

Audible Noise From Amorphous Metal and Silicon Steel-Based Transformer Core

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Abstract. Power transformers are the main components in the electric power system that function as voltage converters in the distribution of electrical energy. With complaints from the public about noise in amorphous transformers that cause fear in the community. The reliability of distribution transformers is significantly improved with a well-written test plan, which must include specifications for transformer testing. On newly manufactured distribution transformers, testing is carried out to determine whether the reliability of the distribution transformer meets reliability standards. The test carried out is a core noise test to determine the noise in amorphous transformers. Testing is carried out at the factory with 2 methods, namely no load test and load loss test. For field measurements using the load loss test method. Testing carried out at the factory and field measurements obtained high noise in amorphous type transformers. This study is to determine the noise that occurs in amorphous transformers whether the noise is still safe for the environment and the community.

Keywords: *amorphous magnetic materials, audible noise, audible noise measurement, transformer core.*

1 Introduction

Distribution transformers (DT) are one of the largest groups of equipment in the electricity network and therefore losses in distribution transformers constitute the largest number of total losses in the network. The most efficient distribution transformers in continuous operation record losses of approximately 2 to 4% of the electricity they deliver, and utilities and the electric industry continue to seek methods and technologies to reduce operating costs and energy losses. Distribution transformers carry loads that vary from time to time throughout the day and night, but in general the transformer capacity is adjusted to meet the maximum load during the day. However, often the average load on DT is much lower than the maximum load which only occurs for a few hours a day. By considering the average load of a Distribution Transformer, the efficiency

throughout the day or efficiency at lighter loads has significance in reducing grid losses of any utility. [1]

Disadvantages of distribution losses: Losses in distribution transformers consist of no-load losses, which do not depend on the load, and load losses which depend on the transformer loading. A low load factor means that no-load losses can constitute a high percentage of the total losses in a transformer, and distribution transformer design is focused strongly on reducing these no-load losses without compromising transformer performance. The main component of losses, namely no-load losses, can be reduced by better design and the use of cores made of high-grade electrical steel. By using high grade/high grade crgo laminates, no-load losses can be reduced significantly. The development of the Amorphous Metal Distribution Transformer (AMDT) offers further reduction of transformer core losses compared to crgo core losses. Amorphous core materials (AM) offer reduced hysteresis losses and eddy current losses because they have random grain and magnetic domain structures that result in high permeability resulting in narrow hysteresis curves compared to conventional crgo materials. The use of spent and impure crgo also contributes to higher losses for DT with crgo. Eddy current losses are reduced by the high resistivity of the amorphous material, and the film thickness. The laminate consists of thin ribbons and the sheet thickness is about 1/10 of crgo, which is about 0.025 to 0.030 mm. Amorphous core transformers offer a 70 to 80% reduction in no-load losses compared to transformers using crgo core material for the same Distribution Transformer rating. Currently, crgo steel is used in distribution transformers, where the permissible flux density limit is up to 1.55 Tesla to minimize core losses [2] [3].

1.1 Materials

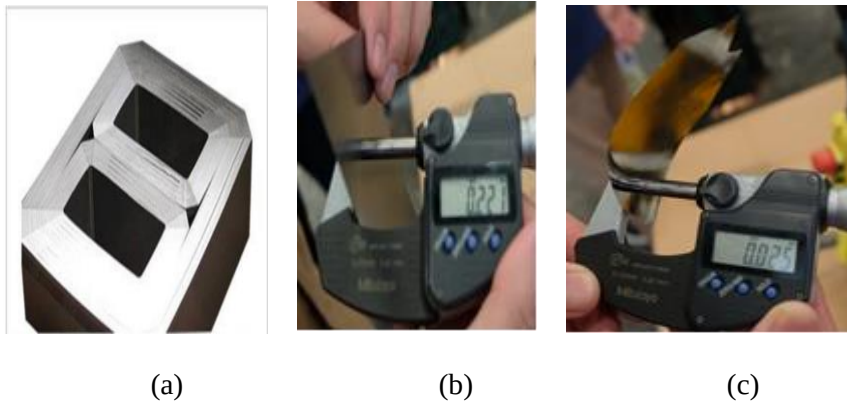


Figure 1 amorphous material a. amorphous and crgo material b.thickness of crgo c. thickness of amorphous

2 Amorphous alloys

2.1 Histori

For nearly 50 years, researchers and engineers have explored planar flow casting techniques for amorphous soft magnetic alloys. These alloys typically have a chemical composition of (Fe, Co, Ni) 70-85% and (Si, B) 15-30% (at.%) with a thickness of about 20 to 30 μm . The magnetic properties of these alloys are adjusted by altering the chemical composition and through subsequent heat treatments. They are used in various applications such as distribution and power transformers, magnetic amplifiers, filters, and sensors. In terms of production volume, Fe-based amorphous alloys dominate due to their cost-effectiveness and use in distribution transformer cores.

The use of Fe-based amorphous alloys in electrical networks was initially driven by the oil crisis of 1973. These alloys, with relatively high saturation polarization (over 1.5 T) and significantly lower core losses compared to grain-oriented silicon steel, began to be implemented in distribution transformers in the United States during the 1980s [4].

Originally, transformer cores were designed in a toroidal shape. However, after the development of cutting technology for amorphous tape, the overlapping joint wound core design became the standard structure for modern amorphous alloy transformer cores. As a result, a magnetic field along the circumferential direction is applied during the stress relief heat treatment. Initially, the size of these distributed overlapping wound cores was limited, so relatively small distribution transformers, such as pole-mounted and pad-mounted transformers with amorphous cores, were primarily installed in the United States and Japan until the late 1990s. There have also been occasional efforts to create amorphous alloy stacked cores for use in distribution transformers and larger power transformers.

Stacked cores made from amorphous alloys have not yet become widely adopted. One technical challenge is the cost competitiveness of the manufacturing process, while another is the handling of the brittle, annealed amorphous alloy. Since the thickness of amorphous alloy is approximately one-tenth that of grain-oriented silicon steel, using the same processing techniques as those for silicon steel leads to a lead time that is ten times longer. To reduce processing time, amorphous tape consolidation is recommended. This involves combining multiple strips of amorphous alloy into a single group, effectively treating them as one band. For instance, six amorphous alloy strips can be consolidated into one.

2.1.1 Improvement of soft magnetic properties of distributed-lap joint wound cores

Distributed-lap joint wound cores of Fe-based amorphous soft magnetic alloys have been widely used in distribution transformers. It is well known that the core loss of wound cores becomes as high as twice of that in straight strips [5]. One of the dominant reasons is due to the residual bending stress at the corners of a wound core. Since the annealing temperature is about 300°C for Fe-based amorphous alloys, it is not high enough to release all the bending stress [6] of amorphous alloys, resulting in the increase of hysteresis loss

3 Experiment

Tests were conducted during manufacturing to assess the noise levels in the transformer. Figure 2 displays the transformers used in this research, which are equipped with amorphous cores and have a rating of 100 kva . The specifications for these 100 kva transformers with amorphous cores are provided in Table 1.

3.1.1 Laboratory manual book

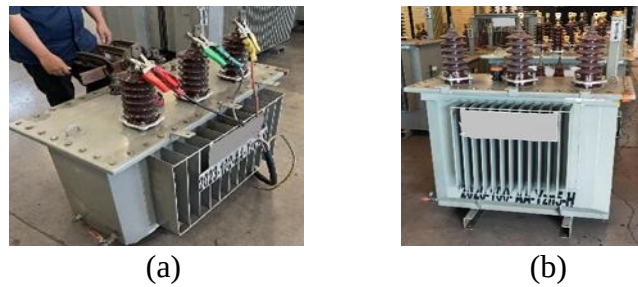


Figure 2 transformer with amorphous core and crgo a.100kva amorphous
b.100kva crgo

Table 1 Specification of the transformer

Detail	100 kva	100 kva
Type	In door/out door	In door/out door
Frequency (hz)	50	50
Serial no	227616	134252
Rated Capacity (kva)	100	134252
Rate voltage hv (v)	200.000	200.000
Rate voltage lv (v)	400	400
Ambient (°c)	31	400
Tap position	3	3
Core type	Amorphous	Crgo

The transformer measurements include two key tests: the no-load test and the load loss test. These tests are crucial for assessing the transformer's performance and efficiency. Additionally, tests were conducted to measure the noise generated by the transformer.

1)No Load Test (Open-Circuit Test)

A no-load test is performed to assess the core losses and no-load current of a transformer. The procedure for conducting this test is as follows:

- a) The high-voltage side of the transformer is left open.
- b) A 400 V supply is applied to the low-voltage side.
- c) The no-load current (I_o) drawn by the transformer is measured.
- d) The power consumed by the transformer during no-load conditions is recorded.
- e) Record the no-load test results for both the 100 kva transformers.
- f) Measure the noise levels on the 100 kva transformers.

2)Load Loss Test (Short-Circuit Test)

The Load Loss Test is conducted to determine the copper losses (also known as load losses) in a transformer, which arise due to the current passing through the windings.

Table 2 Ampere load of test

%	Rating
	100 kva (A)
10%	0,29
20%	0,58
30%	0,87
40%	1,16
50%	1,45
60%	1,73
70%	2,02
80%	2,31
90%	2,60
100%	2,89

- a) The low-voltage side of the transformer is short-circuited.
- b) Voltage is applied to the high-voltage side of the transformer, and the current is adjusted to match the values specified in Table 2.
- c) The power consumed by the transformer under load conditions is measured.
- d) Record the load test values for the 100 kva transformer.
- e) Measure the noise levels on the 100 kva transformer.

In this research included data from others research. The Data transformer with crgo core used for comparison with amorphous.

4 Result and analisys

4.1 No load test

Presents the results of measured noise data from no-load loss test conducted on crgo and Amorphous transformers.

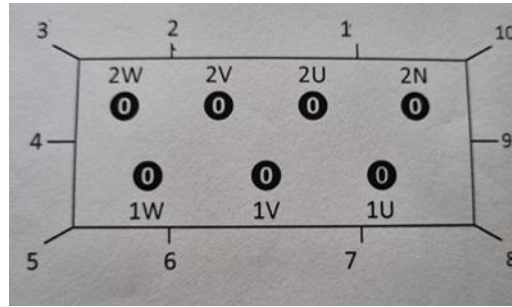


Figure 3 noise measurement in transformer

Table 3 Result noise no load 100 kva Amdt

No	Voltage(V)	current (A)	Background	measure
1	400	0,289	29,8	42,1
2	400	0,578	28,8	42,7
3	400	0,867	26,4	39,4
4	400	1,156	28,1	37,7
5	400	1,445	28,9	42,4
6	400	1,734	31,7	41,3
7	400	2,023	30,2	41,0
8	400	2,312	30,8	39,9
9	400	2,601	30,7	42,6
10	400	2,89	29,6	39,3

Based on Table 3 and Figure 3, the measurement results show different values due to several factors, one of which is that measurements taken near the LV and HV bushings result in higher noise values. However, if the measurements are taken farther from the LV and HV bushings, the noise level produced is lower.

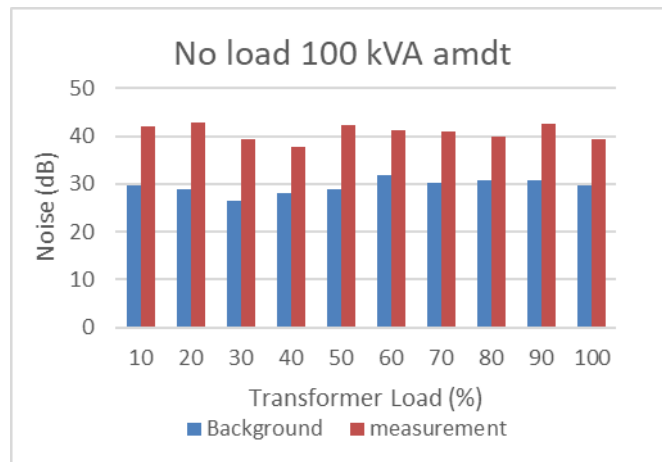


Figure 4 graphic no load 100 kva

Table 4 Result no load 100 kva trafo crgo

No	Voltage(V)	Current (A)	Background	measurement
1	400	0,289	31	37,6
2	400	0,578	31	38,5
3	400	0,867	30	35,7
4	400	1,156	31	38,2
5	400	1,445	31	40,5
6	400	1,734	30	41
7	400	2,023	30	41,1
8	400	2,312	30	40
9	400	2,601	30	39,7
10	400	2,89	30	39,7

Based on Table 4, it shows the noise results occurring in the 100 kva rgo transformer, where the noise is higher when approaching the bushing and lower when moving away from the bushing.

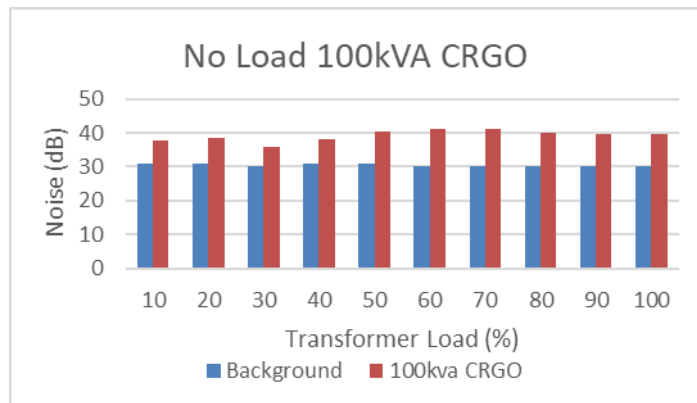


Figure 5 graphic no load 100 kva crgo

Based on the results of the no-load test graph above, the noise generated by the 100 kva crgo transformer is 41.1 dB.

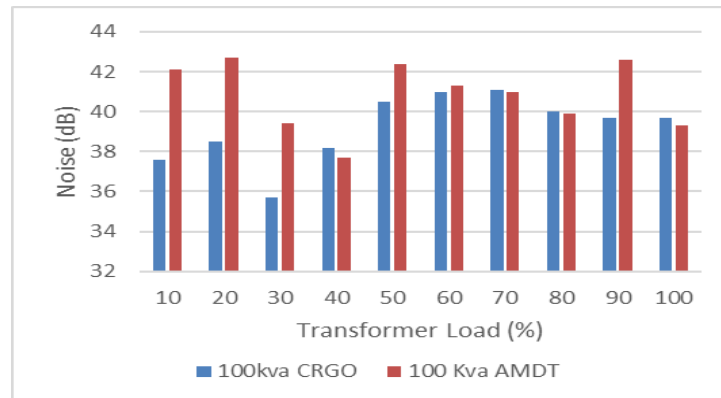


Figure 6 graphic non load 100 kva vs amdt

Based on the no-load test graph above, the comparison between the crgo and amorphous type transformers shows that the noise level is higher in the amorphous type compared to the crgo type, with a value of 42.7 dB.

4.2 Load Loss Test

Presents the results of measured noise data from load loss test conducted on crgo and Amorphous transformers.

Table 5 Comparison crgo vs Amdt

NO	Capacity(%)	crgo	AMDT
1	10	36,82	36,53
2	20	36,11	39,31
3	30	35,62	38,67
4	40	36,17	39,29
5	50	34,73	39,43
6	60	36,64	39,18
7	70	37,5	38,45
8	80	37,5	36,83
9	90	37,66	37,65
10	100	38,17	38,95

Based on the load loss test results table above, it shows that the noise level is higher in the amorphous type, which is 39.43 dB, while the noise level in the crgo type is 38.17 dB. Therefore, the noise of the amorphous type is higher compared to the crgo type.

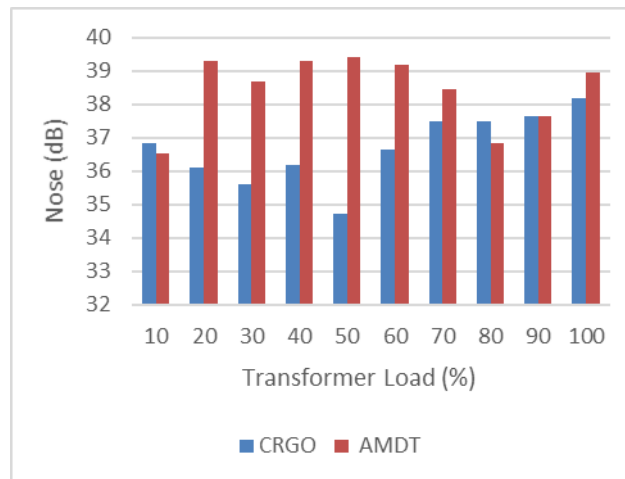


Figure 7 graphic no load 100 kva amdt

Based on the load loss test graph, it shows that the average noise level in the amorphous type is higher compared to the crgo type.

After carrying out measurements using a DB meter in the field with a load of approximately 50-90% of the 100 kva transformer capacity, the following results were obtained.

Table 6 Comparison crgo vs Amdt

NO	Load Transformer(%)	crgo	amdt
1	50	35,39	35,85
2	60	35,42	35,91
3	70	36,4	37,15
4	80	36,99	37,76
5	90	36,53	38,02

Based on the table above, from 5 measurements of the 100 kva amorphous and crgo transformers, the noise generated in the amorphous type is higher, which is 38.02 dB.

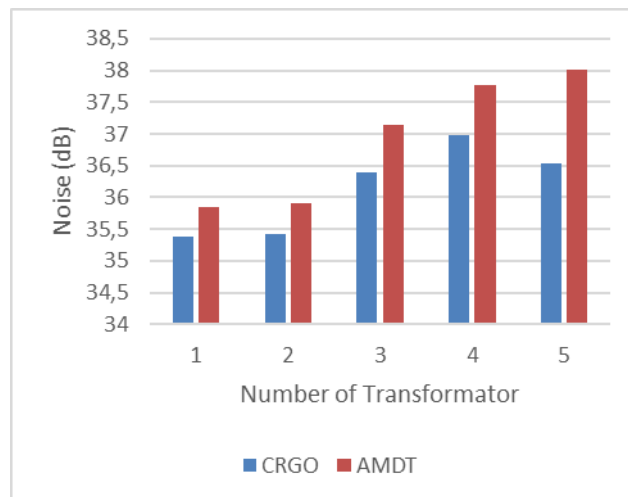


Figure 8 comparison crgo vs amdt

Based on the graph above, the average noise level is higher in the amorphous type. In the amorphous type, as the transformer load increases, the noise level also increases.

5 Conclusion

1. From the data and analysis above, the results of the no-load test and the loss-of-load test show a higher noise level in the amorphous type because the amorphous material is very thin at 0.025 mm.
2. every increase in load on the transformer, the noise will increase. high noise occurs around LV and HV on the transformer.
3. The measured noise is still within the safe range according to IEC 60076-10, which is below 51 dB meters.

References

- [1] C. E. AUTHORITY, *Guidelines for usages of Amorphous Core or CRGO Core Distribution Transformers*, 2018.
- [2] P. K. S. Man Mohan, "AN EFFORT TO REDUCE THE COST OF AMORPHOUS CORE DISTRIBUTION TRANSFORMER," *DISTRIBUTION TRANSFORMER WITH AMORPHOUS-CRGO CORE*, vol. VOL. 7, 2012.
- [3] T. M. Hill, "publication," *Transformers by BHEL*, 2009.
- [4] N. I. M. O. Daichi Azuma, *Journal of Magnetism and Magnetic Materials*, 2020.
- [5] J. M. Y OKAZAKI, "MAGN MATER," vol. 160, pp. 217-222, 1996.
- [6] R. H. S. S. M. T. D. AZUMA, "J. APPL. PHYS," p. 113, 2013.
- [7] K. Takahashi, D. Azuma, R. Hasegawa, *IEEE Trans. Magn.* 49 (7) (2013) 4001–4004.
- [8] M. Ohta, R. Hasegawa, *IEEE Trans. Magn.* 53 (2017) 2000205.
- [9] M. Ohta, Y. Yoshizawa, *Appl. Phys. Express* 2 (2009) 023005.
- [10] M. Ohta, R. Hasegawa, H. Itabashi, *IEEE Trans. Magn.* 54 (5) (2018).