ADP: Baseline analysis of the acoustic emission of induction furnaces

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Introduction

An ADP is an industry-oriented course, in which students are to solve a described task as independently as possible, enhancing their ability to work as a team. In collaboration with several industrial partners the Department of System Reliabiltiy and Machine Acoustics SzM of the Technische Universität Darmstadt has accomplished various ADPs in recent years. As an example for such an ADP, this paper describes the baseline analysis of the acoustic emission of induction furnaces at SMS Elotherm in Remscheid, Germany.
Alternating magnetic fields and Lorentz forces cause oscillatory impulses in the induction furnaces as well as in the metal components which are heated up, partly creating sound pressure levels (SPL) far above 100 dB.
After a week-long introduction in the handling of measuring instruments a group of seven students was entrusted with the task of planning and executing a baseline analysis of the furnaces. This included the identification of sound sources and emitting surfaces as well as an evaluation of the furnace structures from an acoustic point of view. Finally, the students were to work out possible ways of reducing the furnaces' sound emission. To ensure an active contribution of every participant, the students were split in two smaller groups of three and four. Each group obtained a slightly different topic and performed measurements on a separate furnace.

Group 1 – complete assembly

The first group worked with a complete assembly of an induction-heating system, which includes the furnace itself as well as an electrical cabinet and a transport unit.

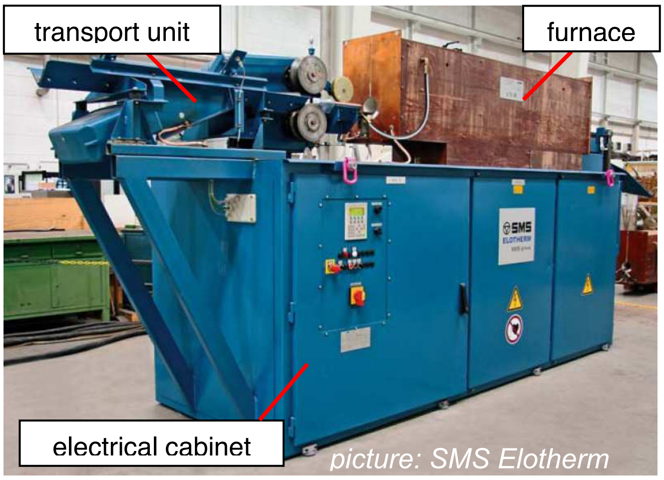

Figure 1: assembly of an induction-heating system

The furnace itself consists mainly of the current coil, two copperplates and four fabric plates. The fabric plates surround the current coil while the copper plates protect them from the heat radiated by heated workpieces.

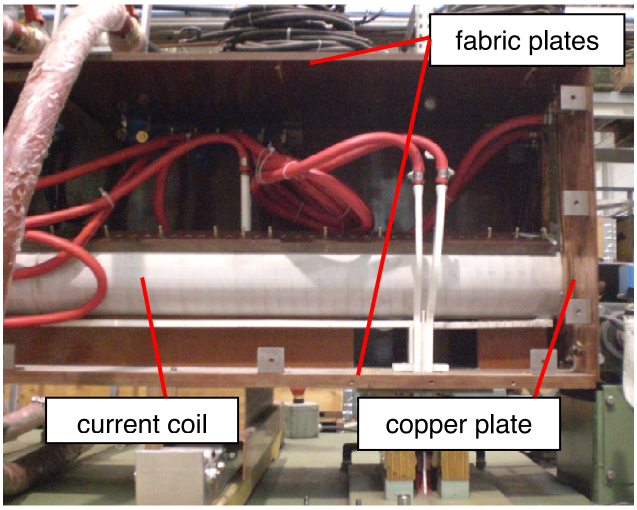

Figure 2: elements of an induction furnace

This group's focus lied on the emitted sound power of the complete assembly and its elements. To compare the emitted sound of the furnace's elements with each other, the group decided to measure the sound pressure levels around the assembly. By use of an 8x8 microphone array in several positions in three levels the students scanned a surface enveloping the assembly.

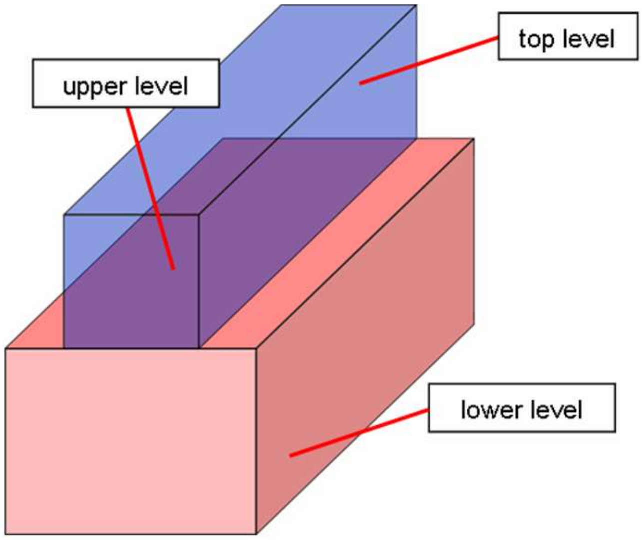

Figure 3: scanned surface around the assembly

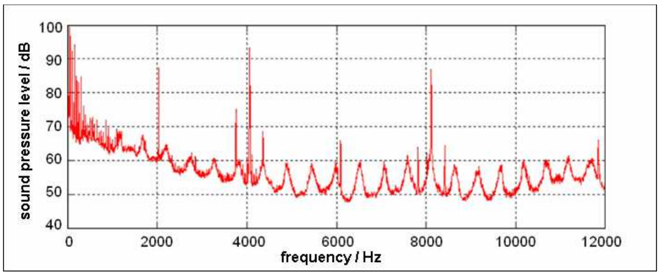

Figure 4: spectrum of measured sound pressure signals

During the measurements the students witnessed that the noise disturbance of the heating system was substantial, particularly in one frequency which dominated the sound. This impression was confirmed by the acquired data and could be seen in the identified spectra. These show distinct peaks at the frequencies of 2030, 4060, and 8120 Hz. Whereas the current frequency in the coil matched the first peak at 2030 Hz the dominating tone could be identified as the first harmonic at 4060 Hz.

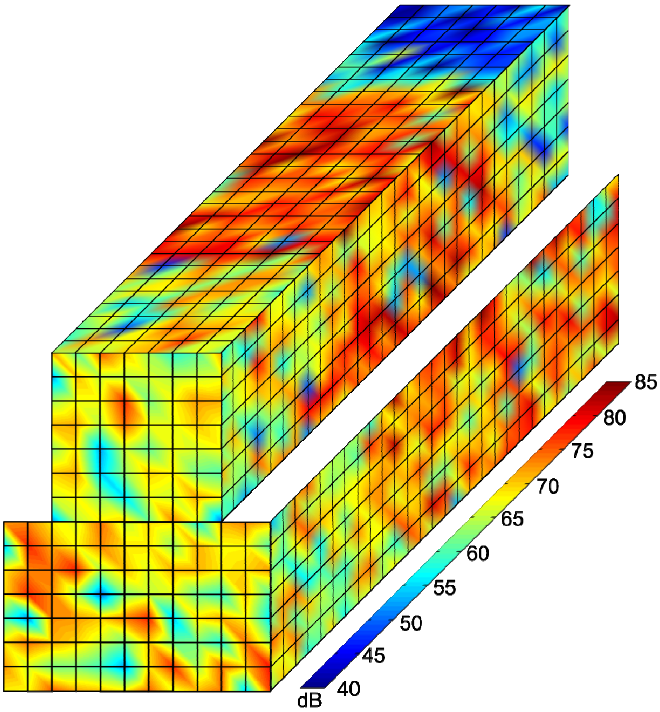

Figure 5: sound pressure distribution at 4060 Hz

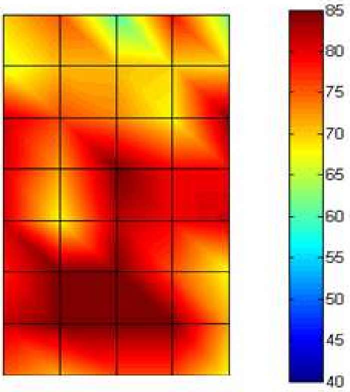

Figure 6: sound pressure in front of the copper plate

The sound pressure distribution at these frequency showed that the highest sound pressure levels were reached above the top plate of the furnace and particularly in front of the copper plates. This can be explained with the metallic structure of the plates, which is excited by the alternating magnetic fields. However, the levels in front of the electrical cabinet were only slightly lower than those near the furnace itself.

This rather surprising result motivated the students to measure the sound pressure levels inside the three chambers of the cabinet. While the first two chambers showed levels about 90 dB(A), the third reached more than 110 dB(A). In further structure-borne sound analyses the students could identify the current bar as a reason for this differing magnitude. This bar was located in the third chamber and was feeding the coil with the alternating current. The acquired data confirmed that the highest acceleration levels among the assembly (above 140 dB) were reached on the current bar and the copper plates.

Group 2 – single furnace

The second group focussed its analyses on the furnace structures and the influence of the heated workpieces on the emitted sound. For that purpose a second furnace located in a certain distance to the electrical cabinet was used.

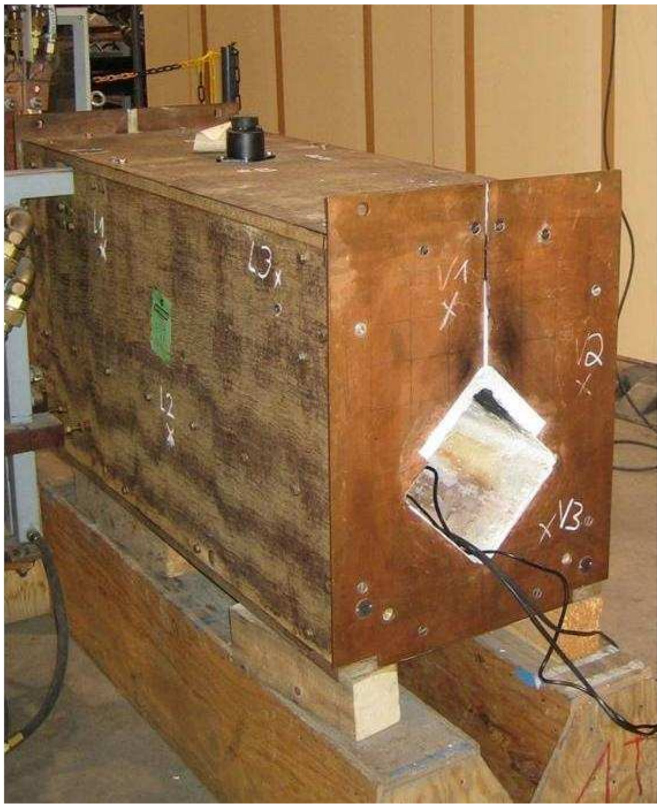

Figure 7: separate furnace

In an attempt to identify the dynamic properties of the furnace elements the students decided to place shakers into the coil and excite it with a white noise signal. By placing acceleration sensors on the furnace elements their admittances could be determined. Whereas the coil showed the highest acceleration levels in a frequency range above

4000 Hz the fabric plates resonated mainly in lower frequencies below 600 Hz. The group concluded that for the coil current frequencies above 2000 Hz are rather disadvantageous and would cause increasing oscillations, while the dynamic properties of the fabric plates can be evaluated as good regarding the typical current frequencies in use.

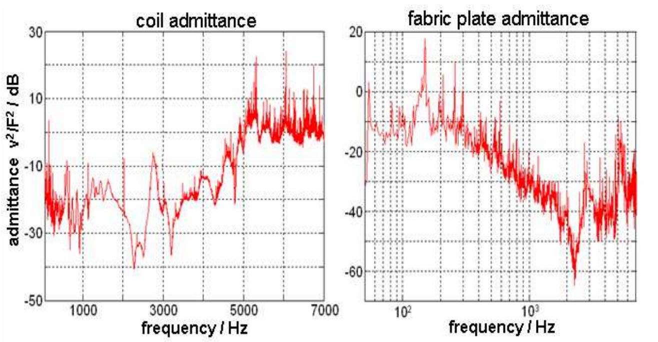

Figure 7: admittances of coil and fabric plates

After the excitation with shakers the group performed air-borne and structure-borne sound measurements during the heating process of three and six workpieces. They could show that the number of heated workpieces had no clear impact on the emitted sound. By analysis of sound pressure levels near the copper plate and directly in front of the coil opening the students proved that the workpieces did not form important direct sound sources as they were dominated by the copper plates, which radiated at a 15 dB higher level.

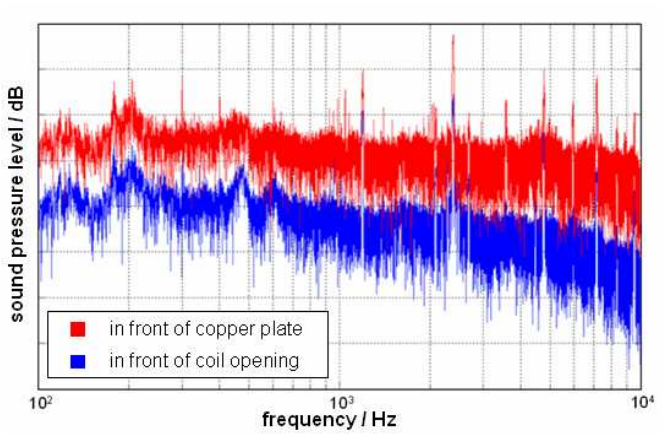

Figure 8: SPL near copper plates and in coil opening

Ways of reducing the sound emission

Based on the analyses and the principles for low noise designs gained in other courses the students worked out several propositions to reduce the sound emission of the heating systems.

A major point was the decoupling of the furnace structures from each other. Since the fabric plates, the coil, and the copper plates were rigidly connected by screw joints the energy flux within the structure was hardly prevented. In order to decouple the elements from each other the students proposed the placement of elastic layers between them. The screw joints should also be decoupled by the use of vibration insulating washers. A third point was a design change of the bedding of the coil on the base plate. Here a rigid beam should be exchanged by elastic mounts.

Other propositions to reduce the sound emission were the use of mass-spring systems on the inner side of the fabric plates and the cabinet structures as well as the substitution of the copper plates by non-metallic materials to eliminate their excitation.

Summary

Working in two groups of three and four, the participating students planned and performed varying measurements leading to an insight into the emitted sound of induction-heating systems. As the first group measured the SPL distribution around the system and identified the current bar as a sound source, the second group determined dynamic properties of the furnace structures and the influence of heated workpieces on the emitted sound.

All in all this ADP was a successful project in which the students worked together effectively and produced promising results. They were also introduced in the typical work of an acoustic engineer.