Acculution
Optimal Physics Insight

SERVICES PORTFOLIO

Research Based Engineering Solutions

Summary

This document gives an overview of some of the services provided by Acculution. While they range across vibroacoustics, solid mechanics, microacoustics, and shape and topology optimization, it is not an exhaustive list, so feel free to contact Acculution to hear more.

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Lumped Parameter Modelling

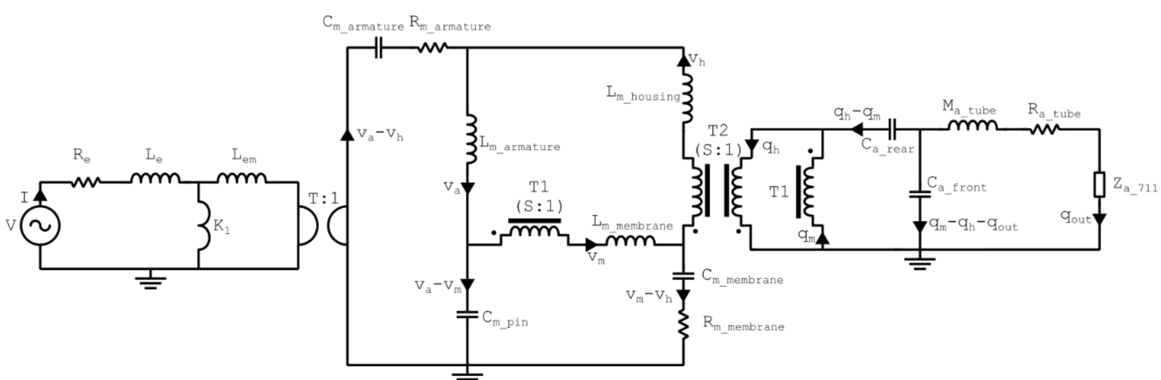
While simulation models are becoming more and more prevalent and complex, the lower order models that approximate the continuous modelling of modern simulation software still have their merit. One such modelling type is the lumped modelling which can often capture the physics sufficiently while at same time being extremely fast and have other, sometimes overlooked, benefits.

Lumped parameter modelling provides very quick insight into a product's overall function.

For structural mechanics, acoustics, electromagnetics, and other physics, simple models can be made where for example masses, stiffnesses, and resistances are 'lumped' together in discrete components with enough degrees of freedom to capture most of the behavior of interest.

Lumped parameter models can be combined with more complex continuous Finite or Boundary Element methods to save computational time while retained the necessary accuracy.

Transducers such as loudspeakers and microphones can typically be modelling using this lumped approach to a very high degree of accuracy. Below is a transducer example for a so-called Single Balanced Armature Receiver.



Transmission Line Modelling

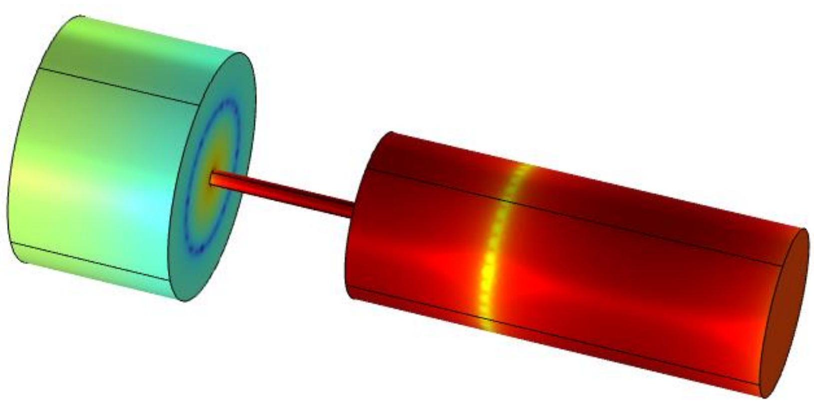
For any model of one-dimensional nature, a transmission line model is an obvious choice to consider. The TL model is analytical and so very fast calculations can be carried out with high accuracy.

With an assumption of plane waves in the cross-section of a tube, acoustic phenomena can be captured highly accurately with a transmission line model.

A transmission line model is typically described via a matrix linking two variables on the input side of a system with two output variables. This will suffice to completely describe the system behavior assuming the cross-sectional variance is either constant or can be averaged out, which is typically done via complex matrix elements.

$$\begin{pmatrix} p_i \\ q_i \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} p_i \\ q_i \end{pmatrix}$$

Highly complex systems, for example describing transducers or silencer/muffler constructions can be represented as series and parallel connections can be collected into a single matrix.

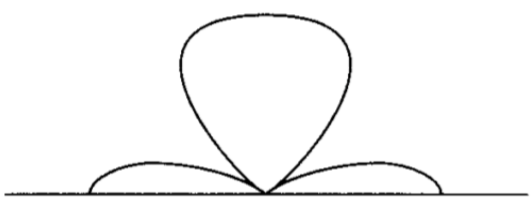


Vibroacoustics

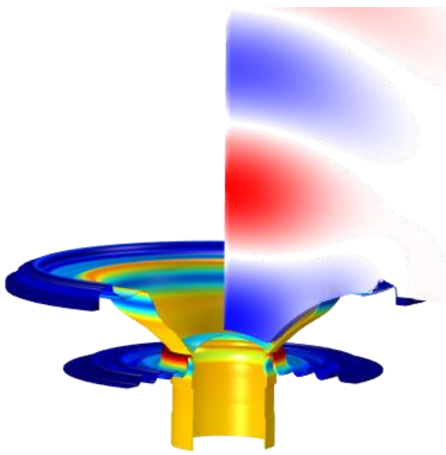
General vibroacoustics is important for example in the development of loudspeaker drivers. Here, there are certain aspects that are always of interest to their engineers. Characteristics such sound pressure level at a distance, polar patterns, electrical impedance, and sound power can all be post-processed from a simulation model of the driver in question.

Vibroacoustic simulations can reveal new insight about existing and new products, which could not otherwise be found.

While measurements can certainly give some insight into the behavior Simulations on the other hand typically depend on measurement input but can then give more insight to the physical behavior and reveal the details of the structural displacements and how they relate to the acoustics. Characteristics such some polar patterns, directivity indices, SPL, and impedance frequency, radiated acoustic power, and any other results of interest can be found.



Plots and animations are of great value to both investigating drivers and management decision situations, as well as for sales material.



With vibroacoustic simulations explanations can be found for dips and peaks in the frequency response, and the simulations can be for virtual prototyping where solution proposals can quickly be tried out.

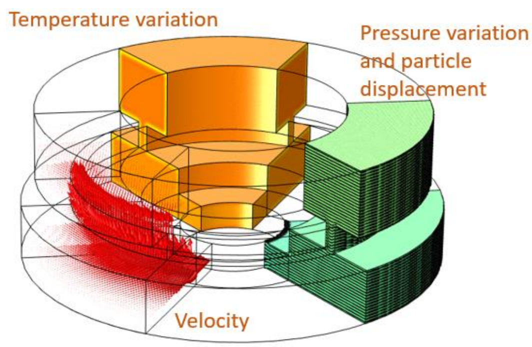
Microacoustics

For most acoustics applications simplified equations are used that omit certain loss effects. However, for small scale geometries such as hearing aids, smartphones, ear buds, and similar products, these microacoustics effects need to be included in models to ensure that the correct output is found.

When dealing with acoustics in small geometries, certain loss effects need to be included in simulations to retain accuracy. As many different models exist with each their pros and cons, it is important to understand the physics and the underlying mathematics.

Several different aspects will determine which microacoustics model is best for the application in questions. Dimension, frequency range, shape, and other aspects of the setup will affect the choice, and it often takes expert knowledge on the topic to pick the right modelling method.

For products such as hearing aids and microphones, the losses are often of importance, but larger geometries can also have some microacoustics characteristics.



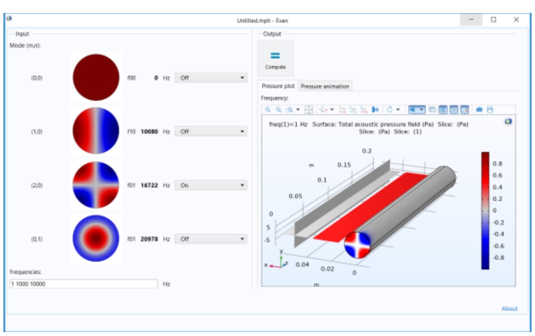
Acculution is one of the only companies in the world that has extensive knowledge of all available microacoustics implementations, both from a theoretical standpoint and from many industry cases. Knowing when to use which is essential for efficient modelling as they each have their own limitations in accuracy and very different computational times.

Apps

Working efficiently with simulation software typically takes one or more experts focusing on the mathematics and physics. However, with apps the abstraction level is taken down and complexity is removed so that engineers can do virtual prototyping within a solution space set up by the experts.

Instead of always relying on simulation experts to model certain aspects of a product, apps can be employed that engineers and other staff can use on their own.

Modern simulation software has capabilities for creating apps that use the complex functionality of the software, but hides most it behinds the scenes, and only show a few buttons and graphics.



If wanted, apps can of course be more advanced and include all the functionality of a full simulation model, but in general apps are best utilized for tasks where a few design variables are changed to create many different designs. The apps can often be self-contained in that they are ready to use, while more complex apps can require training from the original designer.

Apps are useful both for general training of students and engineers, as well as for production purposes, where the effects of design changes need to be evaluated quickly without the assistance from a simulation expert.

Feel free to contact Acculution and we can discuss if apps are in the future for you.

Parameter Optimization

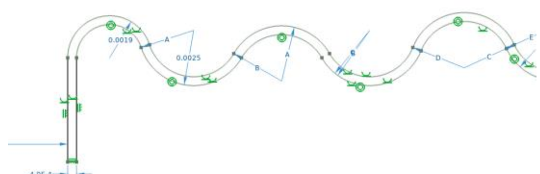
With the more complex optimization methods such as Shape and Topology optimization, new innovative designs can grow out of a given starting geometry and clever mathematics. However, oftentimes practical designs are constrained via a set of parameters, and so it will be more relevant to set up an optimization routine that simply adjusts these parameters towards a desired outcome.

For many practical designs several parameters describe the geometry, and variations in the parameters will result in different outcomes. With parameter optimization the best combination of parameters can be found mathematically using the simulation model framework.

It could for example be parameters describing a certain spider geometry. If this topology is used in many of the company's products, but in varying sizes, parameter optimization can find the best parameters can be found.

If the same topology is an optimization routine can be set up that finds optimization sizing parameters for all radii, widths, lengths, and so on.

Any geometry that has more than a couple of degrees of freedom in their design can benefit from a proper parameter optimization over a more common parameter analyses, especially for setups where the sensitivity to variations in this geometry inputs is very high.



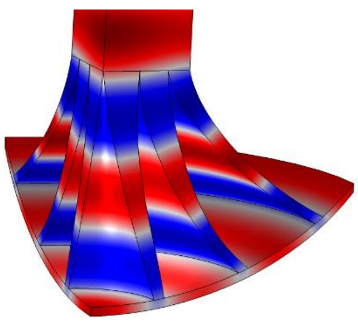
Acculution has used this technique for placement of coils and magnets in hearing aids with great success, as well as for several other applications. Have a look at your product and see if you are always adjusting the same parameters again and again; if so, parameter optimization could be the way to go.

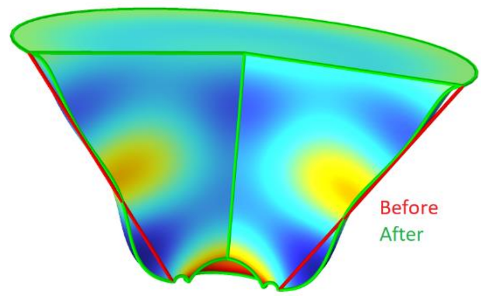
Acoustic Shape Optimization

With acoustic shape optimization new designs can be found that have an optimized shape with respect to certain targets and constraints for given assigned optimization boundaries. This technique can create novel shapes for loudspeaker waveguides or even for the loudspeaker parts themselves.

The acoustic performance of a geometry is highly dependent on the shape of its surfaces. With shape optimization, these surfaces can be warped to obtain certain objectives.

The surfaces near an acoustic output will affect the resulting sound. This could the surfaces in a compression driver phase plug, or surfaces associated with a waveguide. With proper objectives, constraints, and overall simulation setup, a shape optimization routine can be applied to find the best shape of the boundaries to be modified.





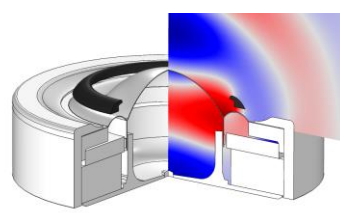
One needs to be careful not to have boundaries collide or overlap in the shape optimization process, and in general have good insight into the underlying physics and engineering principles, and so with Acculution the combination of mathematical knowledge and product experience ensures that the shape optimization results are reasonable and manufacturable.

Acoustic Topology Optimization

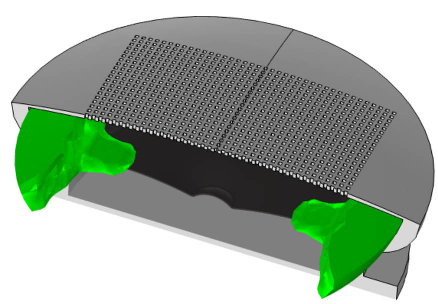
For certain problems a trial-and-error approach is not feasible since the solution space is too large to explore manually. In such cases optimization can be applied to find geometry solutions via a mathematical approach that can remove and add material to a given assigned optimization domain.

Combining a standard simulation model with the mathematics of topology optimization enables the evolution of new geometries that could not have been found using traditional engineering methods.

The optimization problem is stated via certain objectives and constraints for a given optimization domain. A typical objective for loudspeakers is to have a flat SPL frequency response. This may not be possible with standard methods because of the setup of the driver, because of a placement challenging acoustic environments such as cars, or for other reasons. In such cases topology optimization can be employed to design geometries that will modify the resulting sound field to counteract some of the issues at hand, such as the phase plug below.



If an internal domain is available such as for a speakerphone, topology optimization can be applied to find the best distribution of internal parts.

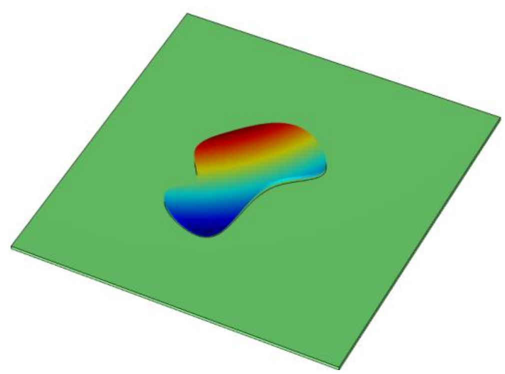


Rayleigh Integral Sound Pressure Estimation

While a full vibroacoustic model will return the sound pressure level in any point of interest, it can be computationally expensive to always include the acoustics domain. With the Rayleigh integral implementation, the sound pressure can be estimated in any point without explicitly including the air around the product.

Coupled structural and acoustics physics are expensive to calculate, and that makes it difficult to come up with solutions quickly and efficiently. With the Rayleigh integral, the explicit inclusion of the acoustics is gone, while the sound pressure is still calculated at practically zero cost.

For a flat radiating surface in a flat baffle geometry, the Rayleigh integral will accurately evaluate the resulting complex sound pressure in any evaluation point of interest, without including any acoustics in the actual simulation model. This provides a huge computational advantage to the standard methods, and so the engineers can do the virtual prototyping faster than traditionally and typically without a significant loss in accuracy.



Acculution can provide the general framework for calculating the Rayleigh integral, or the actual implementation itself in COMSOL Multiphysics®.

Phase Decomposition

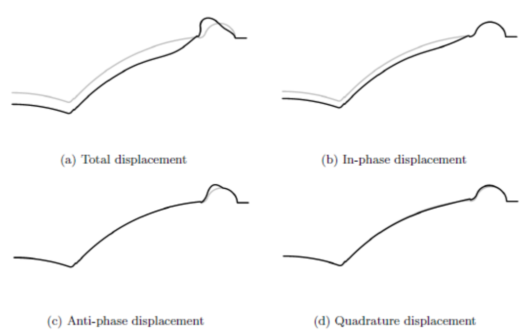
While a simulation might reveal both surface displacement of a loudspeaker driver as well as the sound pressure level in a point in space, it is not in general trivial the complex surface movement with the peaks and dips seen in a pressure frequency response. With Phase Decomposition, three surface displacement components are revealed that give insight to the relationship between movement and resulting pressure.

Relating a given surface displacement with its resulting sound pressure in the near and far field regions can be a daunting task as their correlation is hidden in standard methods. However, with Phase Decomposition their relationship is suddenly made clear.

Phase decomposition is largely an overlooked method, but it provides a tremendous insight into which parts of the moving surface in fact contribute to the overall sound pressure, and which parts subtract from the sound pressure.

In general, each point on the radiating surface falls into one or more of three categories: In-phase, Anti-phase, and Quadrature. In-phase contributes positively to the generated sound, Anti-phase detracts from the sound, and Quadrature movement does neither. The categorization varies with frequency and depends on where the sound is evaluated. The Phase Decomposition mathematics takes these factors into account.

The displacement of a loudspeaker can now be analyzed, and it will be much clearer for example what causes a dip in the frequency response.



(a) Total displacement

(b) In-phase displacement

(c) Anti-phase displacement

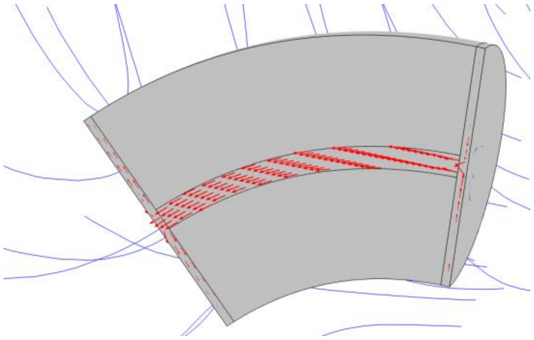
(d) Quadrature displacement

Electromagnetics

Electromagnetics is important in many transducers, and while some aspects of electromagnetics can be analyzed via for example a lumped approach, oftentimes more elaborate simulations must be carried out to capture the complex fields involved.

With a proper electromagnetics simulation model of a part or complete transducer, one can investigate different variables such as magnet fields, eddy currents,

For hearing aids electromagnetics simulations can be very valuable in finding the optimal placement of for example a telecoil relative to the PCB components and layout, as the magnetic fields and associated variables can be calculated and evaluated accurately.



For transducers, the three main transductance types of ‘moving coil’, ‘moving iron’, and ‘moving magnet’, simulations will be extremely helpful in linking a certain input voltage to a respective output, such as a displacement or a pressure. This could be the sound pressure from a traditional loudspeaker of the moving coil type, or for a balanced armature receiver of the moving iron type, for a given input voltage. Alternatively, the transductance could be from displacement to voltage, such as for a vinyl record pickup cartridge, which could be of the moving coil or the moving magnet type.

Acculution has experience with all the above electromagnetics simulations with the main application being transducers.

Training

For all the above services, training can be provided so that the company engineers learn the skills themselves. This can be set up for individual engineers or for an entire department, with a combination of presentations, homework, and implementation via on-going projects.