

Low noise transformer technology

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INTRODUCTION

It is well known that high noise levels have a negative effect on people mood and health, therefore, in most countries legislation exists, which prescribes maximum allowable noise levels.

Transformer noise in general consists of no-load noise, load noise and cooling equipment noise. No-load noise is mainly due to magnetostriction in electrical steel when core is magnetized at nominal induction. Load noise is caused by magnetic forces between conductors in windings at nominal current. Cooling equipment noise consists of fan noise, oil pump noise, etc.

In this paper some procedures will be presented, which we use during different phases of low noise transformer production.

DESIGN

Design phase is very important, because mistakes made here are very difficult and expensive to correct in later phases. We use custom program called TrafoS which Kolektor Etra developed in cooperation with local university. This program is used in feedback loop to electrical designers and enables us to check electrical design from noise point of view as shown in Figure 1.

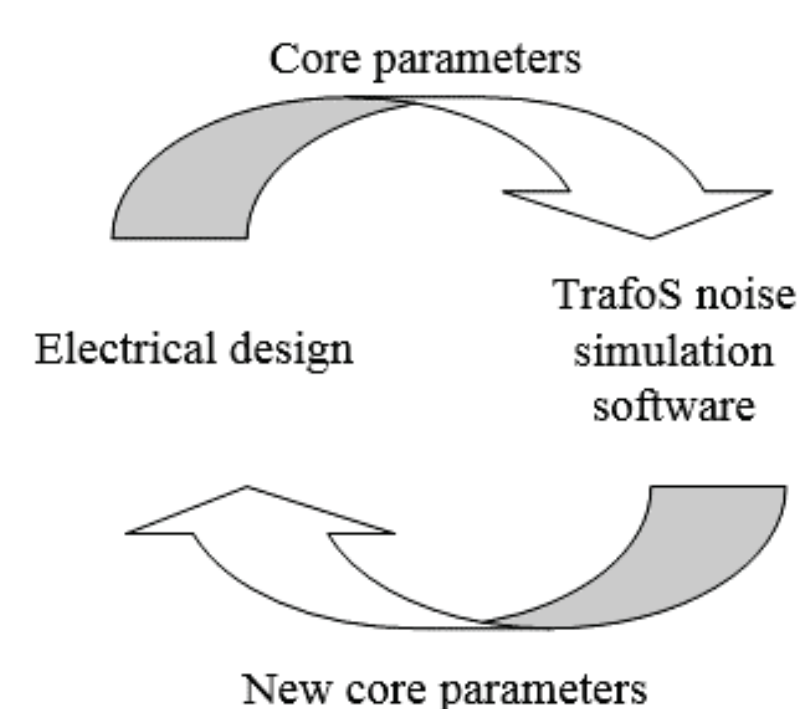


Figure 1: Feedback loop.

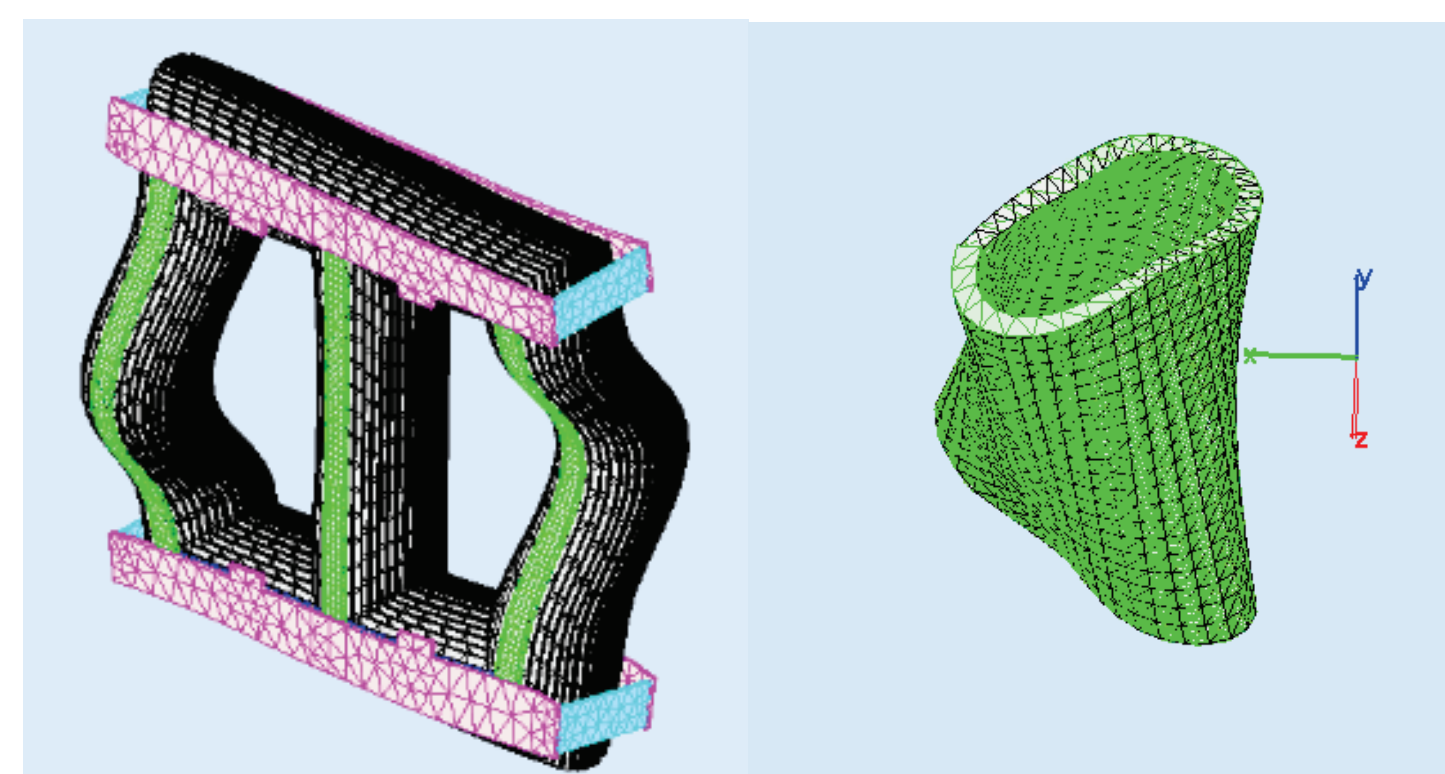


Figure 2: Core and coil resonance.

Correct dimensions are important in order to avoid core and coil resonances which can considerably increase noise levels. In Figure 2 one of the many calculated core and coil resonances are shown.

Core and coil vibrations are transmitted to transformer tank mainly through oil. This is why active part (core and coils) needs to be analysed together with tank in order to obtain tank wall displacement field. In Figure 3 a result of tank harmonic analysis is shown, where as an excitation source active part is used.

The resulting tank wall displacement field is then used as input for boundary element method (BEM). Using BEM we can determine sound pressure at prescribed contour where it will be actually measured later in the laboratory. In Figure 4 typical results from BEM are shown.

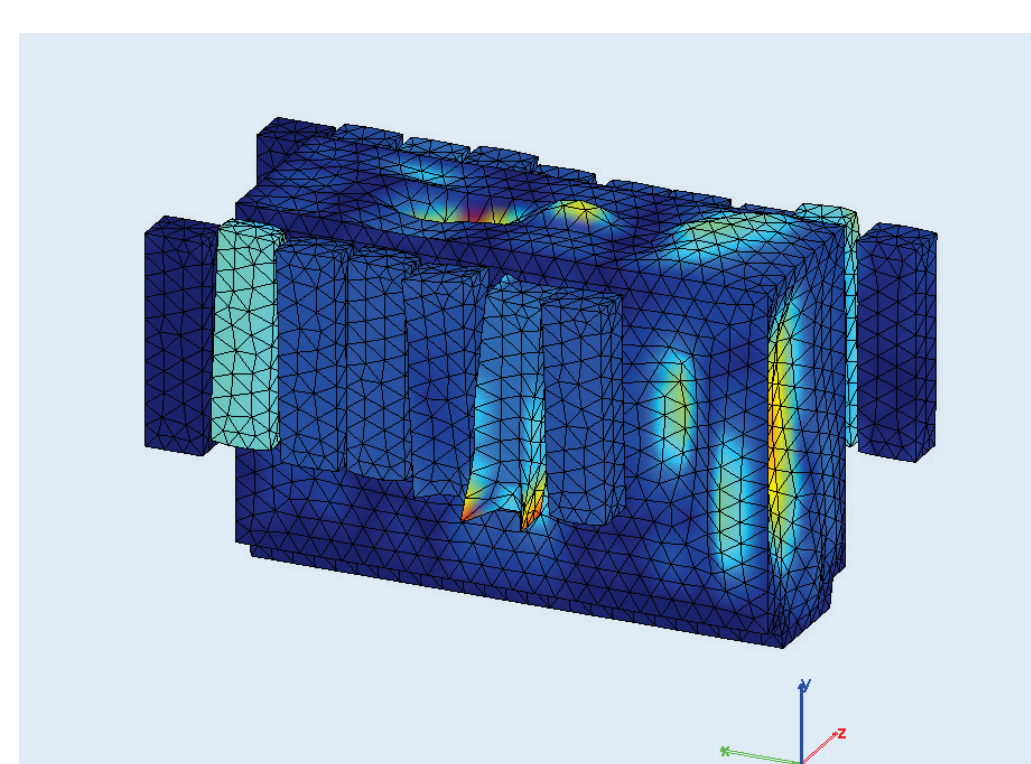


Figure 3: Tank harmonic analysis.

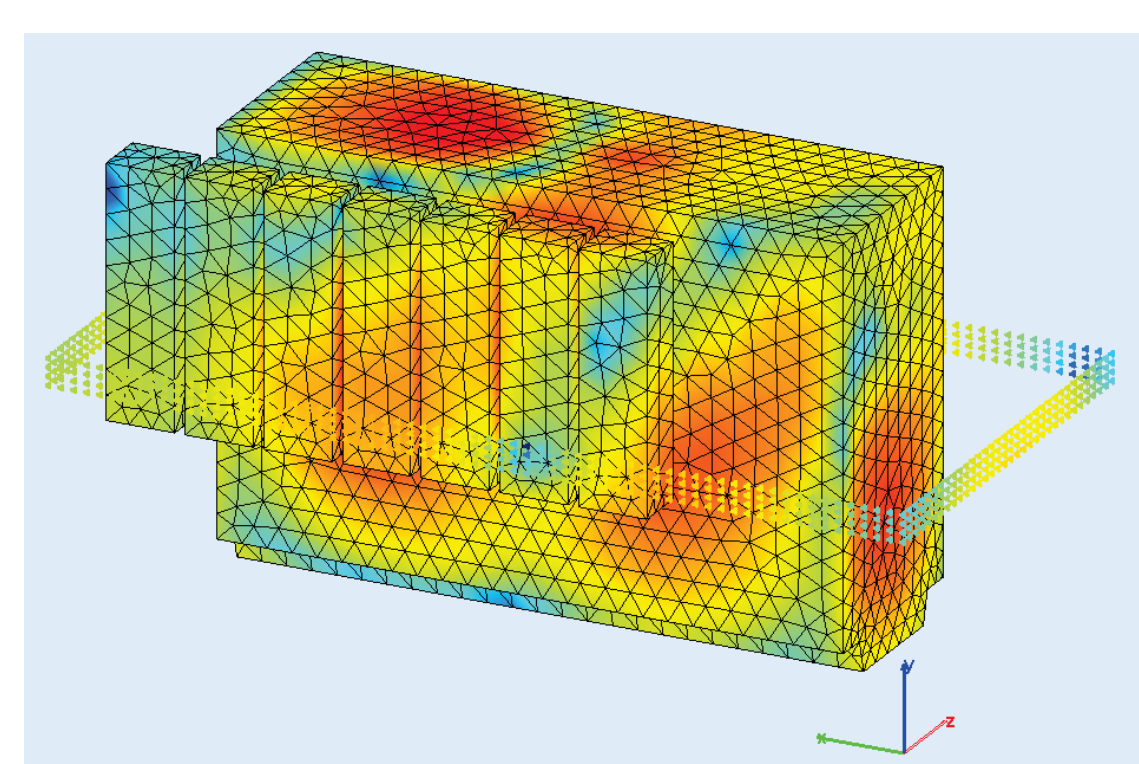


Figure 4: BEM sound pressure results.

Once the numerical results regarding noise are satisfying the electrical design is approved and the manufacturing phase can start.

MANUFACTURING

Manufacturing phase is critical as many parts and materials need to be checked for correct characteristics in order to achieve low noise levels demanded by the customers.

As mentioned before the magnetostriction is one of the main causes for no-load noise. Kolektor Etra has a custom designed device for measuring magnetostriction, which is used to check electrical steel before cutting process. The device is shown in Figure 5 and typical measurement results in Figure 6.

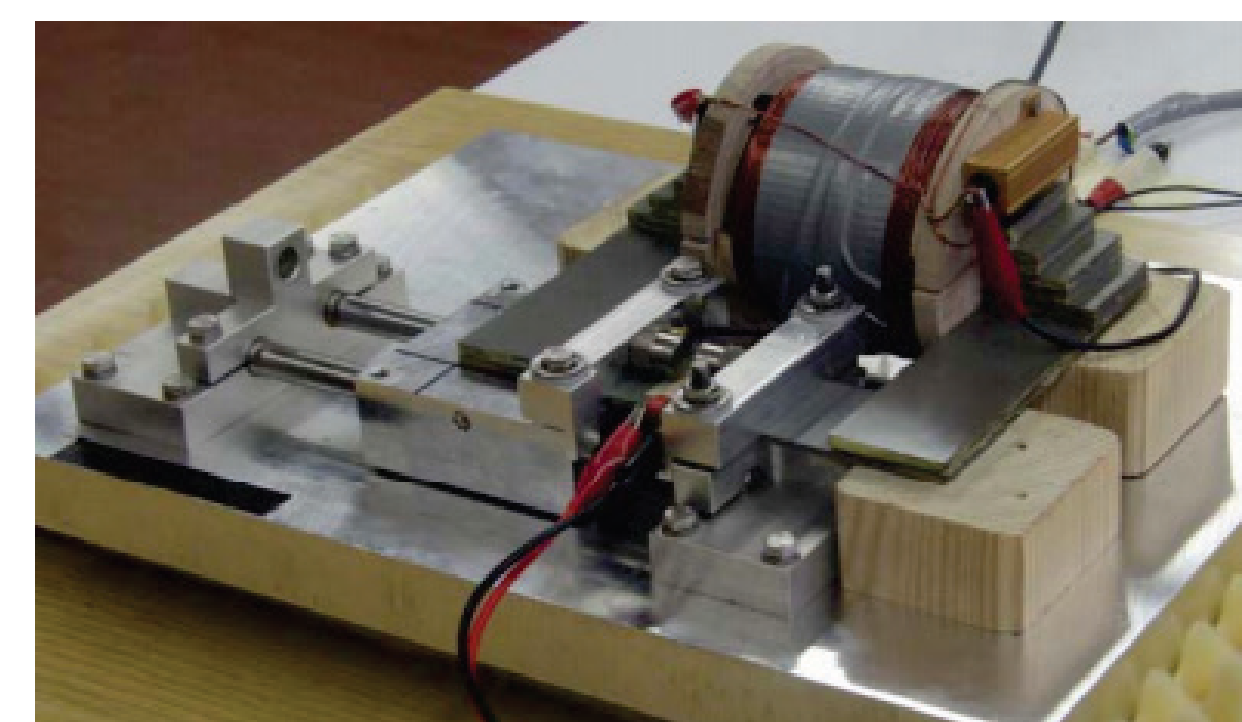


Figure 5: Magnetostriction measurement.

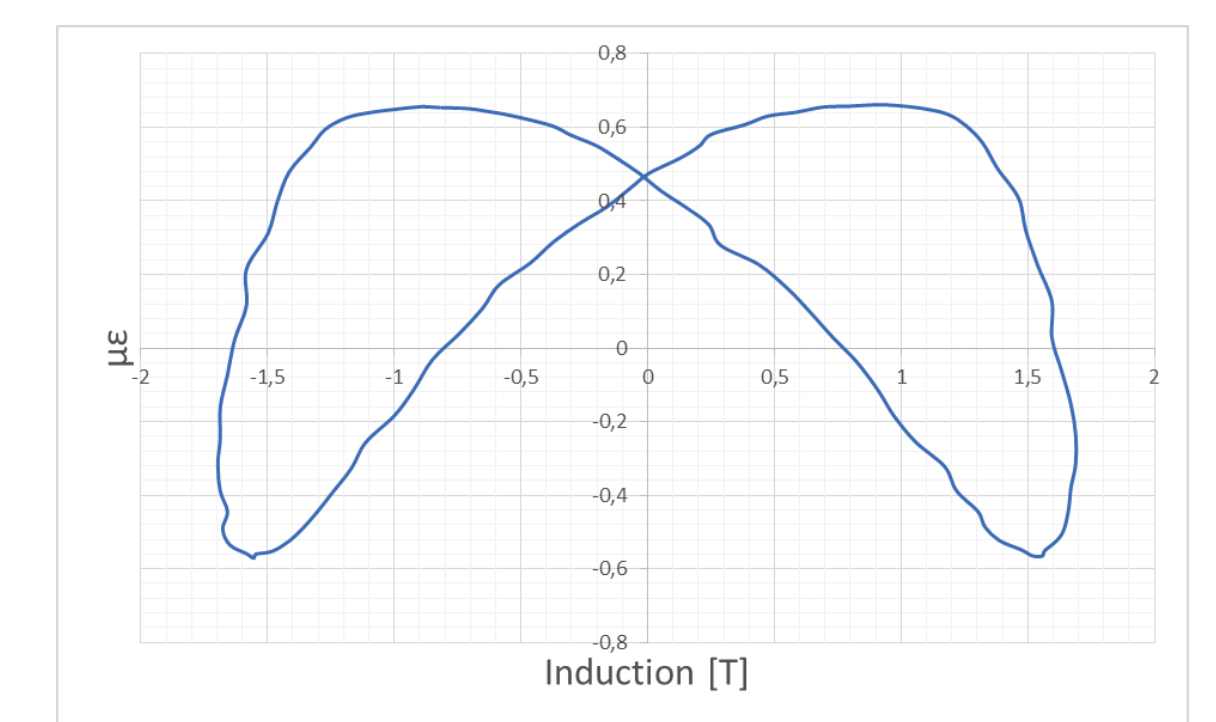


Figure 6: Typical measurement result.

Once the core is assembled the natural frequencies can be measured using experimental modal analysis as shown in Figure 7a. The results are checked against numerical model. In Figure 7b one of the measured mode shapes is shown.

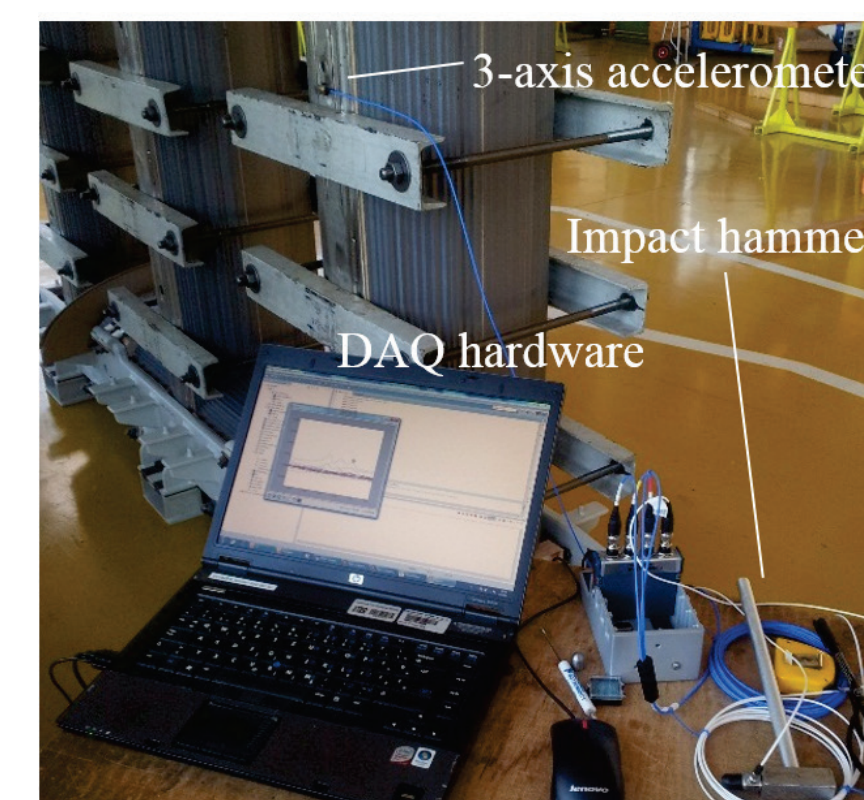


Figure 7a: Experimental modal analysis setup.

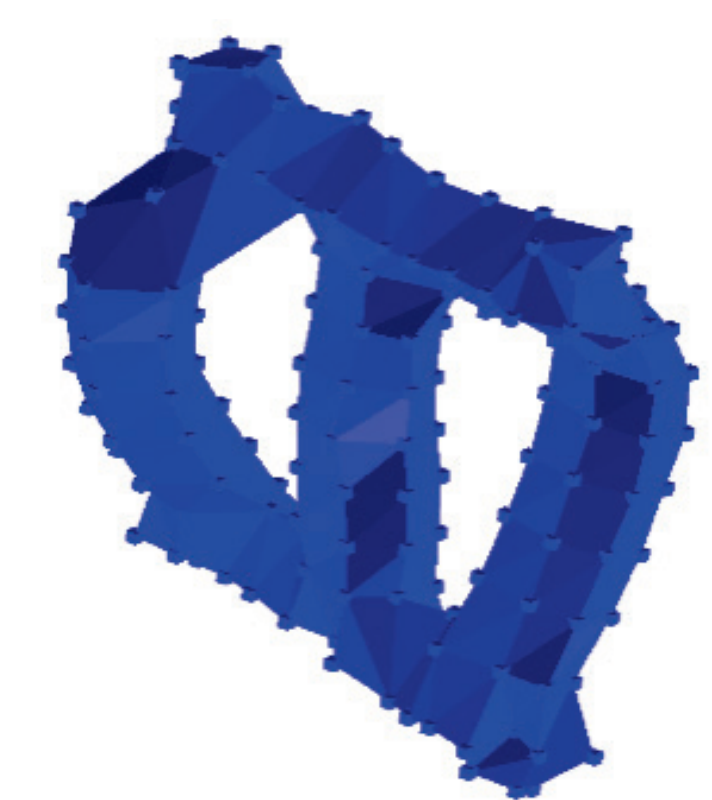


Figure 7b: Measured core mode shape.

Regarding load-noise, where Lorentz forces in the windings are the main source of vibrations, several tests are made to ensure correct low noise characteristics of the windings. For example transformerboard material used for winding spacers is checked for correct mechanical properties. Testing is done on a special custom built press, which is shown in Figure 8.

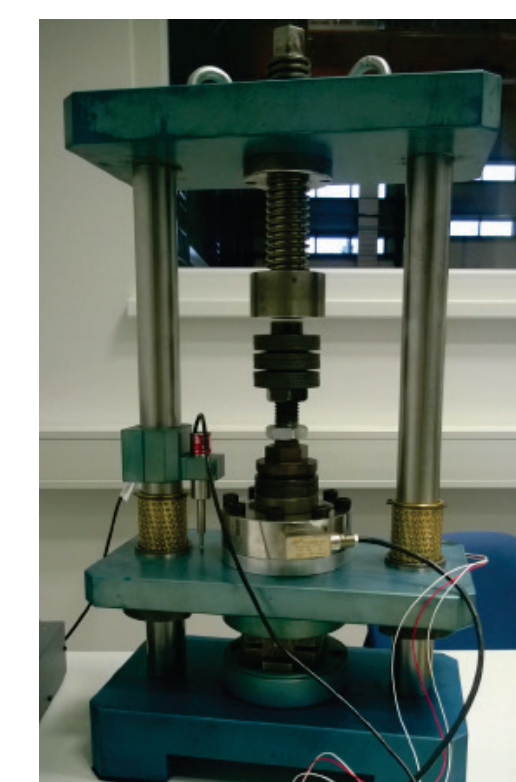


Figure 8: Test press.

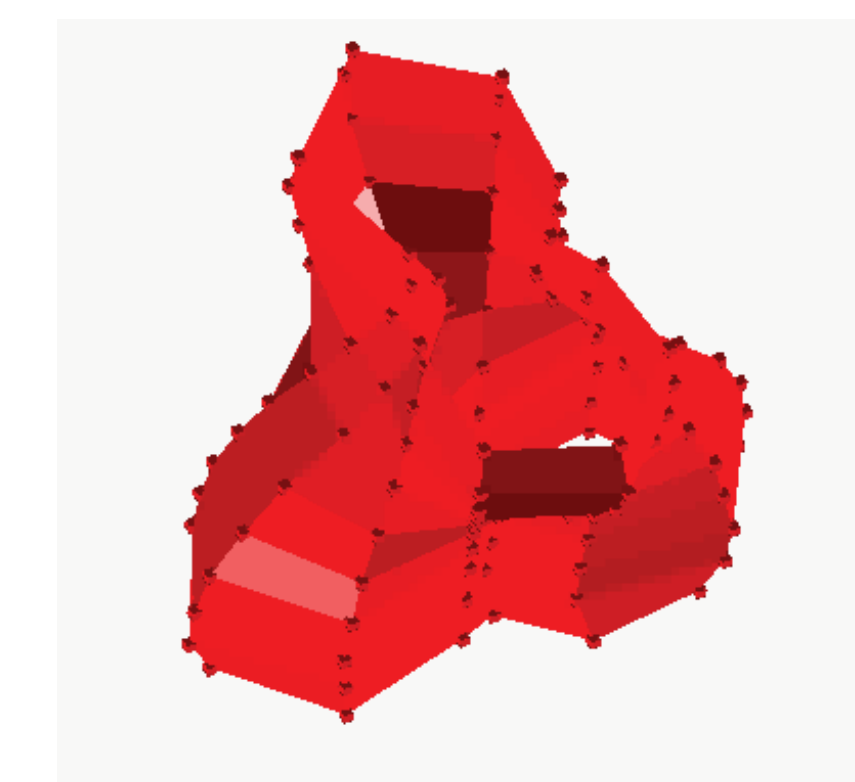


Figure 9: Measured coil mode shape.



Figure 10: Noise measurement.

When separate windings are dried and stabilised the natural frequencies and mode shapes are measured. The measurements are done for all windings and the results are again checked against the numerical data calculated in the design phase. One of the measured mode shapes is shown in Figure 9.

NOISE MEASUREMENTS

Our high-voltage laboratory is equipped with acoustic panels on the walls and double sliding doors which ensure low reverberation times and prevent the noise from production hall interfering with noise measurements. Typically the sound pressure method is used (Figure 10), however, the acoustic intensity is the preferred option.

RESULT

The presented procedures are a part of our low noise transformer technology, which results in high quality transformers with low noise. Typical results are presented in Table 1.

Table 1: Typical results.

Sound power	Standard design	Low noise design
At rated voltage	X	X – 11 dBA
At rated current	Y	Y – 7 dBA