THE TEXTILE FORM OF SOUND

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Abstract

The aim of this article is to shed light on a small part of the research taking place in the textile field. The article describes an ongoing Ph.D. research project on textiles and sound, and outlines the project's two main questions: how sound can be shaped by textile and conversely how textiles can be shaped by sound.
The Ph.D. project is a result of a common interest of the textile company Kvadrat, The Danish Design School and the Danish Ministry of Culture, which together have funded the research.

Building a textile-acoustic idiom

That textile is a good sound regulating material is a well known phenomenon. Part of this knowledge is also confirmed by scientific studies. This is primarily the part dealing with the acoustic properties of the flat textile (Persson et al., 2004 and Rindel, 1982). However, there is another very important factor which is determining the acoustic effect of the textile. This is the shape and location in space, this field is only sporadically studied scientifically (Tooming, K. 2007; Bodin, 2008).

Like the fabric, architecture has a long tradition of regulating sound. However, within the field of architecture exists a rich selection of examples of how both material and shape helps to regulate the sound, and over time a sophisticated acoustic idiom has developed (Long, 2006). The architecture shows clearly that it is possible both to regulate the sound, and at the same time use the sound for giving visual shape, of which Bagsvaerd Church by Jørn Utzon (1976) is an example. But while the materials of architecture most often are reflective, fabric is absorbent, and this fundamental difference requires a different idiom.

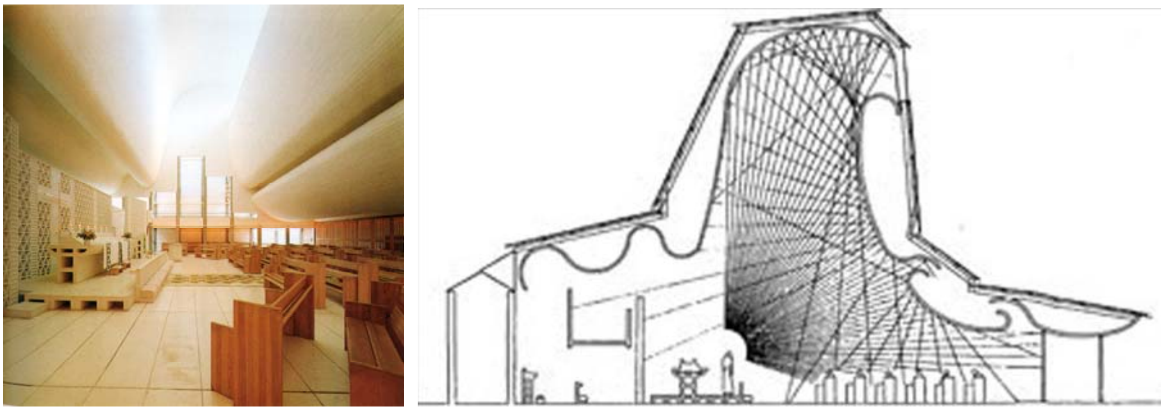

Figure 1. Bagsvaerd Church by Jørn Utzon. The drawing shows the building's interaction with sound. (Utzon, 1976).

To start building up an idiom for sound regulating textiles is to expand the modernist tradition in architecture and design. One of the cornerstones of this tradition is that the form must follow the function (Sullivan, 1896). Still today, this is a fundamental design principle (Bek, 2001), and the beauty of the principle is quoted to consists of a promise of function (Pallasmaa, 2001). The shape and the narrative of the function is therefore a central part of modernism.

Despite this, acoustic regulation materials available on the market today, in most cases makes an effort to be invisible when applied in spaces. This neglects sound as a possible shaping parameter (Pallasmaa, 2005). By exploring how textile can regulate sound through its shape and spatial position, it becomes possible to create sound regulation, which is not blurring the architecture, but continues the intention of articulating the architectural situation at the specific site.

This article briefly reviews the two main problems in building an idiom for textile sound regulation, namely: how can textile be shaped and positioned in a room to regulate sound and how can this shape and position at the same time visualize sound? The aim of the research project is to develop techniques for creating textiles for sound regulation and visualization and thereby initiate an idiom about textile and sound.

The article is divided into three sections. The first section describes the Ph.D project's first main issue, namely the acoustic properties of the textile. This subject is investigated by experiments in a laboratory. A few examples of findings are given. This section is followed by a description of important prerequisite for shaping the textiles. These are my own experiences with textile design and also the physics of sound. The last section is the description of the project's other main issue, which is the inquiry of how a textile form can visualize sound. The Ph.d. project is currently in preparation for this last study.

The acoustic properties of textile

The acoustic properties of textiles are closely connected with sound physics. Sound is vibration in a medium f.ex. air. Sound makes the molecules in the media vibrate and spread from the sound source in all directions as a sphere of pressure waves. Graphically sound is often illustrated as waves. The length of the waves indicates the frequency of the sound, while the height of the wave indicates how loud the sound is (Petersen, 1984).

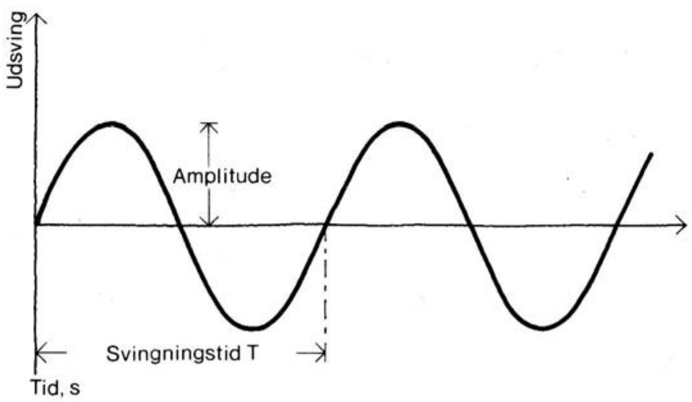

Figure 2. Sound is often pictured as a wave. The distance between the waves indicates the frequency, while the wave height indicates how loud the sound is (Petersen, 1984).

In order to regulate sound with textile, the fabric should be placed where the activity of the air molecules is most vigorous, which they are at the top of the wave. But where should the textiles be placed in a room to catch these points and how should it be shaped in order to curb the air molecules the most?

These questions defined the setting for the project's first inquiry. In a laboratory textiles were shaped and positioned in a variety of ways and the effect they had on the reverberation time were tested.
Textiles were arranged so that a wide range of positions and shape options were tested. Examples of these setups is the importance of 1)distance from the textile to the wall, 2)the quantity of textiles in the room, 3)the position of the textile in relation to walls, windows, doors, etc. and in relation to the sound source, 4)draping and folding of the textile and 5)the number of textile layers.
Moreover, it was crucial to find out in which manner textiles can regulate sound. Can textile both dampen and increase sound?

The experiments showed that textiles always dampened the sound and never increased it. Moreover, it was clear that it was mostly very simple parameters, which determine if the textiles dampened the sound or not. To give an example of this, two sound experiments are described.

The graphs show the absorption coefficients of the textile, i.e. how much sound the textile absorbs in various shapes and positions. On the x-axis the frequencies are read. The higher the frequency, the brighter tone. The y-axis shows the absorption coefficient. The higher the number, the better the absorption coefficient. It is typical that textile absorb more high frequencies than low frequencies.
As the focus of the experiments were the acoustic properties of the textile's positions and shapes, and not the textile in itself, only two types of textile were tested. One textile was a plainly weaved cotton with a structured surface and a weight of $325 g/m^2$. This type of textile has a very good absorption coefficient, with a specific flow resistance of approx. 750 Nsm^{-4} which is an almost optimal flow resistance of textiles for sound absorption. For investigation of the textiles ability to reflect sound, a textile with no flow resistance was tested. This textile was a plainly weaved rip stop nylon with a smooth surface and a weight of 60 g/m^2. Both types of textiles were mounted in wooden frames of $5m^2$.

The following two graphs are results of experiments with the cotton weave. The first graph shows the importance of the distance from the textile to the wall. Five different distances, parallel to the wall were tested.

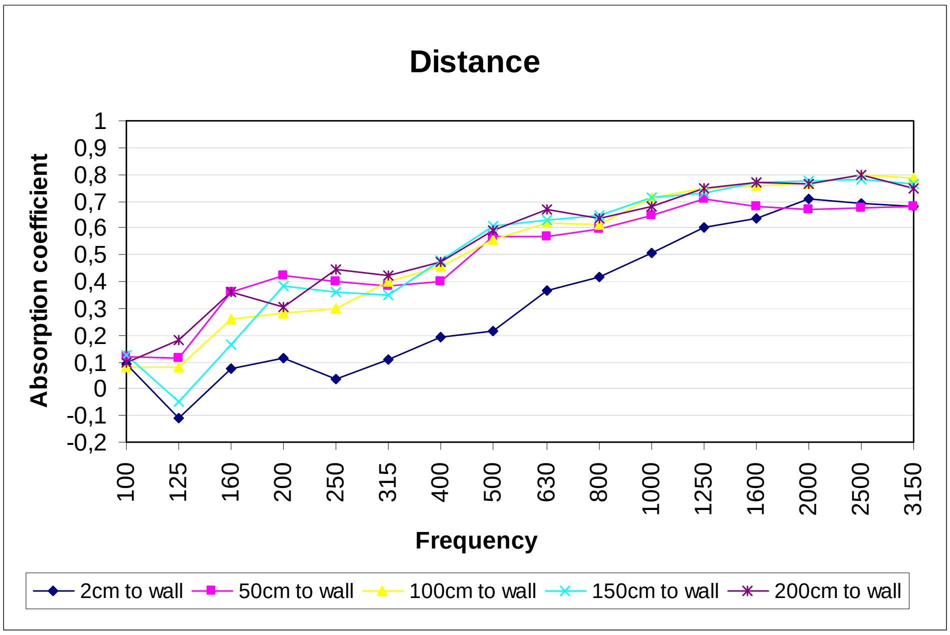

Figure 3. The graph shows the importance of the distance from the textile to the wall. The photo shows one of the two frames with textile.

The graph in figure 3 shows clearly that the position 2cm from the wall does not have as good of absorption as the other positions. In a similar set up, the importance of distances in the range 2 - 50cm from the wall was investigated. From these two studies, a rule of distance was derived: textile must be placed min. 50cm from the wall to obtain maximal absorption coefficient.

The second graph shows the importance of a draping of the textile. With draping means that the fabric is pushed up like a curtain. The 10m2 cotton canvas was first measured in plane mode, then draped to half width, and finally to quarter width.

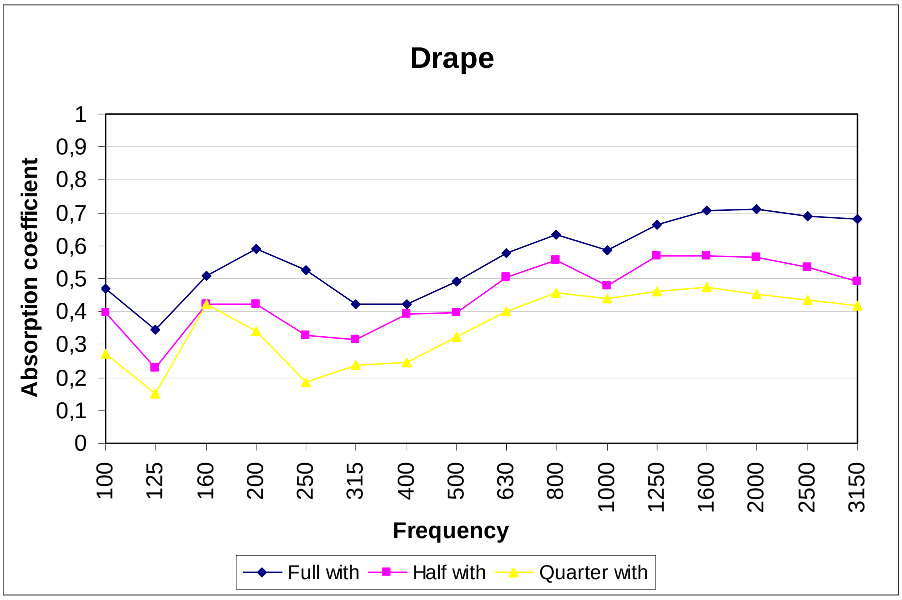

Figure 4. The graph shows the importance of the draping of the textile. The photo shows one of the two frames with textile.

The graph in figure 4 shows that the more the textile is draped the poorer its absorption coefficient gets. This result is obtained by calculating the absorption coefficient from the actual textile area (10m2). If, instead the calculation is done from the projected area after draping, it turns out, however, that a draped textile absorbs more sound than a not draped textile.

By examination of approx. 50 different set ups, nine rules were derived. The rules define the positions and shapes that influence the sound. The following two rules stem from the displayed graphs:

1. An optimal absorption is achieved by placing the textiles min. 50cm from the wall.
2. Textile is used most efficiently if it is completely unfolded and flat.

Two important prerequisites for the shaping of textile

Two prerequisites are particularly important for the study of the project's second main question which is about how fabric can be given shape and thereby both regulate and visualize sound.
The design of textile objects requires a thorough knowledge of textile processing techniques besides a position on what is the aesthetics of textile. Therefore, the author's textile design practice, done previous to the research project described here, is used as a starting point for the research.
Sound physics is another important prerequisite for the study. In aiming at getting to the core of the sound in the shaping of the textile, it is important to know the physics of sound.

<u>My approach to textile design</u>
The author's approach to textile design can broadly be described as architectural. The textiles ability to create space and spatial structures being in focus. Also, the interaction with the space surrounding the textiles is important in the textile design.

Especially one series of textile works may exemplify this approach to textile design. With three textile structures, it was investigated how textile could be shaped in a spatial structure, making it interact with the weather. This ended up to be three "weather-screens", both exposing and shielding against sun, wind and rain. The three-dimensional structures of the weather-screens were constructed by respectively cutting, sewing and weaving.

The phenomenon of weather is, in this textile design, regarded as a three-dimensional geometry containing great poetry (fig. 5). The geometry of weather consists of sun, wind and rain directions coming from the atmosphere to the ground in more or less vertical angles or across the earth's surface from all directions. Moreover, all three types of weather have certain characteristics in their contact with materials such as sunlight reflection, wind deflection and continuous, dripping raindrops.

Figure 5. The directions of sun, wind and rain and their characteristics.

The cutted screen (fig. 6) was based solely on the technique of cutting. By cutting slits in a piece of rip-stop nylon the fabric could either be pulled to a relatively stiff shielding construction, hanging loose the lobes would flutter in the wind and play with the sunlight.

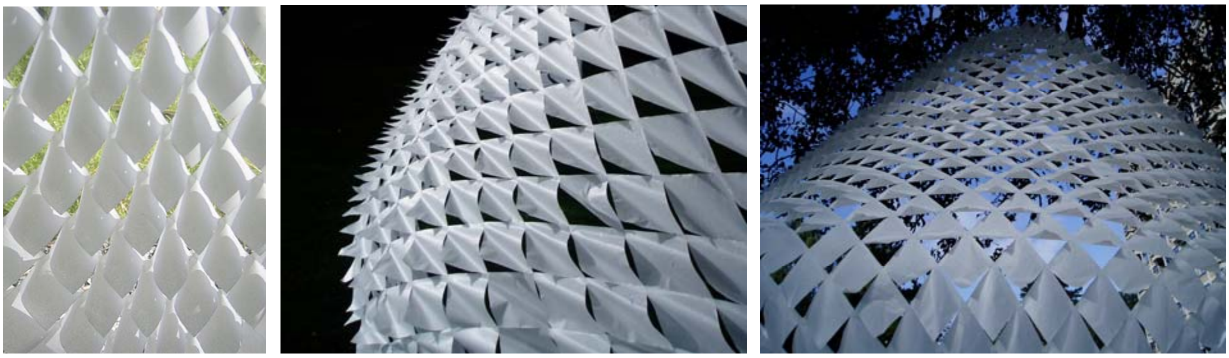

Figure 6. The cutted screen.

The sewed screen (fig. 7) consisted of approx. twenty layers of rip-stop nylon, sewn into channels which unfold when pulled. Due to the staggered layers and the slope of the construction, the rain runs into the channels, under the screen, and finally hangs like drops in the channel mouths.

Figure 7. The sewed screen.

The braided screen (fig. 8) was "braided" of straight, crossing strips. In this way the screen, viewed from the side, became a very spatial structure, while viewed form the front it was almost completely closed. This gave a special interaction with sunlight and streams of rain.

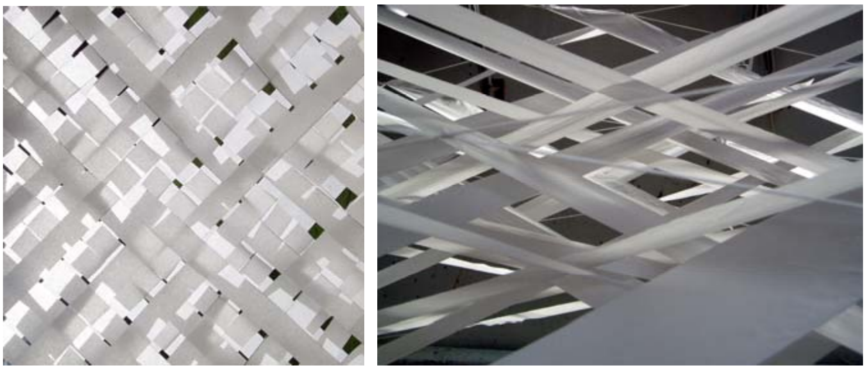

Figure 8. The braided screen viewed from the front and side.

The three weather-screens are examples of how functional requirements, textile techniques and spatial geometries can form a whole. This way of designing constitute the approach to the study of how textiles can be shaped to regulate and at the same time visualize sound.

<u>Physics of sound</u>

Like the weather, sound is a spatial geometry. And like the weather, sound makes it possible to point out many different characteristics, depending on the quality of the sound intended. One obvious characteristic to point out in relation to sound regulation with textiles is the activity of air molecules at the top of the sound waves. It is these active molecules that the textile must curb to dampen the sound.

The sound waves create a great variety of different geometries in space. The simplest may be the pattern of a clear tone, which spreads its regular oscillations in all directions with a wave front as a sphere (fig. 9, left). For multiple simultaneous sound sources in a room, the oscillation interfere with each other, and varying patterns will arise (fig. 9, right).

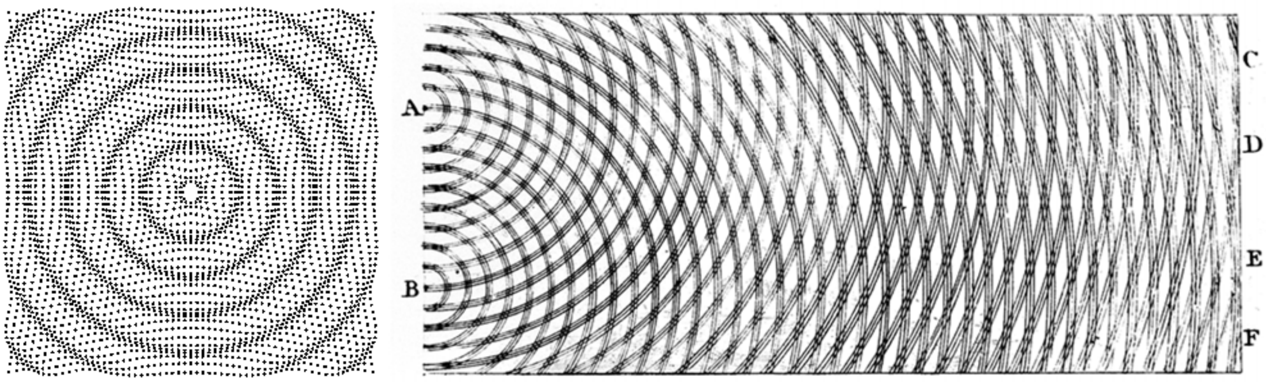

Figure 9. A sound sphere spreading freely and two sound spheres interfering. Here it is made visible that geometry is changing depending on how far from the sound source the sound wave is. (Left: Russell, D., 2001. Right: Young, T., 1803).

While limiting the idea of sound to the varying activity of air molecules in sphere formations the geometry of sound is not becoming simple. There are several factors that determine this geometry. This is for example the way in which different frequencies interferer with each other. Light tones are short waved and low tones are long waved. A complex sound, composed of several frequencies, which is emitted simultaneously, will by this reason obtain a complex spatial interfering geometry (fig. 10, left).
The oscillation of the sound can be mathematically described as a sine wave. Through this definition, as one of the trigonometric functions, sound wave geometry is related to a vast mathematical system closely connected to both plane and spherical geometry (fig. 10, right).

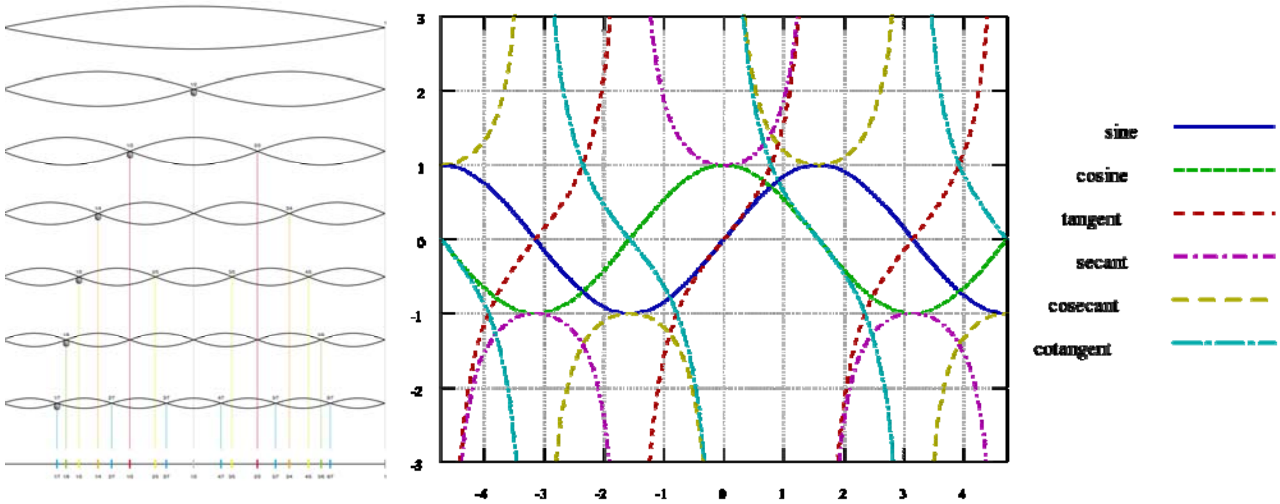

Figure 10. Interfering frequencies (mood-swinger scale) and the sine wave in relation to other trigonometric functions (Left: Yuri Landman, right: Alessio Damato)

The sound can thus be described as a rich and complex geometry from which to shape the textiles.

How can sound be visualized in a textile form?

The investigation of how sound can be visualized in a textile form is a synthesis of the sound measurement experiments, the authors textile design practice and the physics of sound. The investigation is not yet complete, and is therefore full of uncertainties and gaps. Moreover, problems in this part are described as *wicked problems*, because they can not be defined completely in advance, which means that the questions to be answered are to be found in the process of solving them. Also, wicked problem does not offer any absolute answers as stated by Rittel (1973).

The question "how can sound be visualized in a textile form” is about both the technique and the finished forms, i.e. both about how to *achieve* the shapes and how shapes *appear*.
This means that several types of knowledge are searched in the investigation. The question of how to achieve the shapes depends on the *design technique* used, while the question of how shapes appear depends on a *subjective evaluation*.

The solution to a wicked problem can not be said to be either true or false, the solution rather lies within the spectrum of good or bad (Rittel, 1973). To apply this way of evaluating two experiments are carried out: By performing two experiments a basis for a comparison and a formulation of the differences and similarities is established and a range of good and bad solutions can be pointed out. In addition, two experiments unfold a broader field of possible design techniques.

The first design principle focuses on the mathematics of sound. The sound unfolds in space following a series of physical principles, which may also be used in relation to design textiles. In the field of architecture and design an approach called emergence is used. Emergence can be defined as unexpected wholes that arise through simple interactions among individual parts. By tagging a textile sub-element with a simple code, borrowed from the mathematics of sound and then letting it interact with other tagged textile sub-elements, it might be possible to produce a textile whole which is a visualization of sound.

An example of this design principle is Alisa Andrasek´s fabric *Creature* (fig. 11). This work combines 1) algorithmically derived cuts between the layers, 2) the constraints of the laser cutting technique and 3) material properties. (Ednie-Brown, P., 2004).

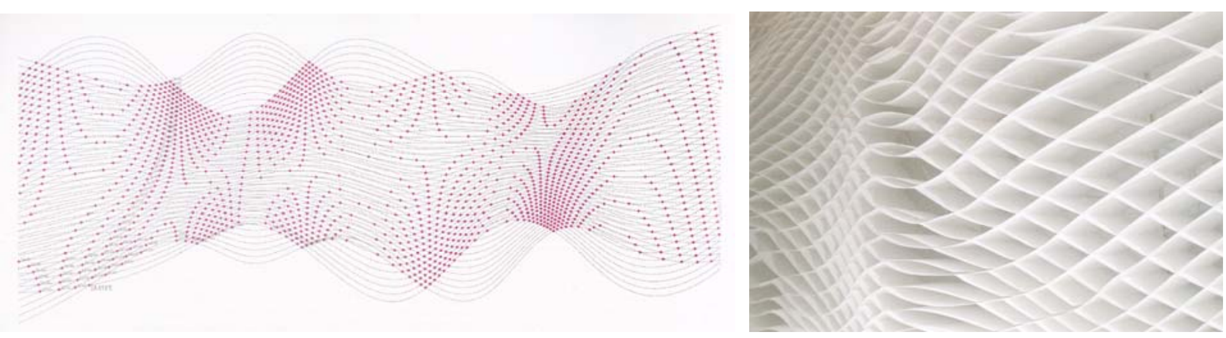

Figure 11. Alisa Andrasek´s algorithmic work Creature. (Ednie-Brown, P., 2004).

The second design principle focuses on the visual form of sound. To access this, the phenomenon of cymatics is studied. Cymatics is the study of visual sound and vibration. Here sound vibrations are visualized in a physical material, being solid, liquid, granular or other. The vibrations of the sound are applied to the material by an oscillator and appear as two and three dimensional patterns and shapes, depending on the material and the sound frequency.

An example is the Chladni figures (fig. 12) which was actually a study of how the frequency could be determined by the pattern formed on a metal plate with salt when a violin bow was swept over the edge (Chladni, 1817).

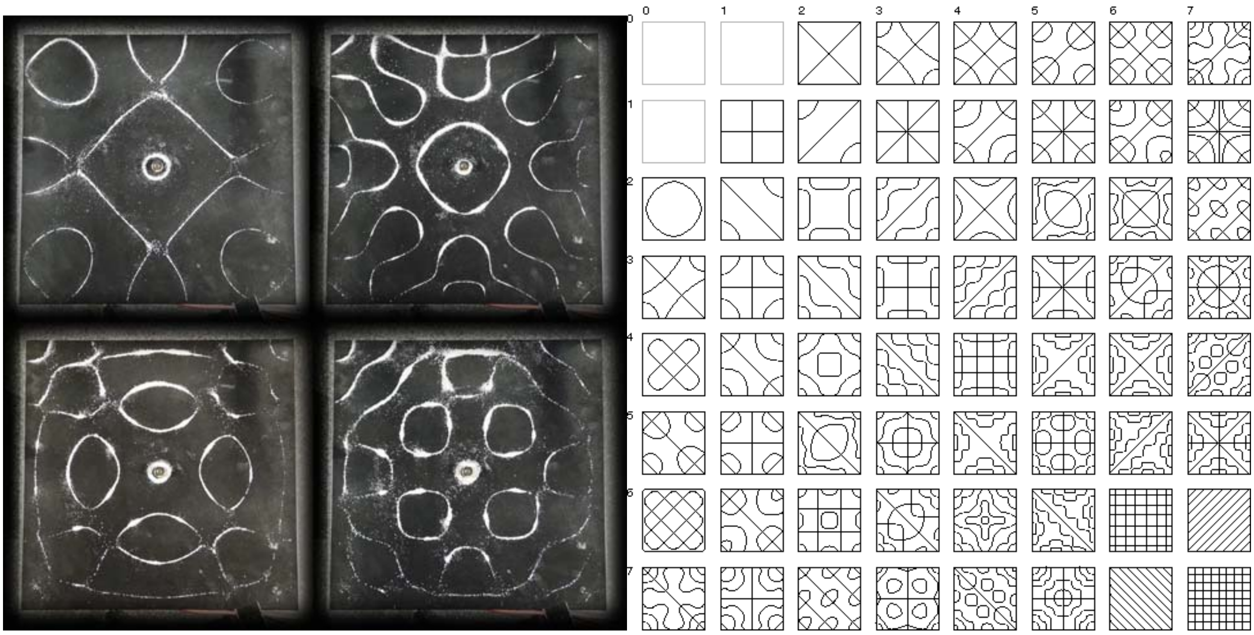

Figure 12. Metal sheet with salt showing four Chladni figures and a graphic system of Chladni figures (Left: MIT. Right: Chladni, 1817).

The shaping of the textile will in this experiment be an interaction between sketches of sound forms, as they appear in cymatics and practical experiments of how the textile can be shaped in relation to them.

Conclusion

The questions, treated in this article, as well as in the Ph.D. research project, was how a textile can be shaped and positioned in a room to regulate sound and how this shape and position at the same time can visualize sound.
The first question turned out to be rather simple to answer. Textile forms and positions were tested in a

laboratory, and the acoustic impact of this was measured with an instrument. The instrument's results were unambiguous and easy to understand: Textile should be placed at least 50cm from the wall to achieve an optimal sound absorption and also textile is used most efficiently if it is completely unfolded and flat. These kinds of results can be used directly by designers and architects for sound regulation in building projects.

The other question, however, was more complicated. The formation of textile by sound was compared to the formation of textile by weather. Sound is a force which moves the molecules of the air, but the force is too weak to move the textile material and form it. In this respect, the formation of textile with sound cannot be compared to the formation of textile with weather. Sun, wind and rain have a visible physical interaction with the textile form as they create shadows, fluttering and dripping which almost form the textile by their own physical power. The creation of a textile form related to sound needs a human hand to f.ex. cut, sew or braid the textile. But even this human hand cannot, at least not by the use of a sound measure instrument, give rise to forms that sufficiently visualize sound.

Sullivan's statement *form follows function* do thus not apply to this field as the form following the most efficient acoustic form and placement is rather boring. A plain textile, placed 50cm from the wall do not visualize a regulation of sound. However, Chladnifigures and algorithmic patterns can be useful for this purpose. Even they do not have any direct connection with the regulation of sound, it might be possible to make them look like they do while the deep nature of these structures has similarities with the deep nature of sound.

By conducting at least two experiments of how to visualize sound with f.ex. Chladnifigures and algorithmic patterns, it might be possible to identify and articulate in which way they do visualize sound and in which way they do not. By placing identified and articulated elements in a scale of good and bad as suggested by Rittel (Rittel, 1973), it might be possible to derive an operational knowledge about how textile can visualize sound.

In the end we will have two set of guidelines. One for forming and placing the textile in a room to regulate sound and one for forming and placing the textile in a room to visualize sound and a textile-acoustic idiom has taken its beginning.

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