Acoustic Analysis of a Harddisk Drive

M. Cetinkaya, A.J. Svobodnik

NAD - Numerical Analysis and Design GmbH & Co KG, Vienna, Austria

M. Rauer, M. Kloepzig

PM°DM Precision Motors Deutsche Minebea GmbH

Villingen, Germany

Summary

In this paper we will show the calculation of airborne sound emitted by a harddisk drive as typically used in computers such as PC's or workstations. The work can be described by a set of three milestones:

- Principal analysis to understand the dynamic behavior due to electromagnetic forces
- Detailed analysis of the vibration behavior with respect to fluid-structure interaction
- More detailed analysis (especially in the region of the stator device)

The evaluation of the electromagnetic forces was carried out via the use of the ANSYS/EMAG software, while the analysis of the structural dynamic behavior and the calculation of the airborne sound due to fluid-structure interaction was done with the general purpose acoustic software *NAD*work/Acoustics. Some basics of the theory behind *NAD*work/Acoustics can be found in [1].

Keywords

Computational acoustics, structural dynamics, fluid-structure interaction, *NAD*work/Acoustics

0. Introduction

One of the main field of environmental protection is noise. (Unwanted) Noise arises in many situations of our life. There exist many governmental regulations with respect to noise. One important field of problem is noise pollution at work place. Usually there are many sources of noise at our work place. Nearly everybody is using a computer which consists of a harddisk device, which is one of the main sources of noise.

Thus it is of very high interest to know the principles of noise pollution of a harddisk drive. This knowledge will give us the possibility to further reduce sound emission. The work in this paper was done in cooperation with the German based company PM°DM Precision Motors Deutsche Minebea GmbH which develop the electro motors as used in harddisk systems to serve as a power source for the rotating disks. Generally it is said, that this motor is the source of excitation which produces airborne sound. However, there has to be a dynamic system (the harddisk housing) to vibrate due to this excitation and to finally react with a surrounding medium (usually air) to produce some kind of noise.

So in this work we will show the acoustic analysis of a harddisk drive including all relevant acoustic (structural as well as airborne) parts of the harddisk system. The work was originally carried out in three phases, which will be described in the next sections.

1. Principal Analysis

In a first step we modeled a very simple model of a harddisk drive where we studied the influence of electromagnetic forces. Usually there act two different kind of forces in the air gap between stator and rotor:

- Radial forces
- Axial forces

In this very simple analysis we first discovered, that the axial forces are the main source of dynamic vibration of the housing, and thus the main source of airborne sound. However, later we will show that this first conclusion was wrong.

A typical view of the sound pressure level distribution of the simple model can be found in Fig. 1.

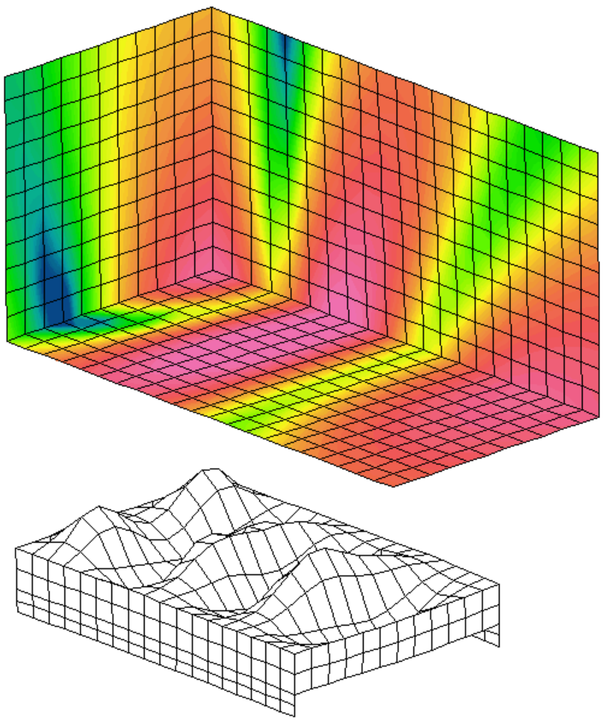

Fig. 1: Typical sound pressure level distribution for simple model

In this model we also studied the different kind of coupling procedures and acoustic analysis types:

- Two-sided coupling (Beids. Kopp.), full “mathematical” coupling, structure acts on fluid and vice versa
- One-sided coupling (Eins. Kopp.), only structure acts on fluid, not vice versa
- High Frequency Approximation (HFA), only structure acts on fluid

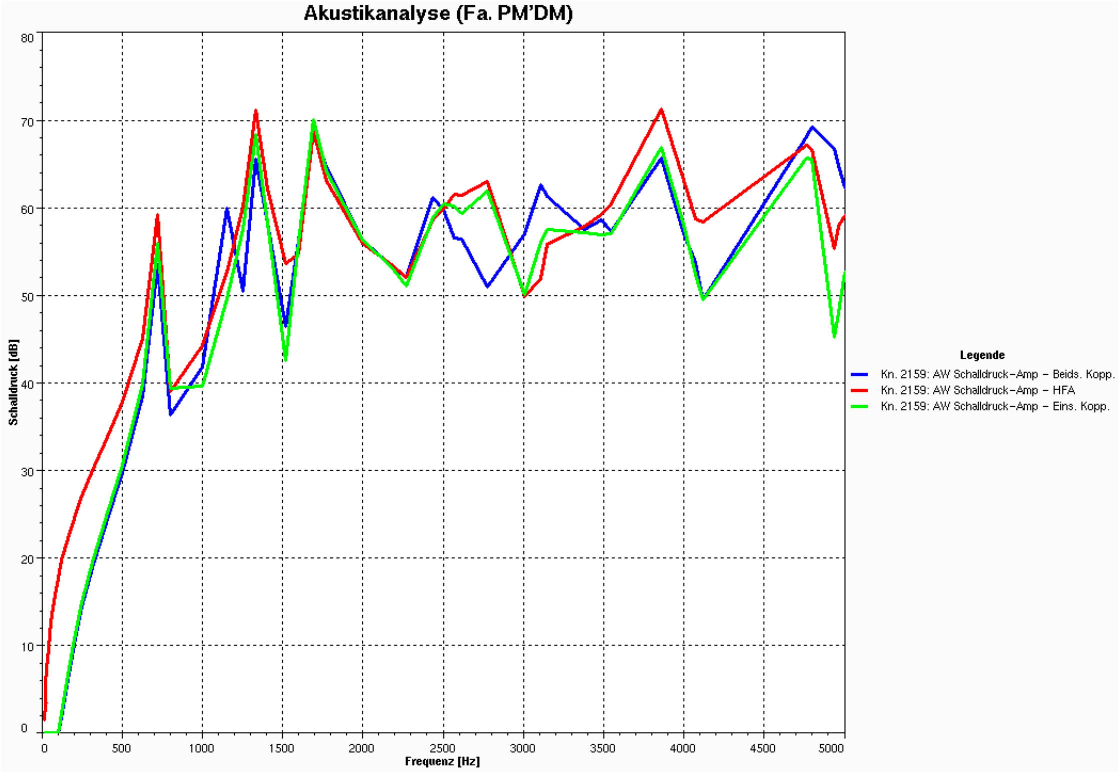

Fig. 2: Sound pressure level over frequency for different acoustic analysis types

Coupling means that we couple the physical effects of the structure (structural dynamics using finite elements) with the effects of sound propagation in a fluid (computational acoustics using boundary elements). Thus we use the term fluid-structure interaction.

In Fig. 2 you can see the calculated sound pressure levels without any weighting at a predefined reference point. Please note, that in this analysis we use unit forces, which are not realistic, thus we get relatively high sound pressure levels. As one can see there is a tremendous drift between analysis types in the region from 2500 up to 3000Hz. This is due to the effect of “air stiffness” inside the housing of the harddisk drive, which can only be accounted for when using a two-sided coupling procedure. So we decided to use a two-sided coupling procedure for all the following analyses.

2. Detailed Analysis

Based on the results of the principal analysis we developed a detailed model based on CAD models. In Fig. 3 you can see the derived finite/boundary element meshes. Not shown in this analysis is a piece of foam, where the drive was put onto. However, this piece of foam was modeled too.

For these analyses we used forces acting on the system stator/rotor which where based on a 2D electromagnetic calculation without any hysteresis effects. We simply defined a distribution of the forces in the time domain following the form of a saw tooth, and transformed these distributions into the frequency domain via FFT, which can be activated directly within *NAD*work/Acoustics.

Some typical plots of the vibrating housing due to electromagnetic forces can be found in Fig. 4.

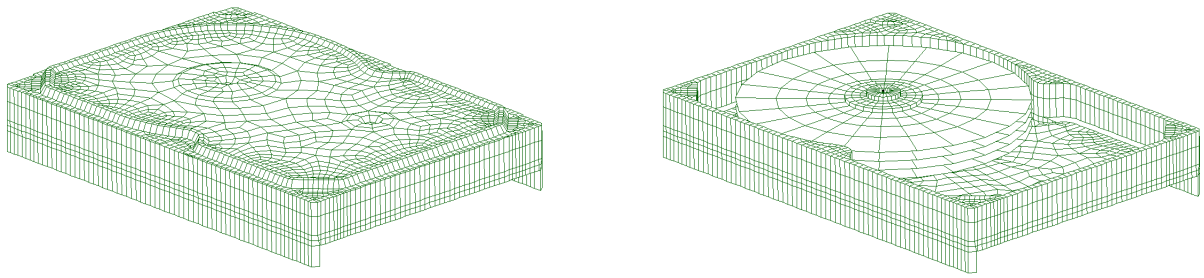

Fig. 3: Finite/boundary element mesh of detailed model (right-hand side without top cover)

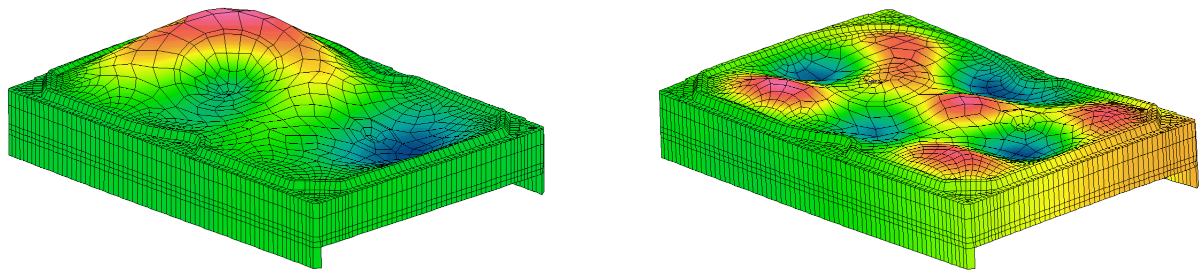

Fig. 4: Typical plot of vibrating housing for two different frequencies

With this model we also studied the influence of the discs itself. In Fig. 5 you can see the results for a system without discs. You can see two curves. Both curves represent the sound pressure level at a reference point (300mm above top of spindle axis). However, one curve is due to FFT of the forces, while the other curve is due to a unit load (constant unit load over frequency).

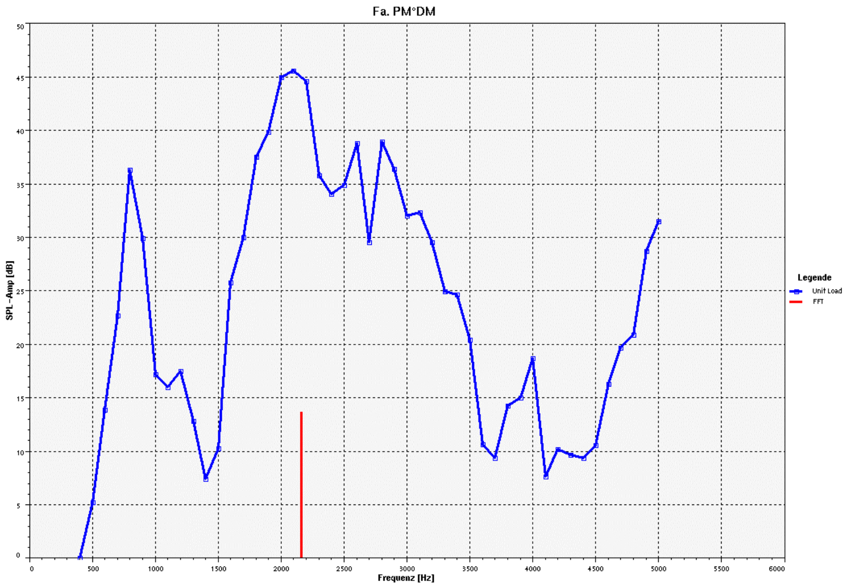

Fig. 5: Distribution of sound pressure level at reference point due to FFT and unit load

As one can see, there is very little effect of forces due to FFT. So we decided in a next step to use a 3D analysis to evaluate electromagnetic forces including hysteresis effects via the use of the ANSYS/EMAG software.

Furthermore, we found that in contrast to the conclusion proposed within the assumptions of the simple model, the radial forces are the main source of airborne sound. In Fig. 6 you can see the displacements of the housing at a frequency of 2150Hz for phase angles 0, 45, 90, 125 and 180 degrees due to pure radial excitation (no axial forces). Though there are only radial forces we see axial displacements of the housing.

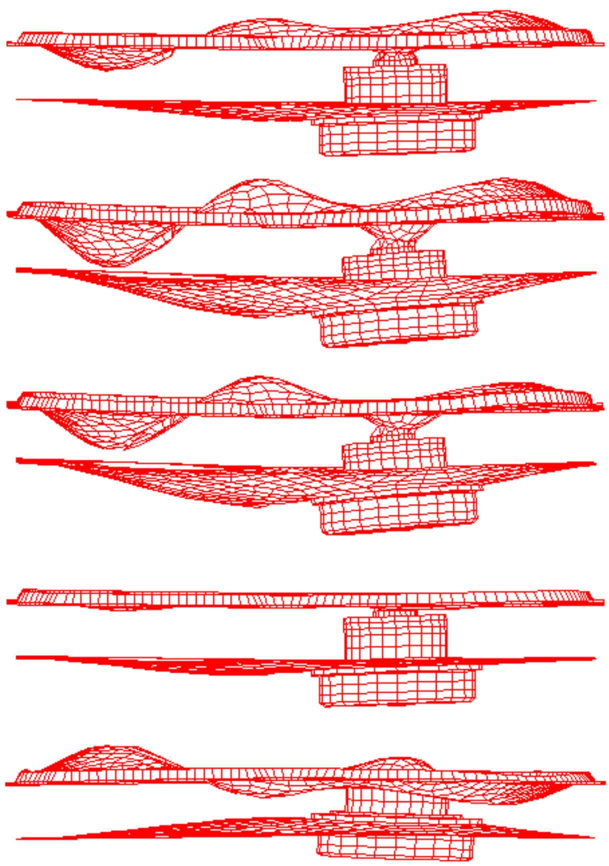

Fig. 6: Displacements of housing at a frequency of 2150Hz for phase angles 0, 45, 90, 125 and 180 degrees (from top to bottom) for pure radial excitation

So in a next step we developed a more detailed model with respect to the geometry of the stator, and the electromagnetic forces.

3. More Detailed Analysis

Based on the results of the detailed analysis we developed a more detailed model. Due to the fact that the radial forces are the main source of airborne sound we refined the mesh of the stator (see Fig. 7).

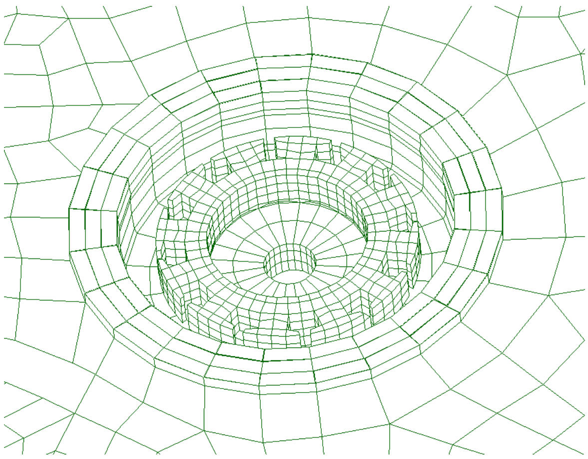

Fig. 7: Refined mesh of stator

Furthermore we used results (radial and axial forces) of a detailed electromagnetic analysis using ANSYS/EMAG. Some typical force distributions in the time domain of the forces acting in the air gap between stator and rotor can be seen in Fig. 8.

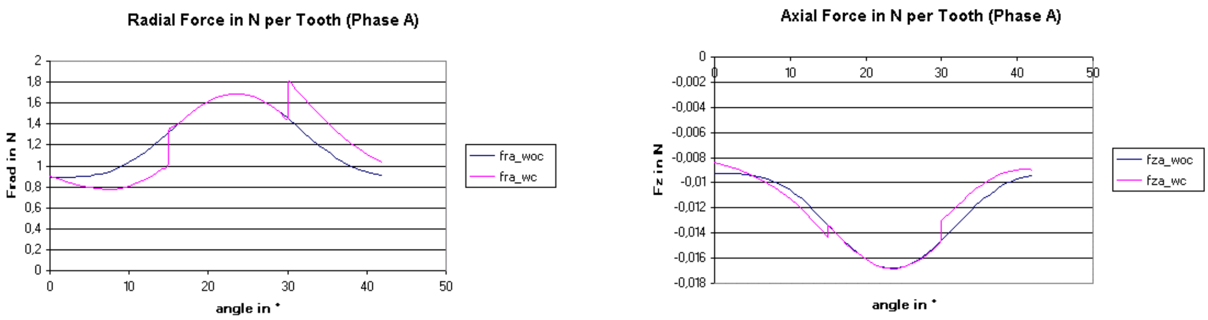

Fig. 8: Radial (left) and axial (right) forces due to detailed electromagnetic analysis

The final work then ended up with the development of a set of spreadsheets describing the transfer functions between the electromagnetic forces and the sound pressure level distribution at the reference point. In Fig. 9 you can see the sound pressure level at the reference point (without any weighting) with the amplitude of the radial forces of 1N and the axial forces of 0.001N. The two curves show different phases of the axial versus the radial forces.

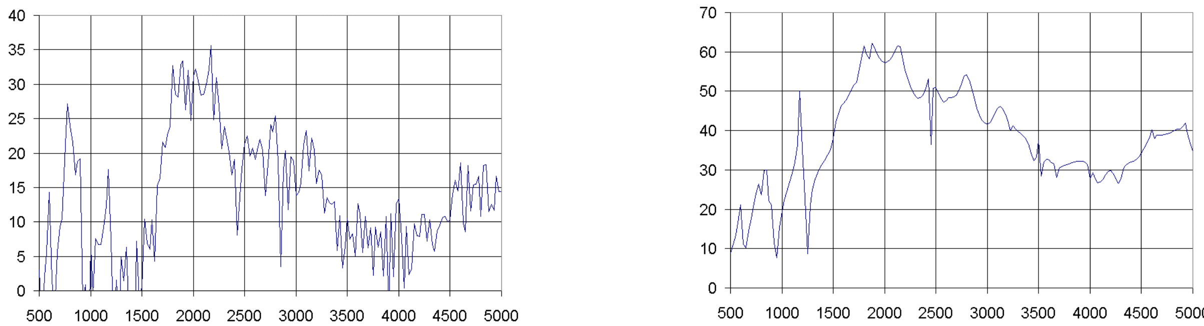

Fig. 9: Sound pressure level with axial/radial forces out-of-phase (left) and in-phase (right)

With these spreadsheets it is possible to fast and easily predict the acoustic (airborne) behavior of a harddisk drive when varying some parameters of the electromotor. Thus it is a very important tool for the development of electro motors for powering discs of harddisk drives.

4. Conclusions

Within the framework of this project we analyzed the acoustic (structural as well as airborne) behavior of a harddisk drive. Via the use of software tools like *NAD*work/Acoustics and ANSYS/EMAG we could perform some detailed analyses to understand the evolution of airborne sound due to the rotating disks of the drive itself.

Furthermore, due to the here proposed work, we developed a set of tools to predict the sound pressure level when varying parameters of the electromotor. Thus it is now possible to further optimize airborne sound pollution early in the design phase of a motor.

5. References

[1] Chen, Z.-S, Svobodnik, A. J., Hofstetter, G., „A Coupled FE/BE Method for Elasto-acoustics: Formulations and Applications", Seventh International Congress on Sound and Vibration, 2000, pp 1951-1958