Thermal and Radiation Aging Characteristics of Hydraulic Snubber according to Silicone Oils

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1. Introduction

The hydraulic snubber absorbs the thermal deformation within the normal range generated by the supporting pipe or structure, and transmits the momentary dynamic load caused by impact or earthquake to the support structure[1].

The snubber's restraint and support performance must meet performance requirements according to Korea electric power industry code[2] and the technical specifications required by the power producer. In particular, for nuclear grade snubber, the KHNP(Korea Hydro and Nuclear Power) technical specification(APR-1400) requires Equipment Qualification considering the installation environment conditions of the nuclear power plant.

Therefore, in order to ensure the performance of nuclear power grade hydraulic snubber, it is necessary to study the change of characteristics of silicon oil, which is one of the main factors affecting performance, under nuclear environmental conditions.

In this study, in order to understand thermal and radiation aging characteristics of the hydraulic snubber according to silicone oil, viscosity analysis of silicone oil according to thermal and radiation conditions and the accelerated aging test for hydraulic snubber were performed.

2. Viscosity characteristics of silicone oil according to thermal and radiation conditions

The viscosity characteristics of silicone oil were analyzed according to the thermal and radiation conditions before the accelerated aging test of the hydraulic snubber. The silicone oil used for the viscosity analysis was as shown in Table 1.

Table 1 Silicone oil for viscosity analysis according to temperature and radiation condition

Silicon oil	Material type	Viscosity (at 25 ℃)
AK 350	Polydimethylsiloxane	351 cSt
DC 550	Dimethyl, phenylmethyl siloxane, trimethyl-terminated	125 cSt
DC 710	Phenylmethyl siloxane, trimethyl-terminated	500 cSt
HIVAC-F-5	Pentaphenyltrimethyltri-siloxane	160 cSt
KF-54	DiphenylDimethicone	400 cSt

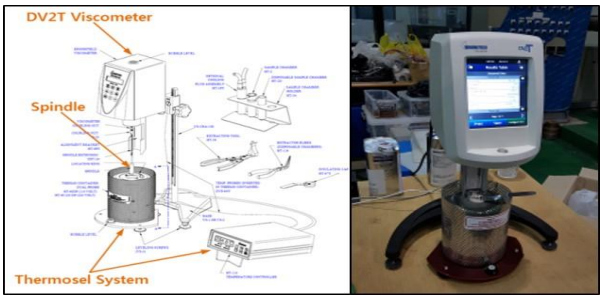

Fig.1 Silicone oil viscosity measuring device

The viscosity was measured in the range of 1.5 to 300,000 cP using a rotational viscometer(DV2T, BROOKFIELD) (Fig. 1).

The viscosity of silicone oil was measured at various temperature conditions(20~200 ℃) to confirm the change in viscosity characteristics due to thermal aging. The viscosity of the silicone oil decreased with increasing temperature. It has also been found that the methylphenyl type silicone oil, which is known to have excellent heat resistance and radiation resistance, has a larger viscosity decrease than the dimethyl type silicone oil with increasing temperature.

Based on the results of the viscosity measurement according to the temperature, the viscosity characteristics of the dimethyl type oil and the methylphenyl type silicone oil were analyzed according to the radiation environment. The radiation environmental conditions were considered to be 200 ℃, 2.0 x 10^6 Gy, an environmental condition that could be exposed to nuclear power plants. As a result of measuring the viscosity according to the radiation environment, the dimethyl oil was hardened in the normal radiation environment of the nuclear power plant, and the methylphenyl oil was increased in viscosity according to the irradiation dose, but hardening did not occur.

3. Accelerated aging test of hydraulic snubber

Two kinds of snubbers[rated load(F_N): 30 kN, stroke: 300 mm)]: 30 kN, stroke: 300mm) were fabricated as shown in Fig. 2 using different silicone oils to confirm the change of the performance of the hydraulic snubber due to the type of silicone oil and thermal and radiation aging.

Fig.2 Hydraulic snubbers for accelerated aging test

The snubbers were used of dimethyl type oil(AK350_Snubber A) and methylphenyl type oil(KF-54_Snubber B), and the sealing material was NBR(Nitrile-butadiene rubber).

In order to check the change of performance of the hydraulic snubber due to aging, the initial performance test was carried out before aging and the performance test was performed on the drag and activation which are representative performance factors of the main functional parameters. As a result of initial performance test, snubber A and B both satisfied the drag and activation required by KEPIC-MFD as shown in Table 2.

For the thermal and radiation aging of the hydraulic snubber, accelerated tests were carried out in consideration of the radiation and thermal aging environment that could be exposed during the design life in the nuclear power plant. The aging conditions were as follows.

Radiation aging was performed based on cumulative radiation dose of 3.0 x 10^5 Gy. Thermal aging was performed for 498.24 hours at above 120 ℃, which is the accelerated test condition calculated by Arrhenius equation, considering non - metallic material activation energy based on environmental temperature(40 ℃) and design life(60 years).

As a result of the visual inspection of the test snubbers after accelerated aging, silicone oil hardening occurred due to the influence of irradiation in Snubber A. As a result of performance tests on drag and activation for Snubber B, drag was similar to the initial performance test, while activation was increased(Table 3).

In the case of the methylphenyl type oil having excellent radiation resistance characteristics, it is considered that the viscosity of the oil decreased due to the effect of thermal aging on the effect of radiation on aging, resulting in an increase in the activation

Table 2 Performance test result of hydraulic snubber before aging

Test Parameter	Requirement (KEPIC-MFD)	Test results (T : Tensile) (C : Compression)		Remark
Drag	< 1.5 kN (< 5% of F_N)	Snubber A	0.65 kN (T) 0.74 kN (C)	Satisfied
		Snubber B	0.89 kN (T) 0.83 kN (C)	Satisfied
Activation	0.847~8.467 mm/s	Snubber A	1.28 mm/s (T) 1.69 mm/s (C)	Satisfied
		Snubber B	0.95 mm/s (T) 1.78 mm/s (C)	Satisfied

Table 3 Performance test result of hydraulic snubber after aging

Test Parameter	Requirement (KEPIC-MFD)	Test results (T : Tensile) (C : Compression)		Remark
Drag	< 1.5kN (< 5% of F_N)	Snubber A	Fail	Oil hardened
		Snubber B	0.80kN (T) 0.97kN (C)	Satisfied
Activation	0.847~8.467 mm/s	Snubber A	Fail	Oil hardened
		Snubber B	3.62mm/s (T) 4.28mm/s (C)	Satisfied

4. Conclusion

In order to check the change of thermal and radiation aging characteristics of hydraulic snubber according to silicone oil, the viscosity of oil according to temperature and radiation and accelerated aging test of hydraulic snubber were performed.

As a result of measuring the viscosity of the silicone oil according to the temperature and radiation condition, it was checked that the dimethyl type oil hardened under the normal radiation environment of the nuclear power plant. Therefore, it is considered that the dimethyl type oil is not suitable for use as a lubricating oil of a nuclear grade hydraulic snubber. Whereas, the methylphenyl type oil did not cause hardening of the oil even in a nuclear accident radiation environment.

As a result of the accelerated aging test of the snubber, the activation was increased in the snubber using methylphenyl type oil. It is considered that this is caused by the decrease in viscosity due to thermal aging of the silicone oil in the snubber.

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