Application of Micro-perforated Panel in the Reducing Noise of an Oil-Immersed Amorphous Metal Core Transformer

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Abstract. This paper focuses on reducing the vibration noise of amorphous metal alloy core distribution transformers (AMDTs) with a micro-perforated panel (MPP) absorber. A micro-perforated sound absorption structure was designed and installed in the inner sides of the tank circumference. To understand the reduction in vibration noise behaviors of AMDTs installed with MPPs under normal operation, an AMDT model was used as the test object, and a single MPP, double MPPs, and different backed cavities filled with transformer oil were investigated experimentally and compared when rated voltages were applied to the AMDT model. Testing was also implemented with the application of different applied voltages to the AMDT. A data-acquisition platform was set up for signal measurement. The results validate that the performance is improved by partitioning the backed cavity into differently sized sections, and that the performance is affected when the cavities are filled with transformer oil, and over-excitation voltages are applied to the AMDT model.

Introduction

Considering the fact that amorphous metal core transformers are used all over the world, the role of amorphous metal core distribution transformers (AMDTs) for energy efficiency and the reduction of worldwide CO₂ emissions is becoming significant [1]. However, the noise of an AMDT is larger than that of corresponding grain-oriented silicon steel based unit. This is because the magnetostriction of amorphous metal strip material is larger than that of silicon steels, and a high noise level is inevitable. Currently, environmental consciousness has led to efforts to reduce the noise of transformers further [2-3]. It is necessary to use some methods to reduce AMDT noise.

Previous researchers [4] have investigated ways to reduce the noise resulting from cores, which is attributed primarily to magnetostrictive vibration. Some measurement platforms of three-phase transformers were developed in [5-6], where the vibration of a transformer tank was the main concern, and some sound-reducing measures are recommended. Methods used were increasing the stiffness to reduce the amplitude on the tank surface by welding the rib-reinforcement, increasing the porous buffer between the body and junction and insulation banding belt around the cores, and considering the reasonable AMDT structure in the design to avoid the resonance frequencies in the transformer. These methods mentioned above are not widely used in transformers because they may lead to some other uncertain factors.

A micro-perforated panel (MPP) backed by a cavity and rigid wall was proposed to control noise, and the theory and design principles of MPP construction were established by Ma [7-9]; however there are few documents about the MPP absorbers used in transformer oil. An MPP absorber consists of one or more MPPs and one or more cavities, and the MPP absorbers can form Helmholtz resonance with the backed cavity when the MPP absorbers are installed in the AMDT. Most of the vibration
energy from the transformer magnetostriction and electrodynamics force will be absorbed by MPP absorber, and therefore AMDT noise will be reduced. In this paper, a noise reduction measurement for AMDTS is presented and verification is carried out by some experiments. Therefore, this paper emphasizes discussion on the effect of the whole diameter, perforation rate, air cavity distance, oil cavity, oil temperature, and applied voltage.

Experimental Setup and Procedure

In order to investigate the AMDT vibration characteristics, the outer and inner frame cores of an SBH15-10-10/0.4 AMDT and coil made with enameled copper wires were chosen as the main objects of the experiment, and their related parameters are listed in Table 1 [10]. A tank 460 mm in length, 310 mm in width, and 240 mm in height was made. Figure 1 (a) shows the sensors installed on the tank surface. The position F2 is in the middle of the front side, and the positions F1 and F3 are in the middle between F2 and the tank edge. The position B2 is in the middle of the back side, and the positions B1 and B3 are in the middle between B2 and the tank edge. The position L1 is in the middle of the left side, and the positions R1 is in the middle of the right side.

The multi-channel vibration measurement scheme is presented in Figure 1 (b). The testing system includes two separate parts: a signal collection unit and a data-processing unit. The former consists of vibration sensors. The latter consists of the signals sampled by an A/D data sampling card and personal computer (PC). Vibration sensors based on the principle of a piezoelectric accelerometer have the advantage of light mass, high stability, and amplifying circuits. Also, these sensors are appropriate for putting on the surface of the tank using insulated magnetic seats. ICP AD1000 type vibration sensors, which have a frequency range from 0.2 to 8000 Hz and a sensitivity of 1000 mV/g, were selected.

The noise meter measures sound pressures. The commercial FLUK 945 noise meter, which has a noise range from 30 to 130 dB with a resolution rate of 0.1 dB, was selected. The noise was recorded with the FLUK 945 placed 0.3 m from the outline of the AMDT. The noise-recording procedure was in accordance with the IEC60076-10 standard.

An A/D data sampling card with USB ports was chosen to convert the analog voltage signals to digital signals, with a resolution of 24 bits, and the maximum sampling frequency was 128 kHz. A 50 Hz magnetizing current of 0.015 A would produce a magnetic flux density of around 1.337 T.

![Figure 1. Experiment setup for the vibration of AMDT Model (a) Sensor arrangement on the tank. (b) Experimental setup.](156)
According to the vibration characteristic of the AMDT, an MPP absorber is designed. Therefore, the audible noise can also be reduced by installing the MPP absorber in the inner sides of the tank circumference. In order to reduce the tank vibration further, Double-MPPs absorber were designed with a diameter of 0.4 mm, a perforation ratio of 0.005, and a panel thickness of 1 mm, and the cavities depths were 80 mm (60 + 20 mm) and 60 mm (40 + 20 mm), respectively. The structure of the MPP absorber and its installation are shown in Figure 2. The positions of $F_1$-$F_3$, $B_1$-$B_3$, $L_1$ and $R_1$ in Fig. 1 are the same with these in Fig. 2.

Figure 2. Installation of MPP absorber in the interior of the tank (a) Single MPP (b) Double MPPs.

**Results and Discussion**

**The Effect of Transformer Oil on the MPP Absorber**

The testing was implemented on the tank surface filled with 25# transformer oil when the single MPP, double MPPs, and no panels were installed in the inner sides of the tank circumference, respectively. The total installation distances and volumes of the single and the double MPPs were the same and they were installed in the tank with oil. The single MPP backed cavity was divided into two different lengths.
Figure 3. Relation between the amplitude and frequency obtained from the vibration waveforms on the surface of tank filled with transformer oil.

Table 2 shows that the SPL will be reduced when an MPP is positioned approximately 80 mm in front of the rigid tank wall. Because the particle velocity inside the hole and the viscous friction in the holes are large, the noise for the SPL is reduced from 47.80 to 44.13 dB. The noise for the SPL is reduced from 43.39 to 41.13 dB when the double MPPs are installed in the inner sides of the tank circumference. It is shown that the performance of the MPP is improved by partitioning the backed cavity into multiple cavities with different lengths.

Table 2. SPL Comparison with oil cavity.

| Item       | Sound pressure(SPL),dB |
|------------|------------------------|
| No panel   | 47.8                   |
| Single Mpp | 44.13                  |
| Double MPPs| 43.39                  |

The Effect of Applied Voltage on the MPP Absorber

It is well-known that the AMDT tank vibration is caused by the magnetostriction of the core. The applied voltages were 0.9, 1.0 and 1.05 UN of the rated voltage, respectively.
Figure 4. Relation between the amplitude and frequency obtained from the vibration waveforms on the surface of tank with single MPP filled with transformer oil when the model was applied different voltages.

Figure 4 shows the relation between the amplitude and frequency obtained from the vibration waveforms on the surface of the tank with a single MPP absorber cavity filled with transformer oil when the different voltages were applied to the AMDT model. Then, the core’s vibration acceleration caused by magnetostriction is [10]:

\[
a_c = \frac{v}{t} = \frac{d^2(\Delta L)}{dt^2} = -\frac{2\lambda_s L U_0^2}{(N_i \omega B_i)^2} \cos 2\omega t
\]  

(1)

The transformer vibration increases with the applied voltage. The experimental results correspond to the theoretical values. The core will over-excited when the applied voltage is large enough. The vibration and noise will increase quickly. The noise increases from 41.13 to 47.38 dB in Table 3. The double MPP absorber has the same characteristic as the single MPP absorber.

Table 3. SPL Comparison with different applied voltages at the ambient temperature with single MPP.

| Applied Voltage | Sound pressure (SPL), dB |
|-----------------|--------------------------|
| 0.9 U_N         | 41.31                    |
| 1.0 U_N         | 44.13                    |
| 1.05 U_N        | 47.38                    |

Conclusions

The steady state vibration and noise characteristics on the tank surface of an AMDT filled with oil and air have been surveyed. Single and double MPP absorbers were designed with the electro-acoustical equivalent circuit model and installed in the inner sides of the tank circumference according to the vibration characteristic of the AMDT. Absorbers based on single and double MPPs are proposed for the AMDT. The following main conclusions can be obtained:

1. Experiments contrasting the use of an AMDT with a single MPP, double MPPs, and no panels were implemented. The SPL reduction was about 3 and 4.6 dB when the inner sides of the tank circumference were installed with the single and double MPPs, respectively. The results also demonstrate that the designed MPP absorbers are reasonable, and the amount of vibration energy spreading to the MPP installed in the inner side of the tank without oil can be reduced considerably. The performance of the MPP absorber can be improved by partitioning the backed cavity into two cavities of different lengths without changing the volume of the cavity.
The higher the oil temperature in the backed cavity of the MPP absorber, the weaker the performance.

The performance of the MPP absorber is also weakened when the core is over-excited.

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