optimization of the foil size. It will be expected that the number of foil hits becomes less than half with new foil which will be installed this summer maintenance.

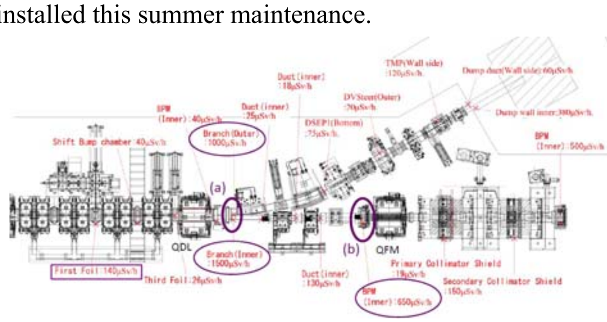

Figure 4: Residual activation at injection area. These activations were measured with contact on the vacuum chamber. Measurement conditions were as same as the conditions shown in fig. 3.

(3) Beam quality

RCS has to satisfy the requirements as high power injection to the MR as well as a high power beam source to the MLF. The key issue to satisfy a requirement for the MLF is how to realize big beam size and uniform beam on the neutron production target. Beam studies have been performing to manipulate the optics of the transport line from the RCS to the neutron production target (3NBT). On the other hand, the key issue to satisfy a requirement for the MR is how to realize small beam size and small emittance for injector of the MR. To reduce the beam halo is essential in the case of high intensity beam because the collimator aperture installed in the beam transport line from the RCS to the MR (3-50BT) is 54 πmmmrad and current collimator limit power is 450 Watt. We have been simulated and measured the beam halo of the RCS beam for several beam power levels [10]. When the beam intensity extracted from the RCS becomes more than 300 kW, the beam halo reduction is a key issue especially for the MR injector.

CONCLUSIONS

The RCS has been operated for the neutron and MLF users program from December 23rd, 2008. The RCS operations not only in support of the MLF but also were providing beam for the MR user program. Before scheduled maintenance last summer beam power was limited by the front end of about 20 kW, after that maintenance the RCS has been operated the beam power of more than 100 kW for MLF users. In parallel we are challenging to realize higher beam power operations with better stability.

- User program operation could be continued from 23th December 2008, and stable beam whose power of more than 100 kW could be deliver to neutron and MLF users.
- On December 7th, 2009, the RCS achieved the beam power of more than 300kW to the neutron production target with 25Hz

There are some issues for high-power and stable operation as follows, (1) stable operation for users, (2) reduction of beam losses in the case of high power operation, and (3) realizing of good beam quality for the MR injection. We continue to challenge for high power and stable operation in the RCS.

REFERENCES

[1] M. Kinsho, EPAC'08, THXG02.
[2] H. Hotchi et.al, Phys. Rev. STA.B **12** 040402(2009)
[3] H. Kobayashi, PAC'09, WE1GRI02.
[4] M. Kinsho, PAC'09, TU6PFP065.
[5] M. Nomura et. al, IPAC'10, THPEA022.
[6] M. Watanabe et. al, IPAC'10, WEPD086.
[7] K. Yamamoto, et. al, IPAC'10, WEPEB065.
[8] H. Harada, et. al, IPAC'10, THPEB017.
[9] P.K Saha et. al, IPAC'10, THPEB018.
[10] H. Hotchi, IPAC'10, MOPEC068.