Musical Ferrite

Realgymnasium Rämibühl Zürich

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This project addressed the question: *To what extent can the vibrations of a ferrite rod inserted into a periodically changing magnetic field be described by physical theory?* An answer was found and an experience report of the Swiss Young Physicists' Tournament, where the phenomenon will be debated in 2020, was added.

What is Ferrite?

A ferrite material is a **metal oxide**. The chemical formula is $MO \cdot Fe_2O_3$ and important properties are: extremely brittle, poor electric conductors and ferromagnetic (they can be magnetized). Mg-Zn and Ni-Zn ferrites are most common materials in electronic appliances. **Vibrations** of objects made out of ferrite can produce **annoying audible sounds** or lead to **damage in machines**.

Experiments

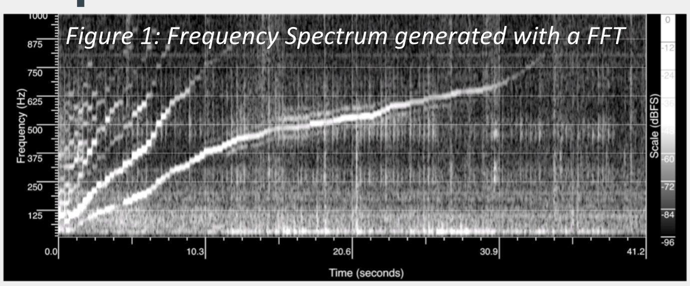

Figure 1: Frequency Spectrum generated with a FFT

Key to the experiments was to trigger **ferrite rods** to **vibrate** under the application of an external changing magnetic field as magnetostriction suggests. Measuring the vibrations was approached by recording the **sounds produced** (*Figure 1*). Environment and ferrite rod's properties were varied: different solenoids and currents for generating the changing magnetic field, five rods with various dimensions (volume and shape) and various materials (magnetic coercivity). *Figure 2* illustrates the sounds generated by various electric currents for the five ferrite rods.

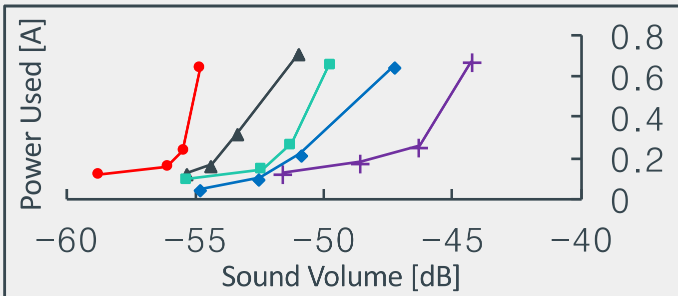

Figure 2: Sound Volume vs. Power Used for Different Rods

Magnetostriction

Ferromagnetic materials have **magnetic domains**, where the magnetic moments of the electrons are aligned. In materials that experience magneto-striction, the domains themselves rotate instead of realigning their moments. This is due to **magnetic anisotropy**: the material is more easily magnetized in one direction than another. Domains rotate to make the magnetic field need the least energy possible to magnetize the material. For objects with crystals (like ferrites), the crystals rotate as well, causing stress and deformation. Ferrite objects in periodically changing magnetic fields change dimensions periodically and thus vibrate.

The magnetization (measured by magnetic flux density B) depends on the applied magnetic field (strength H). The process is modelled by the **magnetic hysteresis loop** shown in *Figure 3*.

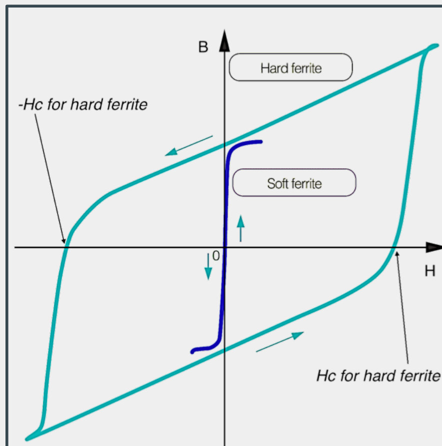

Figure 3: The Hysteresis Loop

The shape of the loop depends on the coercive magnetic field strength H_c. It is larger for a hard ferrite than a soft one, therefore, the latter was used for the experiments. This project also addressed modelling the change in dimensions of an object by the **magnetostrictive hysteresis loop**.

The SYPT

The Swiss Young Physicists' Tournament is a team competition graded by a jury. **Participants present** their own solution to one of **17 physics problems**. A contestant of the opposing team critiques and leads a discussion about physical concepts and theories.

Sources

Competition: sypt.ch

Ferrite materials/rods: tdk-electronics.tdk.com, ferroxcube.com, megatron.ch

Theory:

- Trémolet de Lacheisserie, E., 1993. Magnetostriction: Theory and Applications of Magnetoelasticity. USA: CRC Press.
- Wurm, T., 2012. Chemie für Einsteiger und Durchsteiger. Wiley-VCH Verlag & Co.
- Wilfried, K., 2014. Kuhn Physik. Westermann Druck GmbH.