MAGNET-RELATED FAILURE EXPERIENCES AT THE SPring-8 STORAGE RING

K. Tsumaki, N. Kumagai, S. Matsui, M. Ohishi, H. Yonehara, SPring-8/JASRI, Hyogo, Japan
T. Tateishi, Y. Torii, KOBELCO RESEARCH INSTITUTE, INC., Hyogo, Japan

Abstract

High operation rate is required for synchrotron radiation sources for their many users. Keeping high operation rate, we need to maintain the equipments continually and raise the reliability of each component. To raise the reliability, it is important to clarify the cause of failure of equipments. In this paper, we describe the major magnet-related failure experiences of the past six years for the SPring-8 storage ring: failure of flow switch, dissolution of copper in water, and radiation damage of equipments.

INTRODUCTION

The SPring-8 storage ring is the third generation synchrotron radiation source with 1436 m circumference and 6 nm emittance and has been operated since 1997[1]. Since radiation sources especially large facility like SPring-8 have many users, the high operation rate is required. To maintain the high operation rate, the high reliability of components of the storage ring is needed.

In the SPring-8 storage ring, actual operation rate for scheduled one since 1997 is 98.3 %. In 2001, total scheduled operation time is 5456.1 hours and the down time is 87.1 hours. Down time due to failures is only 1.6 %. In the failure time, about a half is due to beam line failures and the residual is due to injector and storage ring. The causes of the storage ring failures are due to RF, magnet, vacuum, and control. In this paper, magnet-related failure experiences are described.

In 1997, magnet-related failures were mainly power supply troubles. In 1998, failures of magnet flow switches occurred frequently. In the same year, strainers for cooling water was found to be covered with red substance, the main component of which was copper dissolved from the coil surface. In 2001, a rubber hose was broken due to radiation damage. Since then five rubber hose was broken. In 2002, cooling water leaked from the sextupole magnet coil. The causes of failures are changing with the operational years. We describe about the flow switch, coil and radiation damage in this paper.

FLOW SWITCH

Operation of cooling water system was started in May 1996. First failure of flow switch occurred in June 1998 for sextupole magnet and since September of that year, failures occurred frequently. We studied the cause of failure and concluded to change them for the other type of flow switch.

The number of flow switches and the parameters of cooling water are shown in Table 1 and the structure of a flow switch is shown in Fig. 1. When the water flows in a flow switch, the pressure difference between before and after orifice is generated and due to this pressure difference, a rod moves downward. If the flow rate reduces, the rod moves upward and a micro-switch becomes off state. There were two capabilities as the cause of failures. One was the hardening of rubber diaphragm and the other is the erosion of rod. The maker thought it was due to the hardening of a rubber diaphragm. We measured the hardness of the diaphragm. Results are shown in Table 2. There is only a small difference between used and unused diaphragms.

Table 1: The number of flow switches and parameters of cooling water.

	number	flow rate (l./min)	velocity (m/s)
bending	88	~20	1
quadrupole	464	10~18	2~4
sextupole	292	4~6	0.8~1.3

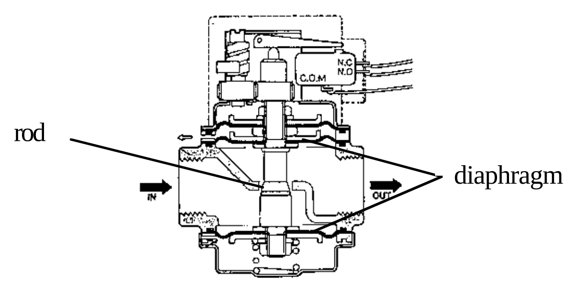

Figure 1: Structure of flow switch.

Table 2: Hardness of diaphragm rubber

	position	hardness
used	upper	81
	lower	82
unused	lower	79

Next we observed the rod. The rods for used and unused flow witches are shown in Fig. 2. The rod is seriously damaged by erosion. If the rod becomes thin by erosion, pressure loss becomes small. We measured the pressure loss for used and unused flow switches. Pressure losses for used and unused flow switches are 0.024 MPa and 0.054 MPa, respectively. We concluded the cause of failure is due to the erosion of rod and resultant reduction of pressure loss of water flow. We stopped the use of this

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type of flow switch and employed float type flow switches.

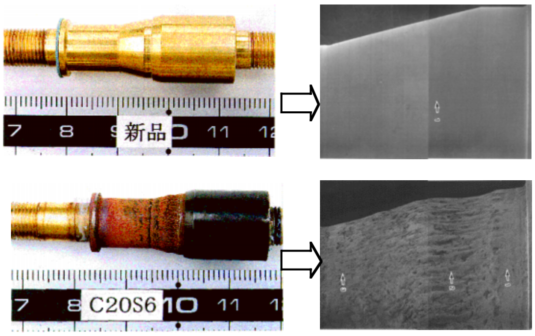

Figure 2: Rods of unused and used flow switch.

COIL

In 1998, it was found that the surface of strainers for cooling water was covered with red substances. We analyzed them and found they were copper oxides. We then investigated the water. Copper of 100~400 ppb was dissolved in the water. The cooling water system is for magnet and vacuum chamber. We investigated the copper pipes and magnet coils. The inner surface of hollow conductor was slightly eroded. We concluded the copper dissolved in the water was from magnet coils. The concentration of copper in water decreased with time and reached to the 10 ppb level. We thought that at first there was no copper oxide on the inner surface of coils but with time copper oxide covered the surface of inner surface of the coils and prevented copper to dissolve to the water.

In May 2002, water leaked from a sextupole magnet coil. We removed the coil and exchanged to the new one. The leakage was occurred at the point where two coils were connected by brazing. There was a small hole made by corrosion on the surface of brazing point. We cut the coil and found that the brazing was insufficient. We concluded that the slight corrosion at insufficient brazing point led to the leakage of water.

RADIATION DAMAGE

Damaged equipments

In January 2000, a new crane was installed for the magnet rearrangement to construct the 30 m long straight sections[2][3]. After two weeks beam time for users, we tried to operate the crane but it did not work. The electronic circuit of the crane was damaged. The crane was placed just above the crotch absorber. We thought the radiation from the crotch absorber damaged the electronic circuit of the crane.

In September 2001, cooling water leaked from the rubber hose for quadrupole magnet at injection cell. Usually magnet hoses face to the inside of the storage ring but at injection cell, the hoses face to the outside of the ring to avoid interference with a transport line from a synchrotron. For that reason the rubber hoses face the absorber directly. We measured the radiation strength and the radiation level at the leaked hose is one or two order higher than the other cells. So we considered the injection cell was special. Rubber hose at injection cell was shielded by the lead. However in January 2003, water leaked from the other normal cell hose and during one month and a half since that time, water leakage occurred three times at normal cells. All leaked hoses were at Q7 and Q10 magnets, where they faced to the absorbers named AB3 and AB4. We exchanged the rubber hoses for all Q7 and Q10 magnets where radiation dose is higher than the other magnets.

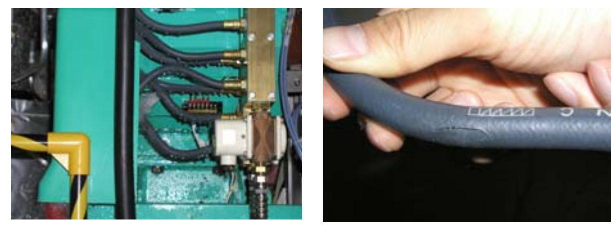

Figure 3: Water leakage from a rubber hose for a quadrupole magnet.

In 2001, damage of interlock wire became conspicuous as shown in Fig. 4 and Fig. 5. Cracked covers of the wires were mended in summer of 2002. As for the cover tube of connection point of interlock wire of heat switch, we left them untouched though the color is changed from brown to black.

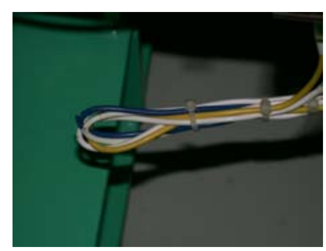

Figure 4: Cracked cover of interlock wire.

(a) Undamaged tube. (b) Damaged tube.

Figure 5: Cover tube of connection point of interlock wire.

Measurement of radiation dose

Radiation sources are the absorbers (AB1~AB4) and crotch absorbers (CR1, CR2) as shown in Fig. 6. Radiations from bending magnets are scattered by these absorbers and damage the surrounding equipments.

We measured radiation dose around the absorbers and crotch absorbers: radiation around quadrupole magnet coils, rubber hose, absorbers, interlock wires, cover of connection point of interlock wire, cover of a bending magnet power cable. The dosimetry media (GAFCHROMIC film) was used for measurements.

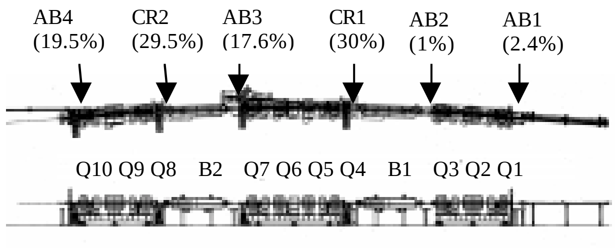

Figure 6: Magnet and absorber arrangement and radiation power distribution from the bending magnets. Total radiation power per cell is 21 kW.

Measurement Results

Magnet coil

Measurements were done for the quadrupole magnets of both ends of girders. One of the measurement results is shown in Fig. 7. Integrated current during irradiation was 0.1179 A*h. Integrated current at April 2003 is 1678 A. Therefore maximum integrated dose is $1.6x10^7$ Gy. No radiation effect is observed for magnet coils until now, however, if there is any effect, it becomes serious. So we are planning to study the radiation effects for magnet coils.

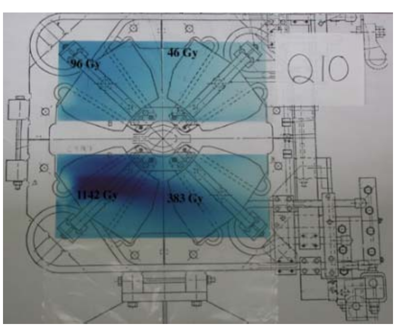

Figure 7: Measured results of radiation around the magnet coils.

Rubber hose

Radiation dose for the rubber hoses, from which the water leaked, was measured together with the rubber hoses for both ends of the girders. Radiation doses for Q7 and Q10 magnets are one or two orders higher than the other magnet. Maximum integrated dose is $4x10^5$ Gy. There are eight rubber hoses for a magnet. Leakage occurred for the rubber hose at the same position. Rubber of leakage point was hardened by radiation.

Absorber

Radiation dose behind the absorber was measured as shown in Fig. 8. High energy x ray was transmitted through the chamber even though the lead plate was placed for shielding the radiation. Maximum integrated dose is $2x10^9$ Gy. It is clear that the thickness of the plate should be increased.

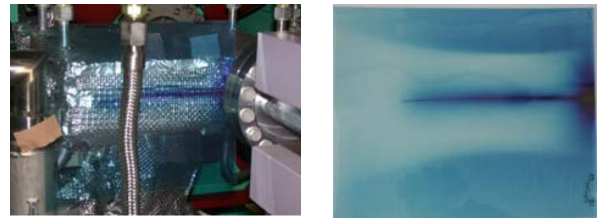

Figure 8: Radiation distribution behind absorber 3.

Others

Radiation dose around the cover of interlock wires was measured but it was under the measurable level of GAFCHROMIC film. Radiation level around the thermal sensor wire was $4x10^5$ Gy.

White powder appeared on the surface of the insulating cover of the bending magnet power cable owing to the radiation. But radiation dose was less than the measurable level.

SUMMARY

Six years have been passed since the operation of SPring-8 storage ring started. There were many failures in these six years. As for the magnet, following failures occurred.

Magnet flow switches began to give a false signal. The rods of flow switches were eroded and pressure loss of water in the flow switch became small even if the sufficient water flowed, which caused a false operation. We changed them for float type flow switch.

Water leaked from the brazing point of a sextupole magnet coil. The cause is that the surface of the coil at a brazing point was corroded and a small hole was made, where the brazing was not sufficient.

Water also leaked from the rubber hoses. Radiation scattered from the absorbers hit the rubber hoses of quadrupole magnet. Integrated radiation dose at the rubber hose was $4x10^5$ Gy. We exchanged all the rubber hoses near the absorbers. We are planning to shield around the absorbers. Problems of the radiation damage become serious with the increment of integrated current and it is one of the important subjects for the operation of the storage ring.

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