MASTER THESIS PROJECT
CONCEPTUAL SPEAKER STUDY
HAMPUS MORBERG

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Summary

This thesis project is a stand-alone project with the goal to develop an optimized material suited for speaker cabinets, with the focus on acoustic abilities, production possibilities and environmental impact. And to further on design a high performance to price speaker, using the developed material properties and todays technology. The thesis is focused heavily on testing material, starting with research and thereafter creating and testing samples, to continue with find a material combination that would work for a product fit for the market. The final product should fulfill the demands of typical furniture handling, meaning it should be able to be moved around and withstand moderate abuse from daily events. The project results in a functional prototype for evaluation of material and the overall design. The project is based on design methods and design thinking.

Methods used: Design thinking, Project planning, Product breakdown structure, image board, Target group analysis, Function analysis, Double diamond, Material selection strategy, Goal-Action-Feedback loop, Competitive analysis, Questionnaire, Interview one-on-one, Sketching, 3D modeling, prototyping.

Keywords: speaker design, speaker cabinet, open baffle speaker, dipole speaker, material design, industrial design.
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1 Introduction

1.1 Background

Music is a billion dollar industry and a large part of our entertainment in life, therefore it is important that the speakers that are representative for music reproduction in our homes are being able to deliver the full potential of enjoyment and enlighten listeners of the dexterity of music production. There are speakers on the market that complies with this and are great sounding, the drawback with them is that they are relatively expensive, makes only few people privileged to own this level of entertainment.

1.2 Objectives

Large part of the speaker pricing is set by components, research expenses, manufacturing process and materials. The idea with this thesis is to see how a new kind of speaker can be built, how to give it stronger performance/price ratio by targeting manufacturing process, materials and components. As this is an individual project, no restrictions are set by a specified collaboration partner, giving it an open approach for development. As Lawson discuss, flaws in briefs can

1.3 Delimitations

This thesis will be focused conceptual design with material research and development of a functional speaker, however not going to design speaker drivers or crossovers. As it is an individual project no industrial machines or technology of any kind can be used to develop the material.
# 1.4 Disposition

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2 Theoretical Background

This chapter gives the information of what theoretical frames this thesis is built upon.

2.1 Loudspeakers

First it is important to know what a sound wave is. A sound wave is higher and lower diversity of density traveling in a direction. Sound waves can more easily be seen as vibration in various mediums, in this case air. Speaker’s purpose is to generate desired sound waves to create music, non-desired sound waves could be like a distorted part of a tone or added background noise. The brain is trying to isolate the music and trying to fix these imperfections by adding and restore parts to make an interpretation of the intended sound. (Kashino, 2006)

This process is called “phonemic restoration effect” the theory behind this is that the brain has a harder time to relax and the music experience is not as enjoyable as it could have been with a less stressed sound. A speaker should therefore produce as clean sound as possible, meaning that the membrane of the speaker driver is the only part that should produce sound waves and not the cabinet. Speakers in general could be split up in three different parts: drivers, cabinet and crossover. Where the drivers include a membrane that moves air, creating the music. The cabinet is a box or frame that are housing the drivers, the crossover is an electrical device that is splitting up frequencies to different drivers from the ingoing signal.

The purpose of the cabinet is to control the air that the speaker driver design to use for reproducing sound waves, it can capsule air to use it to work as a spring for the membrane, different drivers need different volumes to produce desired sound quality. All in all the cabinet could is used to create a barrier between over and under pressure for increased acoustic efficiency and be as silent as possible. Thus is speaker cabinets built of materials that have acoustic advantages e.g. if the cabinet is not stiff enough, the inside over and under pressure produced by the driver membrane could make the cabinet walls to bend inwards and out wards, seen as vibration.


2.2 Industrial design

The word design comes from the Latin word “Designare”, meaning “to mark out”. This agrees to some extent with the modern ways of interpret industrial design, “to improve the aesthetics of mass-produced products to increase their marketability”. (Oxfordreference.com, 2014) However the origin “to mark out” could be interpret as to make something special or peculiar, and could be in be this in so much more ways than only esthetics. As Lawson argues that good or skill full design is holistic, a design that solves several problems, which in general add a larger value. (Lawson, 2004) A more holistic value could add e.g. production, function, eco-awareness as values to a original brief focused on esthetics. These factors may not been though off in the original problem definition, but the designer could bring this as he/she progressively working, as he/she has a special kind of knowledge. Clients have a hard time to define the whole of the goals in the design brief, but as the designer works it the brief is constantly updated.

Designer’s knowledge

Designer’s knowledge is something that is very hard or impossible to study of literature and instead is learned by exert design tasks repeatedly. Design brings knowledge beyond what is stated in a project brief due to previous experience, also owning the skillset similar to a detective that have access to all the involved aspects and in the end finding a solution. (Lawson, 2004)

2.3 Design methodology

Design can be done in endless ways, due to every design task or project is fairly unique. However there are some guidelines how to effectively practice design.

The older doctrine of the distinct design process is where designing starts with determined phases of briefing followed by analysis, synthesis and ends with evaluation. Although there are more modern ways of interpret the design process of like (Goel, 1995) starts with ”problem structuring” followed by ”problem solving” (“Preliminary design” “Refinement” ”Detail design”) Lawson argues that this design process doesn't always have to be done in a distinct sequenceses, as some famous arhitects starts with ”Detail design” to be able create the general arengement. (Lawson, 2004)

This is connected with “design thinking” which is a methodology rather than a method, it is an approach to design involving usage of a vast variety of methods. The target is to keep being innovative when designing. It consists of a series of divergent and convergent phases, creating a balance between creative and analytic thinking. The design process become efficient by iterating creative and analytic thinking. (Curedale, 2012)

Design methodology purpose is to separate the ideas of how to exert art from design work, design methodology enables a verifiable procedure to gain resilient solutions through knowledge from design science, cognitive psychology and practical experiences. (Birkhofer, 2011)
2.3.1 Double diamond

The double diamond is design process of how to route the work during a project. It is initially developed at the Design council (UK) in 2005. The process is divided into four phases, Discover, Define, Develop, Deliver. Where Discover and Develop are divergent phases and Define and Deliver are convergent phases. (Angus)

This is the overall process pattern of the project, however a speaker development is a bit special, the quality of the music emitted from a new speaker design is very hard to predict. This is due to the baffle shape has a very large influence and a listening test cannot be done until the function prototype is done, this is why it hard to just stick to the double diamond process to get a successful result.
2.3.2 Goal-Action-Feedback

This is a process focused on reflecting on actions made to reach a specific goal and has its focus on being iterative. To reach a certain goal, actions need to be made. As sometimes the exact outcome of actions is unknown, only when the action is made the outcome can be reflected upon and then correct errors and deviations. With this it is possible to optimize the actions, apply the changes and get closer to the goal.

This iterative process could be perceived as a calibration system of what actions are best suited for fulfilling a specific goal. (Dubberly, 2004)
3 Methods

By using design methods and thinking, the process becomes clearer and used as guidance to achieve a better result. The chapter explains what methods are implemented in the thesis and briefly what they are about.

3.1 Project planning

Planning of a project is vital for a well-executed project; to be time effective, hold track of the economy and to not stress the end result.

Project planning could be divided into three parts: Define, segments and time planning. (Österlin, 2011)

3.2 PBS

The Product Breakdown Structure is a method to get a clear view of a product by diving its parts and reflect of their functions.

Characteristics:

- Effective tool that details physical components of a particular product or system
- Hierarchy
- Used to obtain a clear understanding of a product
- Example

(productbreakdownstructure.com)

3.3 Image Board

An image board, also called mood board is a collection of images used as a tool to mediate a mood or feeling connected to a product. It could be pictures of e.g. colors, form, surfaces or materials. (Curedale, 2012)
3.4 Target group analysis

The target group is the persons that are potential buyers of the product. To attract these buyers it is important to fulfill their demands and needs in the product. It is essential to analyze the target group's requirements to not lose focus of the design. (Österlin, 2011)

3.5 Function analysis

A function analysis is a tool for listing products functions so that no part of the product will be forgotten. It is also a way of rank importance and targets of different functions, to clarify the products goals and what is needed to achieve. (Österlin, 2011)

3.6 Material selection strategy

Material selection strategy is a way of linking material to design. To select the material/materials best suited for a task out of a vast selection. The larger amount of surveyed materials are, the higher is the quality of the material research, meaning that it is less chance to miss the ultimate material for the task.

This method starts with translation, by expressing the design requirements in constraints and objectives. Constraints is to set up what essential condition the design must meet, e.g. be strong enough, conduct electricity or tolerate 200 °C.
Objectives is to measure what performance should be maximized or minimized, e.g. cost, weight or Eco-impact.

When translation is set, it is possible to look for material candidates, which materials fulfill the constraints and objectives, this step is called screening.

Thereafter rank the candidates by the most crucial design objective e.g. least cost of ownership.

The last step before deciding what material to use is to establish important attributes as delivery time, Service frequency, nearest dealer and warranty. (Jarfors, 2012)

3.7 Competitive analysis

The competitive analysis is way of strategically acknowledge products on the existing market that is seen as opportunities or threats.

Used to define the product goal in terms of brand statement, values, targeted customer, technology, environmental performance etc. (Curedale, 2012)
3.8 Questionnaire

Questionnaire is a tool used for collecting data from several individuals by letting them answer a number of written questions. It is effective in both time and cost due to several individuals can answer the questions at the same time. The answers are processed to acquire a compiled knowledge about context and user. (Curedale, 2012)

3.9 Interview one-on-one

A one on one interview consists of the researcher and one participant, in a physical meeting. It is one of the best methods for gathering personal information, it also possible to exchange ideas and opinions. (Curedale, 2012)

3.10 Sketching

Sketching is fast hand drawn illustrations for a fast and clear way of sharing and developing ideas. During a project, sketching could be implemented during the whole project time, used as an iterative process. (Curedale, 2012)

3.11 3D Modeling

Three-dimension modeling is a way of creating volumes in a virtual world, it is a fast and accurate method to create a design basis.

Three of the most common ways to create virtual 3d models are polygon, solid and surface modeling, where polygons surfaces are made out of several connected flat surfaces to create the desired shape, solid is based upon primitive geometrics volumes and surface modeling is using accurate nurb-lines.

3.12 Prototyping

A prototype is a physical model intended for evaluating form, function or material.

There are two types of prototypes, Apperance prototype that simulates appearance of the specified product, Performance prototype that simulates the function of the specified product. (Österlin, 2011) (Kumar, 2013)
4 Approach and Implementation

4.1 The approach to build a better speaker

Due to this project is not based on a project brief given by a collaboration partner it is vital to define the goals and how to approach it in an early stage.

4.1.1 Material

The finest reproduced music is the one with silent background, meaning no noise is disturbing it. The most common source of noise comes from when material in the surrounding vibrates to the music. The sound of these vibrations is out of phase and distorted, making them annoying to the listener’s ears and brain as stated in the theoretical background. The vast majority of speaker cabinets today are made out of wood, a material used in acoustic instruments due to its ability to resonate, a performance undesired in speakers. The cabinet should be as silent as possible, leaving the drivers or producing the music. (Wilson, 2014)

By aiming at making a cabinet with high density and good vibration abortion to minimize vibration and resonance, a calmer and non-annoying sound can be produced, the music would become more real and lively.

4.1.2 Manufacturing

Almost all speakers are made in secondary shaping, meaning that materials for speakers are made often in sheet materials and then milled or sawed to the right shape, this gives not only an advanced process for complex surface shapes if desired but foremost a lot of waste material. In primary shaping materials are formed to the desired form in the first process, allowing more advance surface shapes and leaving minimum waste material. Typical primary production methods are Casting, Molding, Rapid prototyping and powder methods.

4.1.3 Components

Crossover is an important part of speakers, it could be referred to the controller of the drivers and the speakers overall sound. Serious speaker design tends to use as few crossover component as possible, due to two reasons, analog filter components is distorting sound and low distorting components are expensive. The function of crossovers is to split frequencies and distribute it to different drivers, they can be digital or analogue. By using digital crossover the distribution of frequencies can occur before the signal is translated into the analogue domain, discarding analogue crossover completely. Too keep a high performance/price point, analog crossovers can be replaced with Digital Signal Processing technology (DSP). Reproduction of music as it once was recorded is the ultimate pursuit; to do this the signal or music information needs to be intact and undistorted all the way from the recording studio to the speakers.
Approach and Implementation

As mostly music is recorded and mastered digitally, the signal stays intact regardless of how many times it gets copied or transferred. This is because of digital signals sending predetermined packages of information that with a buffer are sent again if missed or distorted. Equal to a digital image on a website, the pixels will have the same arrangement regardless of who or where it is opened, in other words the picture will always look the same. As signals lose some information when it is translated between digital and analogue domain, it is an advantage to keep to one domain as long as possible. As this project is focusing on optimizing a cabinet material and then development of a speaker based on that material, the material research is the first part of the process. When the material is determined, ideation process of how to apply this in to a speaker design follows.

4.2 Trends

4.2.1 Visiting HEM 2014

“High End Mässan” is a speaker fair located in Stockholm, which focuses on the high end segment of the speaker market.

A rising trend this year was digital music libraries where e.g. German Burmester and Swedish Bladelius showed their latest products with this technology.

Figure 4, Monolith Audio

A newcomer to the High End Fair was monolith audio, a speaker manufacturer that made cabinets out of molded concrete due to its ability to resist vibration, an unusual material choice for speaker cabinets in the domestic speaker market.
The trend is going progressively to digital music media, where in a poll survey shows that streaming services are the most popular way to listen to music. (Wilhelmsson)

Audio Concept is claiming that there has never been a time better than now to invest in an amazing speaker system, because it has never been this easy to access the world’s music with all new digital streaming media. (Hifi&Musik, 2014). As most music is accessible in the digital domain it is a strong point to use digital crossovers or DSP technology before the digital to analog converter needed for the analogue driver signals. This approach can be seen as in young expanding companies like Australian DEQX and French Devialet, they specializes in DSP technology to control the speaker output signal.
4.2.2 Furniture Fair 2014

Due to speakers often being part of a living room decoration, they could be in the category of furniture, and therefore it is interesting to expand the target group to people that are more interested in design furniture. At the Stockholm furniture & light fair the latest trends is displayed by a vast variety of companies. Ongoing trends are matte surfaces with contrasts, dull colors and solid materials. As production technology progresses products tends to have more refined and advance surfaces.

Figure 6, "Möbelmässan" in Stockholm 2014
4.2.3 Target group

The target group for this project is the people that cherish the modern living and has a good economic situation to enjoy the fine things in life. At the HEM in Stockholm February 2014, it was overall stated that the target group for high-end speakers were males in 30 – 60 years of age. By visiting the Furniture Fair in Stockholm February 2014, has a wider target group compared to the HEM Fair, consisting as many females as males and with a larger span of ages, about 20 to 70 years of age. The targeted speaker should mainly fit into the interests of the High End speaker market, but also, speakers fall in the furniture category to decorate living rooms. Target is to attract HiFi enthusiasts mixed with high social status, showing that high tech sound can be a high quality home decoration.

4.2.4 Type of speaker

To make a speaker that is appealing in both looks and sound reproduction, something unusual is required. The idea is to take advantage of modern technology and use digital signal processing to control an open baffle speaker. As the open baffle speaker lacks a bulky box it has the potential to look smaller and therefore easier to implement into home interior. Theoretically it is possible to get tremendous precision in acoustic instruments and voices, but the trade of is loosening effect in the lower end frequencies, although the lack of low-end effect could be partially compensated with the DSP.

4.2.5 Short Interview

One-on-one interview with Adam Brewitz on HiFi Klubben in Jönköping, a speaker’s reseller. This was made to give more insight in the domestic speaker market.

What is the ratio of men and women buying speakers?
-It is mostly men, they are the most enthusiastic of technology.

In speaker design, what are people looking for?
-The sound is most important, color has a bit of importance but the price is one of the largest factors for a purchase. People can get caught for odd-looking speakers, but in the end it is the sound that matters the most.

What is your feedback of modern cabinet materials?
-MDF is not well regarded, solid wood is often used in speakers that cost 20 000 SEK and over.

How well established is Open baffle speakers?
No so well established, it is a specialized market.

How well established is Digital preamplifiers/DSPs?
The same, it is a specialized market.
4.2.6 Market analysis

Accordingly to Brewitz in the interview, both open baffle speakers and DSP controlled speaker system is not part of the current ordinary market. Although digital technology and DSP:s is rapidly growing. It is a part of countless smaller streaming speakers systems today, meaning that the technology already well implemented in the low/mid part of speaker market, positive to keep a low price point.

Even it relatively unusual with open baffle type of speaker in the ordinary market, there are some representatives of this kind. Kyron, Lyngdorf, Linkwitz are all producers of open baffle speakers with an active crossover, where Kyron and Lyngdorf uses DSP:s. Forsman and Jamo makes open baffle speakers with passive crossover filtering.
Speakers with cabinets made of exotic materials such as milled aluminum are by far too expensive to interest the ordinary market e.g. Kyron Kronos at 450 000 SEK. The speakers made out of wood are acoustically less attractive although they are affordable, but the affordable often lack low frequency extension or the quality look of a status product. The target is to design a speaker that uses specialized material and production methods for the cabinet, to sound as good as the exotic cabinet material but keep the price point lower. Designing with form and surface finish it should express quality and luxury.
4.2.7 PBS

The product breakdown structure is a great tool to understand the regular speaker’s structure.
To keep in mind of parts that has a connection to the sound and other functions.
By studying commercial speaker it is easier to understand its parts and construction.

Regular speakers could be divided into three parts, Drivers, Cabinet and Crossover

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**Figure 8, Speaker exploded view**

**Figure 9, Speaker PBS**
4.3 Material Research

To make a truly good sounding speaker, the cabinet that housing the drivers needs to be completely silent, leaving the drivers for producing the music. In other words, the cabinet should be absorbent of vibrations. An ultimate material would be stiff to prevent from flexing due to the difference in sound pressure, produced by the driver membranes. The material should also absorb a high amount of acoustic energy, coming from the drivers bolted to the cabinet. The abortion of acoustic energy is based on two factors or properties, Density and Mechanical loss coefficient. With higher density it takes more energy to move a certain volume a defined distance. This makes the speaker more stable and less affected of vibrations. Mechanical loss coefficient is a measurement of how fast a vibration in a medium fades away. High MLC means a high damp factor, this is especially important in order to prevent the material of ringing.

4.4 Material selection strategy

The material must own performances to work as a product in the domestic market e.g. room temperatures and normal abuse if fragile. Using material selection strategy it is possible to review a vast selection of materials.

4.4.1 Constraints

Be tough enough
Be produced in primary shaping
Be Stiff enough
Be Air tight
Be Heavy enough (Density)

4.4.2 Objectives

Maximize Mechanical Dampening
Minimize Cost
Minimize Eco impact
4.4.3 CES

The strategy was implemented in CES material database. Figure 10 is showing a chart with mechanical loss coefficient of possible materials.

Screening with
- maximum cost of 10kr/kg
- Density minimum of 500SEK/m$^3$

Process tree:
- Casting, Molding, Rapid prototyping and powder methods.

![Figure 10, CES MLC Chart](image)

The damping factor or mechanical loss coefficient (MLC) is the most important property of the three, due to its ability to cancel out sound and vibration. Asphalt concrete is the most dampening material, although it is only stable under 20 degree Celsius, which makes it not suited for a product in domestic home environment. Second best is Plaster of Paris.
4.4.5 Energy Compensation

A modern approach to material development must involve eco-awareness. Figure 11 shows different ecology comparison aspects of production.

*Figure 11, Energy compensation data from CES*
Given that Plaster of Paris is the best available material in terms of MLC and uses relatively low energy in primary production, makes it the a strong material to proceed with. The plaster owns about 1200% more mechanical loss coefficient than regular MDF board. However plaster is relatively fragile compared to MDF and plywood some strengthening of toughness may be needed to work as a trustworthy material. The company Bowers & Wilkins, a large speaker manufacturer, do not make any tests of durability of their speakers, they rely on the packaging company to deliver a undamaged product when shipped. (See attachment 3) However Plaster of Paris owns about 158% stiffness compared to MDF (Based upon CES data), which makes it more resistant to flex. It is has also twice the density, which makes it less affected of kinetic energy coming from the drivers. Production wise plaster of Paris demands really simple tooling for simple shapes because of its ability to be cold casted.

### 4.5 Material Strengthening

There are many ways to strengthen materials and countless materials to choose from. The methods used for strengthen plaster are based on information from internet forums, webpages and asking people using plaster casting in their line of work. Resulting in:

- Regular plaster, for comparing.
- Molecular strengthen with “Gummi arabicum”
- Capillary plot until saturation with “Schellack”
- Short glass fibers, 2-3 cm
- Long glass fibers, 8 cm
- Tough coating with “Gelcoat”

Five samples of each method are created to spread occurring faults and give a more credible test. These samples are then reviewed to make a convergent test of each method.
4.5.1 Casting samples

The samples had to be relatively large to give enough resistance when put into a material resistance test. The samples were made 100 x 100 millimeters and 20 millimeters thick. By creating two casting frames with 5 samples in each, several samples could be made at once.

The instructions for the plaster was in weigh one part water to two parts plaster. Each cast frame contains has the volume of 1 liter, which is about 600 ml of water and 1200g of plaster.

The mix becomes relatively viscous, and starts to solidify just after a couple of minutes. When mixed with the glass fibers or gummi arabicum the solidification is even faster, making it hard to be poured into the mold in time.

4.5.2 Sample evaluation

The aim with making samples was to test different methods increase of toughness or resistance to break when hit or pressed.

The toughness is tested by pushing a 14 mm diameter steel ball thru the material with increasing force, by recording under what force the material breaks or cracks it is possible to tell the difference between the methods.

By using a Brinell testing machine, it is possible to measure the applied force in kilograms.
The chart underneath is the result of testing toughness of different methods.

![Toughness Chart](image)

**Figure 12, Toughness Chart (The lighter green shows reference toughness of regular plaster)**

**A Regular plaster**
breaks at 374 kg of applied force. The samples crack in three or two clean pieces.

**B Plaster with 14g of Acacia rubber to 100g of plaster.**
Seams to make the plasters surface harder but as seen in the test, more fragile.

**C Plaster with 2% 8cm long glass fibers.**
Makes an composite that is about 400% tougher compared to regular plaster. The samples show small cracks but never splits up in clean pieces, the sample is still intact.

**D Plaster with 2% 2-3 cm long glass fibers.**
Same as test “C” but it show less tough.

**E Regular plaster with Shellac as capillary filler.**
Shellac made a slight improvement, about 122% compared with regular plaster. Still with a clean crack as regular plaster.

**F Regular plaster with “Gelcoat” as coating.**
Gelcoat gave about double the shellac performance, landing on about 144% improvement compared with regular plaster. Still with a clean crack as regular plaster.

**Conclusion**
Longer and shorter glass fibers are by far the best composite in terms of increase toughness, but doesn’t make the surface any harder to prevent scratch marks.
4.5.3 Surface treatment

Plaster has a surface that could be scratched with fingernails, both shellac and Gelcoat are surface treatment that gives a harder shell. Given that Gelcoat is twice the improvement in toughness and harder makes it a better suited coating for the final composite. A combination of glass fibers and gelcoat surface treatment would give a material that is both tough and scratch resistant. A Surface treatment that was drawing attention at the furniture fair 2014 was the products made out of Cristalplant, a white hard ceramic with a matte finish. A high ratio of the people that were passing these products urged to feel the surface.

![Figure 13, Cristalplant product](image)

The more senses connected to the product the more it enhances the impression of design according to Jinsop Lee. (Lee, 2013)

To make a intriguing surface, tests with the same treatment method as Cristalplant was applied on the Gelcoat. This test is done because of the Cristalplant material cannot be applied as a thin protective layer, accordingly to the manufacturer.

By polishing the hardened gelcoat with “240” sandpaper and then “360”, followed up with polishing with rub and “scotch brite” gives an appealing mat surface. (Cristalplant, 2014) Gelcoat applied on a low-density material gives a plastic feel and sound to it, however applied on solid high-density plaster gives the surface a stone like feeling. As Lee advocates, a design that thrills several senses is a more successful design. By using contrasts in the senses touch and sight in the surface treatment, a more intriguing design could be achieved.
4.6 Speaker Design and implementation of developed material

4.6.1 Mood board

The mood board is used as a tool to clarify with pictures what the concept speaker should express. Defined edges are something that can be seen in modern products, like high end cars and furniture, a way of showing advance production methods. The speakers should connect to enthusiasts and their way of thinking by being something extraordinary, using different and better technology than common products.

As stated in trend analysis, speakers progressing towards digital technology, speakers tend to use more digital technology.

A speaker should be able to play the music to the owners liking, one day calm and soothing music, and another thrilling and energetic.

It is important to find a balance in the expression of forms.
Three keywords used when designing:

**Intriguing**
Surfaces, Textures, Form, Technology

**Force**
Powerful, Emotion, Direction, Stability

**Quality**
Materials, Surfaces, Drivers

### 4.6.2 Acoustics

How sound waves are behaving in air and around material is an important part of designing speakers and can take endless of listening hours to compare different solutions. However, there are some researches that are based upon the laws of nature. The one below shows how large baffle is needed to produce a certain level of sound pressure in an open baffle construction.

![Baffle size chart](Figure 14, Baffle size chart)
The chart and study of competitive speakers is used during the design phase to know size of the baffle.

There are many construction options of open baffle speakers.

A listening session with the Forsman D2-8 gave the enlightenment of how well the sound coming from a H-construction open baffle speaker was.

As the H-construction also serves as stable and rigid form, it is a clear pick for the speaker design.

The “wings” of the H-construction are shorter, making it less affected of self-pulsation, in comparison with an U-construction with the same baffle size. The longer the wall is the more is the self-pulsation amplified.

A centred mass given by a H-construction increases the stability.

### 4.6.3 Drivers

There are drivers engineered to cover different parts of the full human hearing spectrum (20-20 000 Hz), speakers tend to use 3 different drivers, low frequency woofer, middle frequency woofer and a tweeter. This is because different frequencies have different wavelengths. In air, a 20 hz soundwave has a wave length of 17 meters as 20 000 hz has a wavelength of 17 millimetre. A longer sound wave needs a larger driver membrane to move the right amount of air. However, a full range driver is capable of handle a larger spectrum than regular drivers, covering the tweeter and midrange wavelengths, although as frequency drops the length of sound waves gets exponentially longer, making it hard for the full range driver to keep up. Larger drivers that moves more air is needed for the lower frequencies, especially as open baffle speakers lose efficiency at lower frequencies.

According to Seigfried Linkwitz driver loose efficiency as the frequencies gets lower compared to driver in a box. At 120hz the output efficiency is the same, thought at 30 hz the efficiency has dropped to a fourth. This means that an open baffle speaker needs more, larger drivers or a very large baffle to have the same low frequency efficiency as a speaker using a box. (Linkwitz)

Target is to create a sleek design with lot of acoustic power, however the acoustic power is connected to cone area due to more area is capable to move more air, another solution would be to use driver with a longer throw of the membrane, meaning how far the membrane can move as a piston. This results in the possibility to use smaller drivers with the same power as a larger one. DSP-systems are a bit more complex than analog systems.
with its setup and their several amplifier channels, to not cast doubt of investment the system would benefit to be as simple as possible. An active crossover 2-way speaker is less complex than a 3-way speaker in terms of driver integration and needed amplifiers, a 3-way stereo system need 6 amplifier channels as the 2-way need 4 (one amplifier channel for each driver). The simplest way to lower the amount of driver is to choose a driver that covers a larger sonic spectrum, this is done with a full range speaker. To complement the full range driver with high acoustic low frequency power, woofers are added, making it a 2-way speaker. By studying a chart of cone area connected to standard driver sizes, it is possible to evaluate what setup of drivers that would meet the requirements.

<table>
<thead>
<tr>
<th>Woofer Diameter</th>
<th>Total Square Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>33.17, 50.24, 78.50</td>
</tr>
<tr>
<td>8</td>
<td>66.33, 100.48, 157.00</td>
</tr>
<tr>
<td>10</td>
<td>99.49, 150.72, 235.50</td>
</tr>
<tr>
<td>12</td>
<td>132.65, 200.96, 314.00</td>
</tr>
<tr>
<td>15</td>
<td>165.81, 251.20, 392.50</td>
</tr>
<tr>
<td>18</td>
<td>198.97, 301.44, 471.00</td>
</tr>
</tbody>
</table>

**Figure 16, Cone area comparison chart**

A speaker with 3 x 8 inch woofers would have the right amount of power and still would be relatively sleek when mounted in a vertical line, however a parallel circuit with three 8-ohm drivers would give only 2.67 ohm, an impedance that is too low for regular amplifiers. A series circuit of three 4-ohm drivers is 12 ohm, which is too high. The impedance should be around 4-8 ohm to not cause disturbance for the amplifier. Four 8-inch woofers makes the speaker too tall or too wide, two 8-inch woofers would not have the right amount of power to really impress people. Advancing from 8-inch woofers to 10-inch, results in fewer woofers needed to create the right amount of sound pressure. Two 4-ohm 10-inch woofers in a series circuit would have 8-ohm impedance, making it ideal in many ways except the speaker get a bit wider.
In the “Munson equal loudness curves” made by Fletcher 1937, it is shown that the human ear has different sensitivity across the hearing spectrum.

This means that the human ear is most sensitive to sounds in 3500-4000 Hz, here distortion and noise should be as low as possible.

This chart is used to see where the integration of different drivers should be avoided and when studying driver frequency responses, a support for the driver decisions.

4.6.3.1 **Selected drivers**

**L26RO4Y** is a 10-inch woofer applied for low frequencies in open baffle constructions. It is developed at SEAS Laboratory in cooperation with Seigfried Linkwitz. (SEAS)

**PS180-8** is a 6.5 full range driver, designed to have a broader frequency spectrum. The driver is developed by Dayton Audio located in USA.


4.6.4 Designing the baffle

The form should represent the implemented production method, casting the cabinet compared to use sheet materials enables different expressions and could be shaped in relatively complex forms and surface textures. Giving it form wise a special segment of the HiFi-market. High quality and precision could be expressed with defined edges and high quality surface finish, also enhances the feeling of a status product.

In Sari Kujala’s paper “product symbolism in designing for user experience” she explains that symbolism of products are a important factor why people chose between products, almost half of 142 users in a large qualitative study mentioning symbolic meaning as a decisive factor when choosing between two alternative products. With this in mind, it is important that the speaker looks elegant and express finest music reproduction. The Aim is to make the person willing to invest in a speaker that he/she can relate to its high quality intent. This is also a positive factor due to people tend to invest in things to help express them selves. (Kujala)

There are researches that claim that sound can be linked to form, as Wolfgang Köhler’s research of Kiki/Bouba where Kiki is connected to sharper forms and Bouba is connected to smooth forms. (Köhler, 1929)

To implement this to the design and form language of the speaker cabinet, it is possible to some extent control the impression of characteristics of the speaker and its sound.
4.6.4.1 Driver placement and sketching
As frequency increases the speaker drivers have a hard time to produce a consistent dispersion of the sound. The drivers must therefore have somewhat correct placement, creating a base for the on-going sketching.

Figure 18, Dayton PS180-8 Frequency Response

The diagram above is the frequency response of the Dayton PS180-8, the red line is measured in front of the driver, green is $30^\circ$ off and the blue $60^\circ$.

The full range driver is therefore placed and directed around ear height of a sitting person to not cause any confusion in the soundstage.

The low frequency woofers placed underneath the full range driver, to keep the speaker reasonably in size, to not make a speaker that is too hefty to decorate a family living room.

Ear height is about 900 mm over the floor when a human sitting.

The setup of the drivers gave an articular smaller area and a larger more powerful area to become like a head and a body, something like a majestic statue.

With the drivers and their placement decided, sketching is used as a tool to explore possibilities of the baffle form.
The car industry is one of the leaders in the development of modern forms production methods. Forms and colors from modern cars like BMW i8 and the trends at the furniture fair were implemented to the phantoms, focusing on contrasts and advanced surfaces.
4.6.4.2 **Workshop**

A couple of weeks into the project an group ideation session was formed, the group consisted of industrial design students where each student had half a day to have a short pitch and then got ideation help with her/his own thesis project. The ideation session resulted in some improvement and ideas for the three concepts.

4.6.5 **Three Concepts for mid presentation**

Sketches and ideas were refined into three concepts.

![Figure 21 1st Concept](image-url)
Figure 22 2nd Concept
Figure 23 3rd Concept
4.6.6 Survey

To evaluate the concepts, a survey was made where a focus group was evaluating the concepts by grading different impressions. 1 to 5 grades, where 1 is seen as Slightly, 3 Moderate and 5 Extreme. The aim with the survey was to clarify the impression of the three concepts. In the end qualify in what music genre each concept belonged to, this is to see what music style the concepts where recognized as. The result of the survey was implemented in the further development of the final concept. The survey is divided into 1st, 2nd, 3rd Concept.

Fragile/Ridged impression

2nd concept was seen as the most ridged concept, as it is a very important factor to make an authentic and trust worthy design when working with materials that are perceived as fragile.

Form Expression

Retro/Modern

A design that express extreme modernity, risks to be out of date when trends changes, a design that is neutral lack direction and clarity.

Due to this speaker using modern technology as the digital sound processing and a special developed cabinet material, a moderate modern impression would suit this project.

1st Neither Modern or Retro
2nd Slightly/Moderate Modern
3rd Moderate/Extreme modern

Simplicity/Complexity

To give a clear, harmonic and easy under stood design, it should express simplicity.

1st Slightly/Moderate Simple
2nd Slightly Simple
3rd Slightly Complex
Calm/Energetic

By reflecting calmness, the design is more likely to own the ability to blend into people’s living rooms, making it easier to accept. An open baffle speaker is a speaker that is focused on producing elegant and fine tuned music rather than hectic and loud.

1st Slightly/Moderate Calm
2nd Slightly Calm
3rd Slightly/Moderate Energetic

Form Impression

Stability

1st Moderate/Extreme
2nd Moderate
3rd Moderate/Extreme

Sculptural

A high sculptural score is preferable due to it sets apart from the current HiFi market, as most speakers are made out of sheet material making hem inhibited to box like designs. This new speaker should form wise express something new and innovative.

1st Moderate/Extreme
2nd Moderate
3rd Moderate/Extreme

Symbolic

Symbolism can strengthening design by recognition and ability to waken feelings, the design gains an emotion connection to targeted consumer.

1st Moderate
2nd Slightly/Moderate
3rd Slightly/Moderate

Genre

1st concept had mixed expression, it stated Jazz and Soul.
2nd was also mixed and expressed Rock and Symphony.
3rd did strongly express House/Electrical music
Survey Result

The second concept qualifies as the best concept for this project, due to its originality and conclusions of the survey. It is seen as the most rigid form, an important quality when designing with somewhat fragile material. The form is slightly calm, which fits most living rooms, although it good to express a bit diversity, and show that it can be energetic at the same time. The form mediates a good balance between modernism and neutrality. The music genre expression is divergent and represents two strong genres for HiFi sound. Although the concepts need to improve the impression of stability, to make it look more powerful. The form needs a bit of development to be a bit more sculptural.

4.6.7 CAD Modeling

CAD modeling is a process that has been active in parallel with sketching and ideation phase. The modeling software used is Autodesk’s Alias a surface modeling software, with it’s built in rendering engine it is easy to evaluate forms, contrasts and colors. To faster produce more refined renderings, Keyshot 4.0 was used.

Drivers

The chosen drivers PS180-8 to the left and the L26RO4Y to the right where modeled in Autodesk Alias to evaluate proportions and make a realistic 3D-model.

Figure 24, PS180-8 and L26RO4Y Drivers modeled in Alias
Outlines
In Alias is possible to have good control of the lines, with the drivers positioned and mirroring lines it is possible to have a fast and accurate way of evaluate different speaker contours and overall shape.

Figure 25, A selection of speaker contours made in Alias
**Basic shapes**
The strongest feature ofAlias is its surface modeling abilities, by using this to build quick concepts based upon the earlier sketches and outlines is clear to see the proportions and geometries from all directions.

Surface modeling was used in an early stage to help evaluate what drivers to be used for the open baffle speaker.

*Figure 26, Early concepts made in Alias*
Phantom foot

As the second concept seemed to be less stable in the concept evaluation survey compared to the other concepts, the foot where further developed.

Figure 27, Phantom foot development made in Alias
Figure 28, Phantom further foot development made in Alias
5 Result

5.1 The Phantoms

The result is an open baffle speaker made with an optimized material. The speakers are called phantoms due to their form resemblance of a man and their ability to acoustically blend in to the room.

Figure 29, The Phantoms

Technical specification

Active crossover open baffle speaker.
* One Dayton PS180-8, 6.5 inch full range driver

* Two SEAS L26R04Y, 10 inch woofer drivers

Height 1.3 meters

width body 420 mm

width feet 560 mm

Weight approximately 60 kg
To give the form a sonically impression, sound waves moves thru air and around the baffle of the speaker, the cabinet walls should be somewhat acoustic reliable and not create turbulence. Soft forms found in aerodynamic design are known for its ability to suppress turbulence, something that in certain extent is possible to apply for this speaker. Softer forms also decrease risk for the plaster to chip or crack, a sharp corner is weaker than a blunt one.

The sides are 240mm in width, a measurement based upon baffle size. At the top the baffle is smaller to have a better dispersion of the sound coming from the full range driver. To make the speaker look less prominent and thinner, the sides are split up with contrast. A white continues border with a darkened back, to blend in with the interior.
Closing the white contour risks to increase the impression of a sarcophagus, an impression that was partly noticed by the focus group. By leaving the bottom part open the target is to just have the outline of a man or a phantom, due to a sarcophagus could mediate a negative impression. Thru lifting the whole speaker from the ground and place it on spikes, the contour felt more natural as it is air underneath it. The speaker is resting on smaller spikes to symbolize precision, e.g. used in precision scales. The three points are also an imitation of a milk pallet or a tripod for photography, it is stable no matter the layout of the ground. Spikes are also an old trait in speaker industry to isolate the speaker from the floor in matter of vibrations. It is intended that the spikes push out a bit in front of the speakers; this is to give a protective barrier for the front facing contour line. The spike that is facing backwards applying a hint that the speaker need space between the wall and the speaker, this is because of a dipole speaker need more open space than regular speakers. A dipole speaker is playing half of the music backwards and the other half forward.
Thru studies it has been proven that frequency response of the drivers is affected negatively when not correctly ventilated at the back. A chamfered edge on the backside averts the sound from being perceived as thin and unpleasant. (Gravesen)

Although the mounting screws in the back needs a flat surface to bolt the drivers in place, 6 for the full range and 8 for the woofers. The back is going from a more soft form in the top that fades to a harder chamfer at the foot, this is to give the impression of robustness and stability. The horn has thru mankind’s existence been associated with sound amplification, It is also a strong icon in sound reproduction products like gramophones and megaphones. The idea of implementing a horn shape to the speaker walls is to give a semantic connection to sound reproduction, hopefully result in a clarification of the products main purpose and meaning. Additionally, it gives the form a direction and makes it easier to understand the nature of the product.
5.1.1 Physical model

Casting the Phantoms
Casting is to pour a liquid substance into a mould that solidifies to a desired shape over time. Because of the solidification, the mould has to be shaped in a way so that the casted piece could be removed from the casting form or in other words the draft angles have to be kept in mind. The mould could also be bent, stretch or destroyed to be removed from the casted piece. Because of plaster is rather slow flowing, moulds with big pockets are undesirable. If air gets trapped it means that it could trade space with the casting material, making a piece of the speaker missing when pulled out from the mould. As no vacuum or pressure is used, it is preferable to use gravity and vibration to get mould material to the bottom and the air bubbles to the surface. To minimize the air in the mould material it is preferable to have a large area for the air to escape, it also induce a large in-gate for pouring of the slow-flowing plaster. For the mould a CNC-milled homogenous material is used to keep symmetry precision to a maximum. As the material used for the mould is not ductile, it is created with draft angels. The H-form of the speaker cross section has walls that lean inwards because of the horn shape of the speaker, this makes it impossible for a hard material to be compressed and pulled out. By splitting the mould in two parts and then cast a front side and a backside, the plug could be pulled forward instead, it also induces the large in gate for the moulds.
Because lack of injection molding or vacuum molding, the phantoms needed to be casted in stages.

The milling material consists of orange Sika foam and MDF for lowered cost.

The cast frame is then glued together, sanded in to shape and treated with a coating to separate the plaster from the cast frame when casting.
The casting is divided into two stages, the front is casted first.
Figure 35, Casting back part

The second stage is casted with a collapsible inner wall. A collapsible frame is needed for removal of the cast frame from the inwards leaning walls. The bottom plate is casted separately and glued to the casted front part. Screws and metal wire is used to anchor the back part to the front part.
After the casting is done, reshaping was needed to gain the desired result. Filler and plaster is used to fill cavities and create a smooth surface.
The final model is a prototype of both appearance and of performance kind. As in appearance it is full size made to scale prototype with paint and real materials. As in performance prototype it is built in the researched material with the correct drivers, the speaker is ready to be plugged in for evaluation of the sound.
5.2 The Material

The material is foremost plaster, as plaster is relatively fragile compared to MDF and solid wood it is reinforced with glass fiber, which increases the toughness about five times.

However the surface of the plaster need some kind of protective coating, or else it would be too exposed to scratches and dents.

The coating in this project is gel coat, a material really tough against mechanical damage.

5.2.1 Acoustics

Main target was to find a material that is by it self more acoustic/vibration absorbent than MDF and other wood materials. The material mainly needs more mechanical loss factor and density. It should also be stiffer to not bend when exposed to shifts in sound pressure. The plaster alone results in 1200% MLC, it owns 158% of the stiffness and has twice the density compared to MDF.

5.2.2 Production

In this project the casting was done as regular methods for plaster casting, meaning that the plaster substance is poured into a cast mould, and get rid of the air by vibrating the cast mould.

5.2.3 Sustainability

Plaster is largely used in construction market, this has enabled large-scale manufacturing. The large turnover of plaster results in cheap production, easy accessible and applied recycling process. With regular recycling of dry walls used in construction business 100% of the plaster can be recycled with up to 2 % impurities. This allows the speaker material to be 98% recyclable. (Gypsumrecycling, 2014)
6 Conclusion and discussion

This project started on a blank paper, is there a way to build a better and more beautiful speaker than the existing ones? To my knowledge, one of the biggest problems with speakers (that doesn’t cost a fortune) is that speakers sound like the music is trapped in a box and sounding tinny. A big part of the reason is that speaker cabinets oscillate to the music and emit their own sound, which interferes with the music in the first place. To get rid of this problem, the material had to be considered as the first part of the design process and followed by how to implement this material into a new designed speaker.

The original plan was to start off with the material and finish it in a early stage, although the HEM and Furniture fair occurred in the beginning of the project which started the design process of form and technology in parallel, it slowed down the material research but gave a better overview of the project. This project has had a different approach than regular design tasks, often is industrial design a gate to esthetically enhance a product that already functions, this is to give the product a stronger selling point. However, this design process aims to make a better product and esthetically show that it is something different from the other products.

The project gave me good results in both parts, although it is a foundation of a speaker ready for the market. A speaker is really hard to develop due to acoustics and drivers and their placement and requirements, it need several years to design, due to all listening hours and material tests, even for a company with long experience of speaker building. This applies also for the phantoms as they would need a whole lot more listening tests to further develop layout of the design and forms to make a speaker that can compete with today’s speaker.

The tacit knowledge by building speakers before has both helped and counteracted the designing of the speaker.

With a somewhat good knowledge of how speakers work it has helped me to faster get going and in decision-making, however it has also narrowed the divergent thinking when ideating. If this were a sharp project with more time, a complex project like this would need a lot more of Goal-Action-Feedback loop rather (Dubberly, 2004) than double diamond with two protruding phases. (Angus)

As it is very hard to predict the sound quality outcome, a function prototype must be finished to be able to evaluate the sound. The evaluation is the feedback to know what to further develop and change. Meaning that it most certain that two phases is not enough to get the design and sound to an ideal point. The double diamond is better suited for a task that has a specific goal with determined resources. The material research did fit the double diamond process, where the CES screening part and evaluation would represent the first phase and the strengthening and testing part would represent the second phase.

One hard part of the material research was how to evaluate the outcome e.g. I had to develop an own test to evaluate the toughness of the different samples. It also hard to find a variety of methods to strengthening the plaster due to I didn’t find any experts in that field.
A further development to the material research would be to make test samples with plaster that where strengthen with glass fiber and coated with gel coat to see the combined toughness result, I would also compare these samples to hard plaster from companies specialized in dental cast products, as they claim there products to be really though. The material chosen for this speaker application is foremost plaster, although plaster is more fragile than MDF or solid wood, with smaller speakers like bookshelf speakers it probably owns enough toughness to work as a cabinet material without glass fiber reinforcement. A full-scale test of the materials performance would be with “Cumulative spectral decay” or waterfall plot, a method used by Wilson audio and Magico to tests how dampened their cabinet materials are. (Wilson) (Magico, 2014)

In this project the casting was done with pouring and vibration, on a larger scale and a probably refined result could be done with pressure casting, with a tool including risers or a tool out of porous material. This kind of casting process of ceramic products exists in e.g. sink manufacturing. (Jika.eu, 2014)

As the material is heavier than regular wood, resulting in that the Phantoms weigh about 60kg. Although this is a lot of weight it isn’t bulky to be a high-end speaker. This is actually to prefer, the heavier the more stable, of course there are a limit before it becomes unmanageable, but there do exist high end speaker that weighs several 100 kg e.g. Wilson audio Sasha, that comes in three boxes of almost 100 kg each.

In the trend analysis I mention that the furniture fair would be interesting to analyze due to its design knowledge could be implemented on speakers to capture a larger target group, this is a vision the Danish company Vifa also shares. The sales manager of Vifa, Henrik Sonne Daugbjerg thinks their new speaker should be directed towards the female target group, and this by focusing on exhibit on furniture fairs around the world. A strong sales point as the females represent around 50% of the world’s population. (Edenholm, 2014)

B&O is a well-established speaker brand with a focus on design rather then sound quality, having intriguing design to attract people to buy speakers for their living room. A well-designed speaker that sounds really good would have an even stronger selling point, as this project have the sound quality first in hand, however the production enables new design, a design that could be intriguing for modern living rooms.

Something I learned by building the physical model is that the colours were not as expected, the contrast were to intense, quality of the paint is immensely important to mediate the right feeling and value of the product, it did also differ from the feeling I got when I were looking at the computer rendered images.

I had the vision to be able to evaluate the sound of the concept therefor I needed a DSP of Hifi quality, during two weeks in parallel with the project i modified a Behringer DCX2496 to having a working crossover, equalizer and phase correction.

When testing the single speaker after couple of hours of tweaking the sound was still a bit harsh, the test room for the speakers was 35 m2 with 3,7 m ceiling height with a square like form. As you clap your hands in the room, the eco is very intense.

This eco is probably the reason why the sound is a bit harsh, due to a open baffle speaker plays equally backwards as forwards it plays music In the whole room, meaning that a
dampened room may be more vital for a open baffle speaker than for a speaker that projects the sound in one direction. The Eco effect seams to be hard to counter with a DSP, it can be dampened but not completely cancelled. Could hamper the idea for domestic market due people do not tend to dampen their living rooms unless they are a bit familiar with acoustics. If I had done the project again I would do the same but with a bookshelf speaker in size, due to the immense time pressure and a greater quality of the model could be achieved. The reason why the developed speaker was so big was because I wanted to create a speaker that could represent the whole hearing spectrum, which forced me to use very large drivers in a relatively large baffle.

Even if it doesn’t show in the report, a lot of time went to figure out how to cast the large speaker in the true material, and some parts that had little time like the casting the samples took much longer time than expected, due to little knowledge of plaster casting.
7 References


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Figure 36 Private (Reshaping)

Figure 37 Private (Final model)
### 8 Attachments

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<th>Survey</th>
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Attachment 1 - Survey

CONCEPT 1

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If so, it symbolizes........................................................................................................................................

### 5. Overall thoughts and impressions

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3. Form Impression

Stability  

1  2  3  4  5

Sculptural  

1  2  3  4  5

“The art or practice of shaping figures or designs in the round or in relief, as by chiselling marble, modelling clay, or casting metal.”

Symbolic  

0  1  2  3  4  5

If so, it symbolizes…………………………………………………………………………………………

5. Overall thoughts and impressions
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3. Form Impression

Stability  1  2  3  4  5

Sculptural  1  2  3  4  5

“The art or practice of shaping figures or designs in the round or in relief, as by chiselling marble, modelling clay, or casting metal.”

Symbolic  0  1  2  3  4  5

If so, it symbolizes…………………………………………………………………………………………

5. Overall thoughts and impressions

6. Which concept would you choose to have in your living room?

Concept 1:
Concept 2:
Concept 3:

7. Genre
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Hi Hampus,

I contacted one of our senior product managers in UK and asked if he could comment on your questions regarding speaker cabinets. Here is his reply:

We don’t do anything remotely like the Brinell test, any more than I expect any other furniture manufacturer does. Nor do we take any steps to ensure a speaker remains undamaged should it fall on the floor (for example, drop off a wall). In fact, we don’t even replace damaged cabinets as spare parts, taking the view that such damage is covered by home insurance and the customer would claim for a complete new speaker or speakers. It is also important for us ensure that a complete speakers performs within very strict tolerances. Supplying cabinets as spare parts would incline that the complete speaker had to be reassembled by someone that does not have access to our measurement equipment that ensures that the assembles speakers performs as it should.

We do undertake a certain amount of modal analysis of cabinets, but that is to calculate things like the required panel thickness and where best to place internal bracing. That is purely concerned with acoustic performance, not preventing cosmetic damage.

We do, however, go to some lengths to ensure that products arrive undamaged to the customer by using properly designed and tested packaging. The first step is to commission computer modelling by a packaging consultancy company. This leads to prototype packaging, which first undergoes a series of drop tests. The drop conditions depend on the weight of the product as follows:

<=30kg – drop from 1m onto all 6 faces and all 4 corners
30kg <= 40kg – drop from 75cm onto all 6 faces and all 4 corners
40kg <= 50kg – drop from 50cm onto all 6 faces and all 4 corners
>50kg – tip over onto all 4 sides

The packaging is modified if necessary until that test is passed. It then undergoes real world testing by shipping the product between our UK factory, our factory in Zhuhai, China and our shipping warehouse in Buffalo, USA. Only if it survives all that does it go into production.

Hope this answer some of your questions.

Best regards,

Ole-Vidar

Ole-Vidar Andersland
Product Manager Nordic & Baltic areas
B&W Group Ltd

Bowers & Wilkins