FUNDAMENTAL STUDY OF HAPTIC SENSOR UTILIZING MAGNETIC COMPOUND FLUID RUBBER SENSOR FOR INVESTIGATION OF NUCLEAR FACILITIES

R. Ikeda[1,a], K. Shimada[2,b], H. Kikura[3,c]

[1] *Nuclear Engineering Course, Tokyo Institute of Technology, Japan,* [a]*ikeda.r.ah@m.titech.ac.jp*
[2] *Faculty of Symbiotic Systems Sciences, Fukushima University, Japan,* [b]*shimadakun@sss.fukushima-u.ac.jp*
[3] *Laboratory for Zero-Carbon Energy, Tokyo Institute of Technology, Japan,* [c]*kikura.h.aa@m.titech.ac.jp*

Abstract. Humanoid robots are expectable in a nuclear facility for their manipulation and operation in a nuclear power plant. Therefore, it is necessary to develop a haptic sensor can be adapted to radiation environment. Recently, we have been developed haptic sensor utilizing functional fluids involving MCF (Magnetic Compound Fluid) for artificial skin. Magnetic Compound Fluid (MCF) rubber is a new smart sensor obtained by mixing rubber with MCF. In this study, we clarify the adapatability of tactile function of MCF rubber for investigation of nuclear facilities.

1. Introduction

The robots are expectable in the nuclear facilities for their manipulation and operation in a nuclear power plant involving inspection, prevention [1], decommissioning [2], etc. An important element in developing of a robot for internal investigation in the nuclear power plant is sensing technique. Requirements for sensor loaded on a robot are as follows: (1) it has flexibility and elasticity like a human skin; (2) it does not deteriorate by radiation environment; (3) it can be used in water.

The optimal material fulfilled the overall above-mentioned prerequisites, elasticity and softness of haptic rubber having sensor with sensibility to overall electromagnetic waves, is magnetic compound fluid (MCF), which is one of magnetically responsive fluid consisted of nm-ordered magnetite (Fe3O4) and μm-ordered metal particles such as Ni, Fe etc. When a magnetic field is applied on the rubber compounded with the MCF which is vulcanized by drying or electrolytic polymerization under the production, the Fe_3O_4 and metal particles aggregate needle- or network-like clusters aligned along the applied magnetic field lines like needles in the MCF rubber. Therefore, the MCF rubber exhibits electrically and mechanically anisotropy enough to be haptic for typically sensing force such as piezoelectricity and piezoresistivity along the aligned particles. Futhermore, MCF rubber is not easily degraded by γ-ray irradiation [4]. In this study, we focus on a tactile function of MCF rubber, and clarify the adapatability of tactile function of MCF rubber sensor at nuclear facilities.

2. Foot-type MCF rubber sensor

To confirm the developed foot-type MCF rubber sensor, I experimented at the Cobalt Irradiation Experimental Facility. We measured the electrical signals of a humanoid robot with tactile MCF rubber sensors attached to its legs while it performed a walking motion in an irradiation chamber (Fig.1).

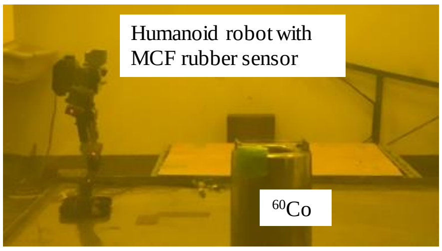

Fig.1. Image of irradiaiton chamber through lead grass for irradiation experiment

Fig.2 shows the results of the voltage change of tactile MCF rubber during 90 Gy/h of γ-ray irradiation. Since MCF rubber measures tactile sensation as a voltage, the vertical axis is the change of voltage. The graph area is divided into three sections, each displaying the voltage values in the standing, walking, and standing. First, the voltage values in standing were constant, as shown "standing". Then when the robot performs a walking motion, the voltage value fluctuates as shown "walking". Finally, when the robot was once again in an standing position, the voltage values were measured to be the same as the steady-state values measured at the beginning.

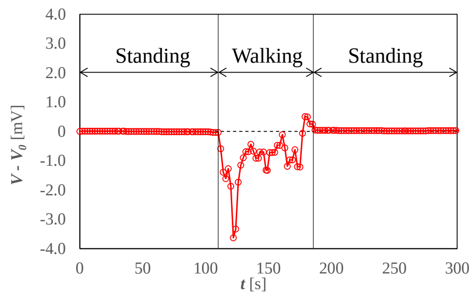

Fig.2. A voltage of tactile MCF rubber sensor during walking in radiation environment

3. Finger-type MCF rubber sensor

The artificial finger mimicking a human body can be simulated the finger embedded with mechanoreceptors or thermoreceptors, μm-scaled cell-like fabric, for example, nerve endings of the receptor, Meissner corpuscles, Pacinian corpuscles, Merkel cells, Ruffini endings, etc. Where by the kind of these receptors, the sensitivity to normal force, shear stress and temperature is different.

In procedure of finger-type MCF rubber sensor, first, we fabricated a sensor simply imitating human somatosensory receptors using Electrolytic polymerization, then to form the shape of human fingers, MCF rubber were coated with urethane rubber, silicone rubber,then finaly made a finger-type tactile sensor as shown in Fig.3.

Experiments were conducted on the fabricated finger-type tactile rubber sensor as shown Fig.4. The finger sensor was lowered vertically into the bottom of a container using a compression tester, and the change in voltage was measured with a digital meter. The results of experiment are shown in Fig.5. A Change in voltage occurs at the moment of contact with the surface. These phenomena depend on the piezoelectricity and piezoresistivity of the electrolytically polymerized MCF rubber resulting from dielectric polarization. Then, when a finger touches the bottom, i.e., when the pressure changes, a change in voltage occurs, indicating that it works as a tactile sensor.

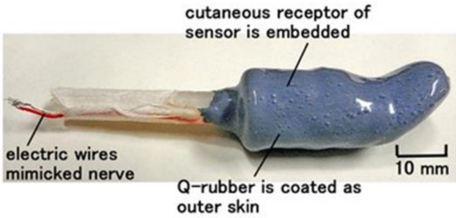

Fig.3. Image of finger-type MCF rubber sensor

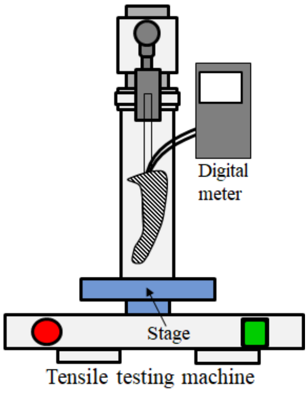

Fig.4. Experimental applatus

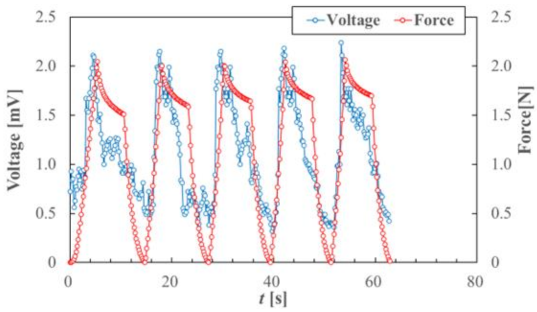

Fig.5. A change of voltage when a finger touches on the surface

Conclusions

Through the development of energy harvesting and haptic enhancement application to sensors that mimic the human body, it will be developed sensing technique for nuclear facilities by haptic sensor utilizing magnetic functional fluid.

References

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