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Recent Issues encountered by AMATERAS: A Cold-Neutron Disk-Chopper Spectrometer

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Abstract. We report recent issues that have been encountered by AMATERAS, which is a cold-neutron disk-chopper spectrometer installed at the Materials & Life Science Experimental Facility at J-PARC. After the last ICANS meeting held in 2014, AMATERAS has continued its user program. On the other hand, the spectrometer has faced several problems, such as a weak shield at the beam dump, failure of one of the chopper disks and many such problems, which we are currently investigating. Further, several instrumental improvements have been performed, such as background reduction, fixing badly designed parts and other such improvements. Our extensive experience obtained in the period of more than 7 years on one of the world's first pulse-shaping chopper spectrometers may help other researchers who are operating or planning to construct similar spectrometers.

1. Introduction

AMATERAS is a cold-neutron disk-chopper spectrometer that is installed at the BL14 port of the neutron source at the Materials & Life Science Experimental Facility (MLF) at J-PARC [1, 2]. As one of the world's first direct geometry chopper spectrometers having pulse-shaping operation (other first generation pulse-shaping chopper spectrometers are CNCS at SNS [3] and LET at ISIS [4]), the spectrometer was designed to perform efficient measurements in inelastic and quasi elastic neutron scattering experiments on powders, single crystals and liquids to investigate versatile subjects that were obtained from corrective excitations in crystalline systems to the diffusion of atoms, molecules and ions. AMATERAS initiated its user program in December, 2009. By the end of 2016, AMATERAS conducted more than 90 proposals (both general user proposals and in-house proposals), which resulted in 30 papers, 8 theses and 3 press releases [5].

Along with performing a user program, we are continually maintaining and improving the performance of the spectrometer. After the last ICANS meeting held in 2014, we encountered some serious problems with our spectrometer. These problems were caused by the increase in the proton beam power at J-PARC or by the aging effects. Many efforts were devoted to newly developed devices that



were employed by AMATERAS. In this situation, it was quite difficult to predict specific problems that the spectrometer may encounter at the beginning. Therefore, potential problems were often overlooked. More than seven years have elapsed since we started the operation of the instrument, and some hidden issues have been revealed now.

In this report, we describe recent issues of AMATERAS, which we encountered during the period from 2014 to 2016, to share our experiences with those who are engaged in the operation of similar spectrometers. This is one of the important tasks of the ICANS meeting, as demonstrated, for example, by J. R. D. Copley's report of his chopper spectrometer [6].

2. Spectrometer Issues

The causes of the problems that we have experienced while using AMATERAS in the period ranging from 2014 to 2016 can be categorized into two major causes. The first cause is an increase in the proton beam power of J-PARC. Until the end of 2014, J-PARC stably continued an operation of 300 kW for two years (including nine months of interruption due to the Hadron accident). Further, a short time trial of 1 MW operation was performed at the beginning of 2015. The continuous 1 MW proton beam power operation came in sight at that time. Thereafter, considerations regarding the radiation dose rate became serious. The radiation dose rate at the site boundary of MLF was discussed severely, because the dose rate is proportional to the beam power and maintaining this condition becomes difficult when the operational beam power becomes higher. The second cause of the issues that have been encountered by AMATERAS were the aging problems. AMATERAS was thought to be able to operate for more than a decade when it was designed. Further, a careful maintenance scenario was considered when the design was prepared. However, the entire AMATERAS system is complicated, and several new devices, of which we had no experience, were employed. Therefore, some of the potential aging issues were overlooked in the original setup.

2.1. A dose rate-related issue

In March 2014, one of the area monitors that were located at the MLF radiation-controlled area boundary recorded a dose rate of 0.26 $\mu\text{Sv/h}$. At that time, J-PARC was operated at a 300 kW proton beam power. According to our regulation, the dose rate at the boundary of the radiation-controlled areas should be less than 0.5 $\mu\text{Sv/h}$. The recorded value implies that the dose rate will exceed this maximum value when the J-PARC beam power will reach 1 MW. Because AMATERAS is the closest instrument to that area monitor, investigation was immediately conducted at AMATERAS. It was soon discovered that when AMATERAS was operated in the white beam mode (all chopper disks are stopped at their open positions), an extremely high dose rate was observed on the surface of the beam dump of the spectrometer. The highest value that was recorded was observed to be 45 $\mu\text{Sv/h}$ at 300 kW of operation at J-PARC.

This high dose rate was unexpected when we designed the spectrometer. An investigation, including neutronics calculation studies, was performed. It was discovered that when the direct beam strikes the inside of the get-loss tube (Fig. 1), a high amount of γ -rays were emitted. The AMATERAS beam dump consists primarily of concrete with borax

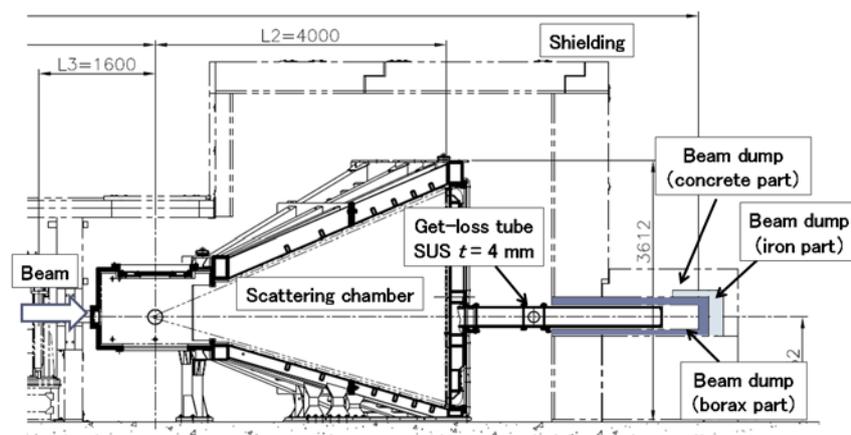


Figure 1. AMATERAS get-loss tube and beam dump.

around the get-loss tube and an iron plate at the end of the hole for the get-loss tube. When we designed the shielding for the AMATERAS, including the beam dump, a get-loss tube was not included in the design, because we did not expect a large contribution from it to the dose rate at that time.

To solve this issue with the help of neutronics calculations, we decided i) to add an additional shielding (100-mm-thick iron) to cover the entire outside of the beam dump and ii) to cover the inside of the get-loss tube with a 10-mm-thick B₄C resin plate. These were installed at the end of 2014, and the dose rate at the surface of the beam dump decreased to a maximum value of 0.4 μ Sv/h under similar conditions in which we had previously observed the high dose rate.

2.2. Aging-related issues

The major part of the AMATERAS construction was completed during the beginning of 2009. During its operation span of more than eight years, we have experienced a number of issues related to the breakdown of parts in the instrument. In the beginning, these were incipient failures that were caused by failures in manufacturing, design mistakes or misfittings. However, the situation has recently altered, and defects were more recently caused by aging.

In March, 2016, a vibration monitor at the housing of the fast disk chopper #3 (a RRM frame overlap chopper [7]) indicated 0.8 m/sec² at 300 Hz of operation, which is normally observed to be less than 0.2 m/sec². We suspected that the disk lost balance due to defects, deformation, or any other such reasons. During the developmental stage of the AMATERAS fast disk choppers, we experienced minor defects in the disks, which involved peeling between the prepreg layers of the carbon fiber-reinforced plastics (CFRP) in most situations, in addition to the major crashes. After initiating the operation of AMATERAS, we encountered two incidents related the disks in the fast disk choppers. We observed the deformation of one of the disks of the fast disk chopper #1 (a pulse-shaping chopper) in 2011. Deformation occurred at the slit. Therefore, we replaced the disk with a new one. Additionally, we realized that liquid was oozing off from the CFRP disks from the beginning [8]. Such a continuous leaking of liquid from the disks may hamper the balance of the disks over the long term.

The fast disk chopper was developed in collaboration with Kobe Steel Co. Ltd. However, the aforementioned company terminated their fast disk chopper business in 2013. Thereafter, we have not been able to find any replacement disks. Currently, we have limited the maximum operation revolution rate

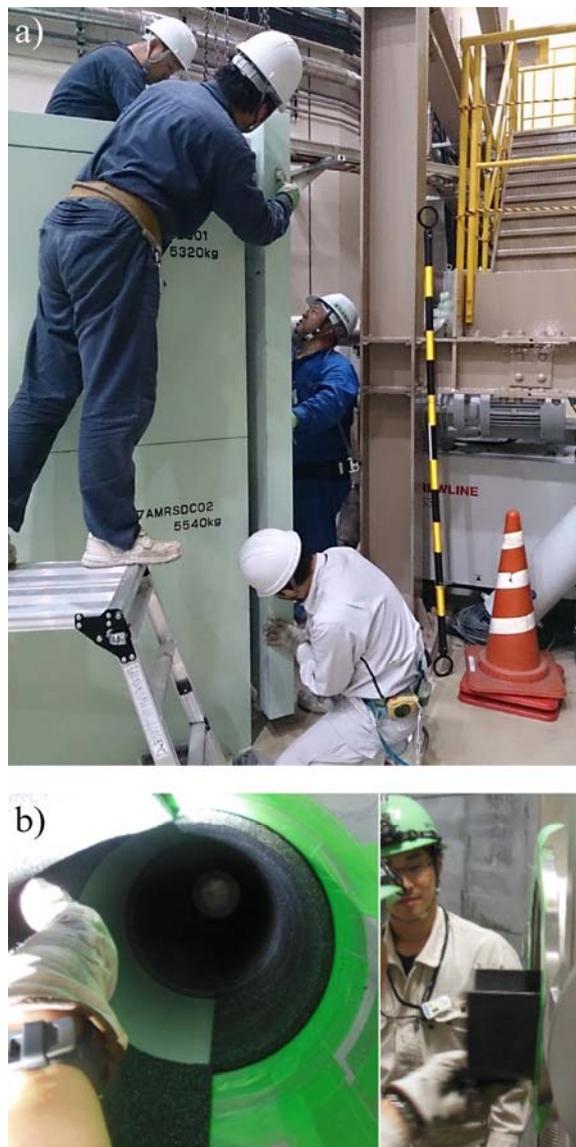


Figure 2. Solution to reduce the high dose rate. a) Covering the beam dump with a 100-mm-thick iron plate, and b) inserting a 10-mm-thick B₄C resin to cover the inside of the stainless steel get-loss tube.

to below 275 Hz, which affects the finest achievable energy resolution of AMATERAS. We have initiated a new development project for choppers with another company, and a new disk is expected to be delivered in 2017.

Regarding other major aging issues that were experienced from 2014 to 2016, we experienced i) the failure of a cryopump to evacuate the scattering chamber and ii) DAQ electronic issues, including high-voltage supplies to the main detectors. We have continuously repaired the cryopump, but have been unable to completely repair it. Therefore, we are planning to replace the entire system. Regarding the defective DAQ electronics, we will be replacing them with new systems until the end of Japanese fiscal year 2016. Computers for the instrument controls and data analysis, data stages, and pumps are regularly replaced and have encountered no serious problems until now.

3. Spectrometer Improvements

Major upgrades are difficult to plan because we cannot expect a huge budget. Regardless, we can plan and perform many small refinements that contribute to the users obtaining improved data. During the period ranging from 2014 to 2016, we primarily devoted our efforts to studying and reducing the background, modifying poorly designed parts of the instrument, and improving utilities to improve the usability of the instrument.

3.1. Background reduction

We have been continuously reducing the noise level of AMATERAS. As we have reported at the previous ICANS meeting [9], the background level in the measurements became approximately similar to the value that was obtained when the accelerator was terminated. The time-independent background mainly originates from electric noise and cosmic rays. Preliminary tests indicated that covering the floor near and underneath the scattering chamber with shielding materials is effective to reduce the cosmic-ray origin background. In 2015, we prepared B₄C tiles that were 10-mm-thick and placed them on part of the floor (Figs. 3 and 4(a)). Thus, we achieved more than 20% reduction of in the time-independent background. Therefore, we have to extend the covered region to obtain a further reduction in the background, which has been planned for the future.

3.2. Refurbishment of vanes

AMATERAS has 14 detector banks that are accommodated in the scattering chamber. The detector banks are separated from each other by vanes to reduce the cross talk background from the detector surfaces. The vanes have a 1-m depth and are covered using 0.5-mm-thick Cd plates. These vanes were previously distorted and poorly aligned, and some pixels of the detectors were hidden by these vanes. These old vanes were stainless steel flames covered by the Cd plates, which hanged from the top of the inside of the scattering chamber. The bottom ends of the vanes were clipped on the bottom inside of the chamber, but contained no tension which caused the distortion. Thereafter, we refurbished these vanes. In the new vanes, each flame experienced an applied tension from both the top and bottom using spring coils and wires to avoid distortion. Careful alignment was performed using a laser marker. Therefore, the shadows of the vanes on the detectors have been completely eliminated, which is equivalent to installing new detectors.

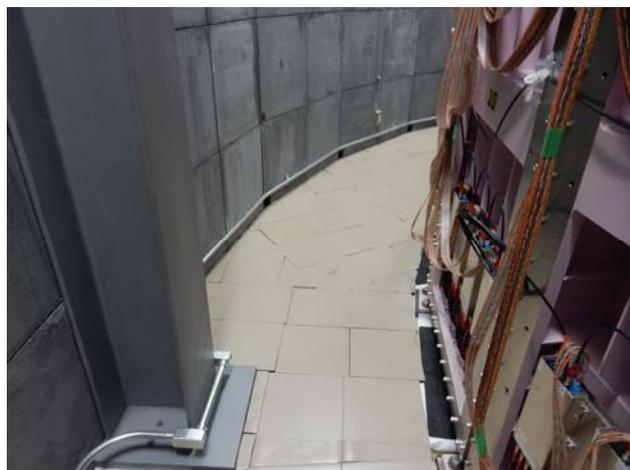


Figure 3. The floor is covered with B₄C tiles (10 mm thick). The upper surface of the tiles are covered with flooring material.

3.3. Other efforts

We introduced automatic butterfly valves for two roughing pumping lines for the scattering chamber. So far, the initial process of vacuum evacuation has been manually performed. Further, we are improving the utility lines, such as gas, cooling water, electric power, He-recovery, and auxiliary vacuum lines for sample environments. Additionally, other minor improvements have been made to improve usability, reduce human burden, and make the experimental work more comfortable so that users and instrumental staff can concentrate easily during their experiments.

4. Summary

We reported the current status of our cold-neutron disk-chopper spectrometer, AMATERAS. AMATERAS is renowned as one of the most advanced neutron spectrometers. However, every spectrometer have their ugly sides [6], which we continuously aim to improve upon as part of the instrumentation business. We hope our experience will help others who operate or are planning to operate or build similar instruments.

Acknowledgments

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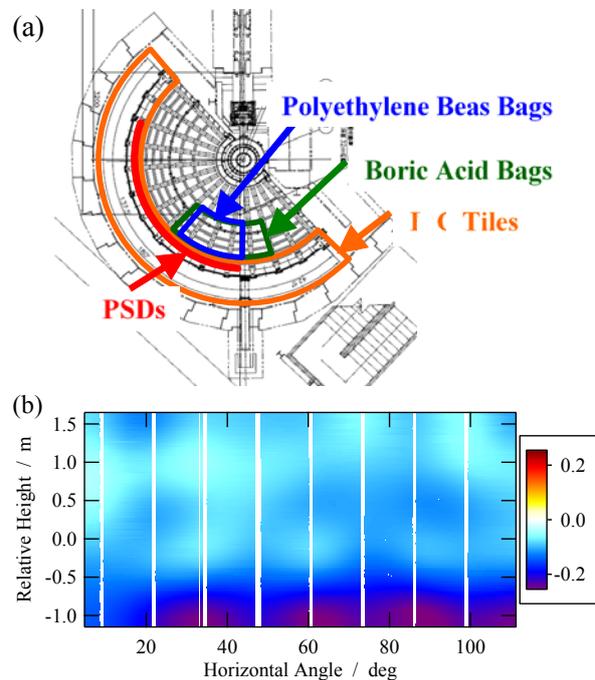


Figure 4. (a) The floor map of the AMATERAS shielding housing where the scattering chamber is accommodated. B₄C tiles (10-mm-thick) were placed in the corridor and just under the PSDs. Bags of borax and polyethylene beads are also placed under the scattering chamber. (b) The resulting reduction of time-independent background is described on the detector map image. A large reduction was observed, especially in the downward pixels.