Conceptual Design of Sensor Transport System for Dry Cask Storage Inspection

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1. Introduction

Several efforts are made to ensure the safety of dry casks for the spent nuclear fuel storage at the nuclear power plants. For such purpose, it is essential to develop a Sensor Transport Systems (SeTS) for the inspection of Dry Cask Storage Systems (DCSS) [1]. Considering the operational and structural conditions, the SeTS should be able to endure radiation and temperature environment, and to access narrow and stepped spaces. The SeTS is composed of tunable magnetic wheels, a motor and associated gears, and a controller. In this paper, a conceptual design of SeTS considering the structural and operational conditions is presented.

2. Considerations for SeTS

In this section, considerations for designing SeTS are presented and discussed.

2.1 Radiation and Temperature

It is necessary to consider the influence of the high temperature and radiation environment inside of DCSS. Any element and/or device used to design the SeTS should be chosen satisfying the operational environment. The radiation effect on the PM seems to be insignificant due to a low level of radioactivity, but the temperature effect seems to be significant. So, it is necessary to use the PM tolerable at a high temperature or an additional complementary design is required [2].

An experiment is conducted to consider the effects of high temperature environment on the PMs. It is a commercial product Neodymium N35 that operates at temperatures up to 80℃ and has a Curie temperature of 300℃. The change of magnetic force with 60 to 100℃ temperature change is shown as Fig. 1. In order to compare the changes with heating time, 15 min and 30 min are given. For the measurement of magnetic force, a force gage is used to pull the PM on a 20-mm thick steel plate.

As a result of the experiment, it is observed that the magnetic forces of the PMs are likely to be reduced even though the maximum temperature of 80℃ is not reached. Also it can be shown that the magnetic force decreases by 10% as the temperature increases by 10 degrees. But the difference between the heating duration is not high. The effect of the temperature on the PMs is identified, so it is necessary to design the SeTS coping with the experimental observation.

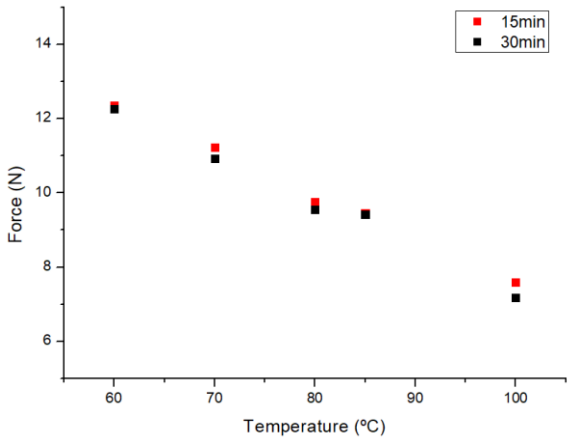


Fig. 1. Change of magnetic force depending on heating duration.

2.2 Narrow and Stepped Spaces

The size of the SeTS depends on the accessible space. The entry route in the DCSS is narrow and stepped, as shown Fig. 2. It is necessary to design the SeTS that can enter such spaces. Then the size of the SeTS could be limited to 0.2 m in length and 0.15 m in height [3]. Considering the size limit of the SeTS, the magnetic wheel must be compact as well as have sufficient magnetic force.

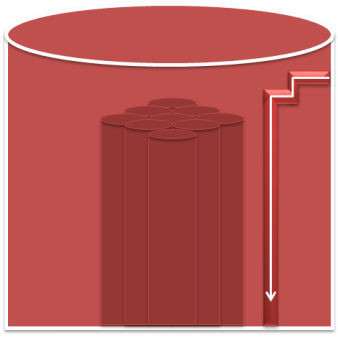


Fig. 2. Entry route in DCSS

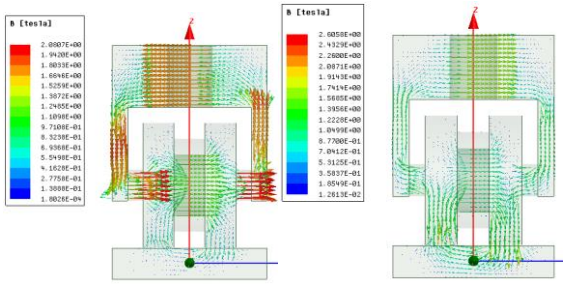
3. Conceptual Design of SeTS

In this section, the design of SeTS is presented in cooperation with a concept of the tunable magnetic wheels.

3.1 Model of a Tunable Magnetic Wheel

A tunable magnetic wheel consists of a cylinder-type magnet (PM1) between wheels rims, and a ring-type magnet (PM2) placed middle of the housing connecting wheel rims and the PM2 [4]. The PM2 controls the magnetic force in magnetic wheels by turning a servo motor and timing pulley. If the system is applied to the SeTS for DCSS inspection, it can be used stably by increasing or decreasing the force even in the unstable situation as the PMs is demagnetized cause of high temperature.

Fig. 3 shows the magnetic flux of the magnetic wheel with a tunable magnetic force. Fig. 3(a) presents the detached-state, which the poles of PMs are positioned antiparallel. Fig. 3(b) presents the attached-state when the PM2 is directed 180°, the poles of PMs are positioned parallel. The two PMs have the forces of attraction and repulsion between each other in Fig. 3(a) and Fig. 3(b), so it is possible to control the adhesive force between the wheels and the ferromagnetic plate.



(a) Detached-state (b) Attached-state

Fig. 3. Magnetic flux of the tunable magnetic wheel

3.2 Conceptual Design of SeTS

The conceptual design of SeTS in cooperation with tunable magnetic wheels is model, shown as Fig. 4. When moving on a horizontal steel plate, the magnetic force can be reduced for controlling the magnetic force to diminish the load applied to the motor.

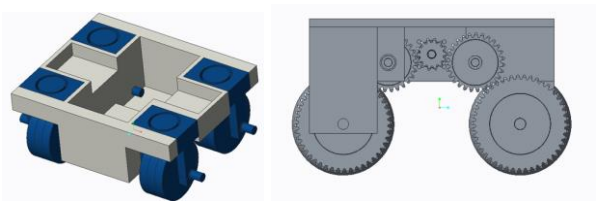


Fig. 4. Conceptual design of SeTS

The SeTS is composed of four magnetic wheels, one DC motor with a reducer, and associated gears to connect the wheels to the motor. Also the size of SeTS is determined in consideration of the internal space of the DCSSs. Therefore the length and height of the SeTS is decided to be 0.25 m in length and 0.15 m in height including the sensors for non-destructive inspection. Moreover the wheel size should be greater than 0.07 m in diameter to pass the vertical path.

4. Conclusions

The development of SeTS for DCSSs inspections is very important because it is directly related to the management of spent nuclear fuel, i.e., safety. Undoubtedly it is important to develop a non-destructive inspection sensor capable of inspecting the inside of DCSSs, but the development of an enterable system should not be neglected. Using tunable magnetic wheels, the SeTS with magnetic force is applicable not only to DCSSs but also to the environment where the magnetic force of the magnet is easily lost. It is expected that a more efficient system can be designed by modifying the tunable magnetic wheel being developed.

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