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Irradiation properties of T0 chopper components

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ABSTRACT

We investigated the irradiation properties of the components of a T0 chopper. The organic materials in the rotor bearing grease, the magnetic fluids in seals, and the rubber in the timing belt, as well as the semiconductor materials in the rotation sensor and motor encoder, were all irradiated with high-energy γ-rays up to 100 kGy. No significant damage that shortens the lifetime of a T0 chopper was observed for the mechanical components. However, the semiconductor components were damaged by the irradiation. For the rotation sensor system detecting the rotor phase, the signal from a marker on the rotor shaft was transmitted outside the shielding by an optical fiber with radiation-proofing and the electrical circuits were removed from the beamline shielding. The lifetime of the motor encoder possibly meets the requirement for the maintenance period of the T0 chopper.

1. Introduction

Pulsed neutron sources emit neutrons in a wide energy range, and hence, neutron scattering experiments are performed using neutron spectrometers by selecting the energy range that is suitable for the spectrometers. High-energy neutrons from the pulsed neutron source are scattered and moderated within the spectrometer, resulting in a large amount of background noise. The T0 chopper is one of the devices for selecting the neutron energy range, and it reduces the noise originating from high-energy neutrons by blocking the incident neutron beamline at around time zero. In the T0 chopper, a massive blade made of shielding materials for high-energy neutrons rotates in synchronization with the production timing of pulsed neutrons. When the blade is initially centered on the beamline, at a rotational frequency of 100 Hz, the blade is removed from the beam cross-section in half milliseconds, and then the spectrometer accepts neutrons up to the electronvolt range, with a reduction in the number of high-energy neutrons.

We developed a T0 chopper rotating at 100 Hz to utilize neutrons with energies up to the electronvolt range for performing neutron scattering experiments at the Japan Proton Accelerator Research Complex (J-PARC) [1]. In this T0 chopper, a rotor with blades made of Inconel X 750 is located in a vacuum chamber and supported by mechanical bearings. The mass of the rotor is 120 kg. The motor is located outside the vacuum chamber, and the rotation motion is transmitted through a magnetic seal to the rotor inside the vacuum chamber. We used a servo motor with a power of 10 kW. The maximum rotational frequency of the motor is 50 Hz, and is doubled to 100 Hz by using a timing belt. To control the rotation of the T0 chopper, a rotation sensor is placed on the axis of the rotor shaft, and a motor encoder is mounted on the motor itself. The T0 chopper is mounted in the primary flight path of the neutron beamline, and then, the neutron beam transmitted through the T0 chopper is incident on the sample to be investigated using a spectrometer. In terms of maintenance, a running time of more than 4000 h without changing any component of the T0 chopper is required, corresponding to the annual beam time. We designed and assembled a test machine for the T0 chopper. Using this test machine, we confirmed that the performance satisfies the specification and that the running time is more than 4000 h. On the basis of the results of the development, we manufactured actual machines for installation at the neutron beamlines of J-PARC.

Because the T0 chopper is located in a relatively high radiation field, we should take care of radiation damage to the components of the T0 chopper. Radiation damage to its components is possibly a factor in determining the maintenance period of the T0 chopper. The main rotational components of the T0 chopper, which are its bearings, magnetic seals, rotation sensor, and timing belt, are located on the rotor shaft at a distance of 300 mm from the neutron beamline. The spatial distribution and material dependence of the absorbed dose around the T0 chopper have been calculated for a proton beam power of 1 MW [2]. In this calculation, a neutron beam with a cross-section of 100 mm $\times$ 100 mm was incident upon a block

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of Inconel X 750 with dimensions of 100 mm × 100 mm × 300 mm (with the length 300 mm along the beamline) at 7.5–7.8 m from the neutron source at the Material and Life Science Facility (MLF) of J-PARC. The neutron source is surrounded by a biological shield of iron over an area up to 7.1 m from the neutron source except for the neutron beamline. Absorption doses were calculated for a material located along the direction perpendicular to the incident neutron beam yet near the Inconel block. The calculated doses in Gy/y at 300 mm from the neutron beamline beside the Inconel block, which is the average in the area between 200 mm and 400 mm, were as follows: 0.46 (n) and 1.14 (γ) for polyethylene, 0.15 (n) and 0.79 (γ) for oxygen, 0.07 (n) and 1.00 (γ) for silicon, 0.02 (n) and 1.32 (γ) for iron, where n and γ indicate the doses for neutrons and γ-rays, respectively. Therefore, the absorbed dose beside the Inconel block at 300 mm from the neutron beamline was calculated at approximately 1 kGy/y for a proton beam power of 1 MW, and the contribution of γ-rays was dominant.

We investigated the irradiation properties of the components of the T0 chopper by using high-energy γ-rays, and the T0 chopper was designed on the basis of these investigations.

2. Irradiation experiments

Irradiation experiments using high-energy γ-rays emitted from ^{60}Co were performed in the Cobalt-60 Irradiation Facility at the Takasaki Advanced Radiation Research Institute of the Japan Atomic Energy Agency (JAEA). The organic materials in the rotor bearing grease, the magnetic fluids in the seals, and the rubber in the timing belt, as well as the semiconductor materials in the rotation sensor and motor encoder, were all irradiated with high-energy γ-rays. These components were used in the test machine for the T0 chopper. To investigate the properties of the materials, the irradiation doses of the samples were controlled to 1, 10, and 100 kGy.

3. Organic materials in mechanical components

3.1. Static properties of rotor bearing grease

Grease consists of a puffing agent and a base oil. The puffing agent is a solid component used to make the base oil gel-like by configuring a three-dimensional structure and increasing the viscosity. We investigated the static properties of the grease in the rotor bearings. The puffing agent consisted of polytetrafluoroethylene (PTFE) particles, and the base oil was perfluoropolyether (PFPE). These two components were separated by supersonic washing apparatus using tetradecafluorohexane. The puffing agent was observed by scanning electron microscopy (SEM), and the base oil was investigated by ^{19}F-NMR [3]. The grease samples were irradiated with the doses of 1, 10, and 100 kGy. Fig. 1 shows the particle size distributions of the puffing agent in the unirradiated and irradiated samples as observed by SEM. The microscope images show that the particle size distribution and the particle connection were almost unchanged in the dose range from 0 to 100 kGy. The observed ^{19}F-NMR spectra were almost unchanged in the dose range from 0 to 100 kGy, and the average molecular weight of the

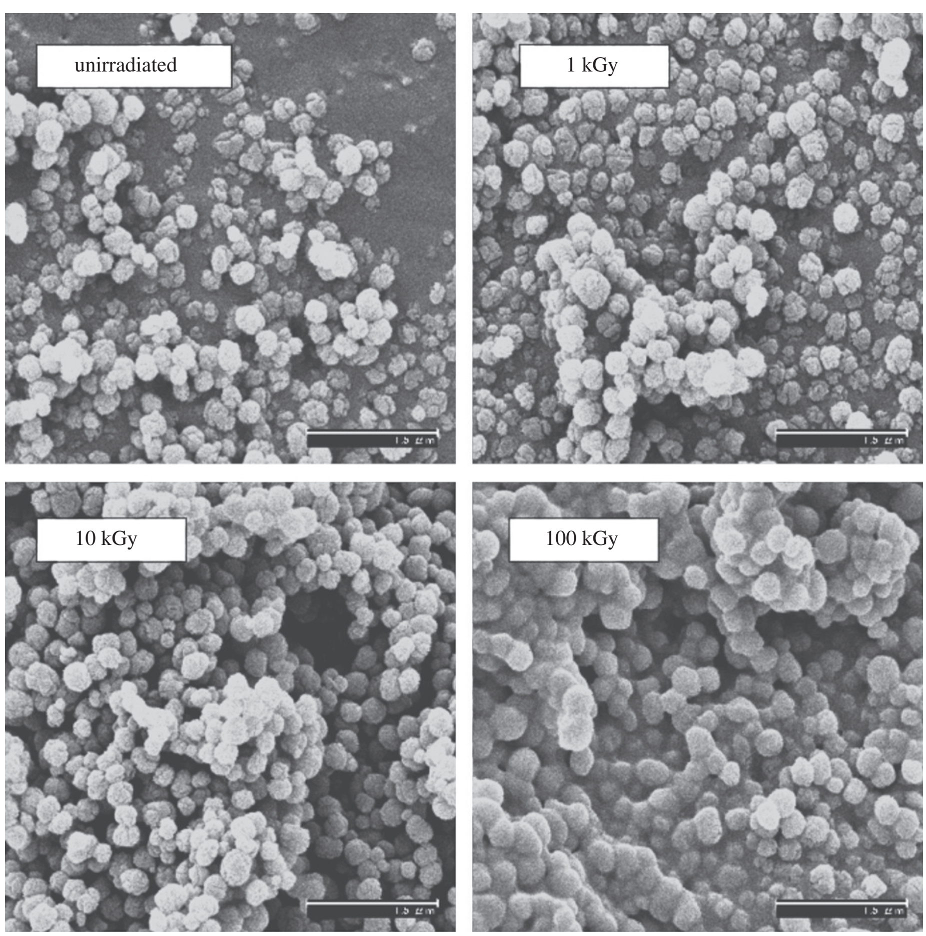

Fig. 1. SEM photographs of puffing agents in grease of rotor bearings. The width of the scale in each photograph is 1.5 μm.