Ergonomic prototyping for seating

The importance of physical prototyping for seating ergonomics in furniture design and critical usage of CAD-software

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ABSTRACT

This article looks at the relevance of utilizing a physical prototype specifically for testing of ergonomics in the design of sitting furniture and assesses to which extent this should be prioritized over CAD-modeling. This method is intended to be implemented in the early stages of a project for a more efficient development process and a more cohesive workflow. Findings from the literature review indicate that physical prototyping is an essential part of conceptualization and ideation. Digital solutions attempt to provide tools for this part of the process, but are insufficient in their current state.

KEYWORDS: Design process, Industrial design, Furniture design, Ergonomics, Flow, Design flow, Mockups, Models, Prototypes, Physical prototypes, CAD, Modeling software

1. INTRODUCTION

Good ergonomics is crucial when developing and designing furniture. There are many possible tools and methods to ensure ideal ergonomics in a given design, such as full-scale prototypes and anthropometric datasets. Prototypes in the late stages of development provides comprehensive tests of a design, but can also be costly and take time, which can be problematic if many iterations are necessary. Anthropometric data quickly provide a starting point and approximate dimensions in the early stages of a project, provided they correlate with the chosen demographic. However, if this largely defines the main dimensions of the design, the development might be limited to the detriment of design exploration. In other words, prototyping should be done throughout the process.

The intention of this paper is to look at the possible benefits of using a prototype solely for testing seat dimensions. This is intended for the initial stages of development when exploring and producing design concepts. This will make it possible to validate and revise design concepts as they are introduced and further developed. This avoids having to scrap a design in the late stages of a project, by identifying issues early.

Additionally, this article will consider the current state of CAD-modeling in relation to physical modeling, in order to further asses the relevance and potential of the proposed methodology. Ideally, the method provides a means for quicker progress in the start and middle of projects and avoid stops by e.g. external prototype production, thus providing a better and more even workflow.

2. METHODS

The methods utilized in this article were a literature study and interviews of groups working on furniture design projects.

2.1 Literature review

To establish what already existed of relevant theory and research, a literature review was performed. It proved very difficult to find literature directly related to the topic, especially in the form of research papers. As a result, it was necessary to look at ergonomics, workflow and the use of prototyping and computer aided design (CAD) more separately.

2.2 Interviews

Further work on the article was performed through more practical research. A simple prototype that provided a large range of adjustment was constructed for testing. The prototype was made available for industrial design students in their final year and students attending a class called Design in Wood at NTNU. The design in Wood students were a mix of industrial design students in year four and exchange students, developing sitting furniture in the final project of the class.

The students were encouraged to use the prototype as a provided tool. Their experience of using this method was then examined through interviews. An additional point of interest was the experience of using this method when the prototype was provided rather than constructing it in direct relation to the project.

3. ERGONOMICS IN DESIGN

The main function of a sitting furniture is sitting and ergonomics are critical for this function to be fulfilled properly. Looking at and measuring existing furniture, getting measurements from existing datasets or development with physical prototypes are some of the ways to achieve this.

3.1 Static anthropometrics

Anthropometrics are a systematic collection of measurements and correlations of the human body. In the context of product design the term is often used to mean static anthropometrics, which are the measurements of the human body at rest. These static measurements are available from several publications resulting from anthropometric surveys and their quality and relevance can be judged by their sample size and target population. (Cuffaro & Zaksenberg, 2013)

Measurements are usually displayed in percentiles, which represents the percentage of the population at or below that specific measurement. I.e., 95% of the population either have a lower or equal height when looking at the 95-percentile body height and 5% of the population is taller. Measurements are usually displayed on a figure of the human body in a specific position, with a selection of percentiles. It is important to remember that percentiles are defined for each measurement individually, meaning that the average of different measurements are not necessarily found on the average person.

Generally, when working with anthropometric datasets it is recommended to design for the extreme. This means developing a design that accommodates both the larger and smaller part of the population, usually referred to as clearance and reach. Using datasets this way is an effective way to

define the basic dimensions of furniture. However, it is limited to the human positions used for measuring the population and the measurements may not be entirely representative of the intended demographic.

3.2 Dynamic anthropometrics

Dynamic anthropometrics describes the human body in motion. These dimensions are usually more complicated than static ones and often specific for a given situation or task. As a result, they are usually more descriptive of the human body for a specific piece of furniture. "Design issues related to clearance and reach are more appropriately resolved using dynamic anthropometrics." (Cuffaro & Zaksenberg, 2013, s. 124)

Because dynamic dimensions tend to be task-specific they are more accurately found through testing and measuring of mockups. It is always recommended to use real people for this and the quality of the measurements will improve with the quantity of people used for testing. (Cuffaro & Zaksenberg, 2013)

4. DESIGN EFFICIENCY

4.1 Design Flow

Dorta, Pérez, & Lesage (2008) observed from data in their paper "The ideation gap: hybrid tools, design flow and practice" that the attainment of a flow state is an indicator of productive ideation. They present the concept of design flow, in which the designer is in synergy with a chosen tool or methodology, leading to ideation, a reflective representational conversation. This concept is an expansion of the general concept of flow introduced by Csikszentmihalyi in 1965 and later expanded on (Csikszentmihalyi, Beyond boredom and anxiety, 1975). Flow is defined as engagement in an activity with high involvement, concentration, enjoutment and intrinsic motivation, caused by challenges mathced by skill.

Obtaining design flow means gaining an efficiency in productive ideation, meaning faster and more productive work. This is maintained by being able to meet continuous challenge and overcoming it. Any interruptions or cause of stagnation will negatively affect flow, requiring effort to get back into flow. Methods or tools that lead to frustration or waiting periods will in other words lead to reduced productivity. (Dorta, Pérez, & Lesage, 2008)

4.2 Efficient prototypes

A study by Yang & Epstein (2005) state that prototypes are a way of simulating design without the risk of considerable time usage and investment. The study found that prototypes with a low part count and a low number of parts later added on, correlated with a better design outcome. Additionally, the amount of time committed to the project did not seem to have a considerable effect on the design. A process with simpler prototypes therefore seem to lead to better design quality.

Designers should ideally choose to utilize prototypes that are as "cheap" as possible while being effective. Simple prototypes that are built as quickly and inexpensive as possible without compromising the gathering of information are better for an effective process. Additionally, simpler prototypes allow for more conceptual feedback compared to more finished prototypes, as more detailed features

might be easier to address. (Dijk, Vergeest, & Horváth, 1998)

5. CAD AND PHYSICAL PROTOTYPING

5.1 Challenges with CAD

Industrial designers engage in the manipulation of form, with focus on the appearance and human interaction of products. Several methods are used for manipulation, but since the introduction of CAD in the late 1980s, virtual modeling has increasingly become important in professional practice and education of new designers. (Evans, Wallace, Cheshire, & Sener, 2005)

Digital modeling software started as a 2D representation of traditional engineer drawings. Increase in computing power enabled the transition to 3D-representations, providing more potential for communicating complexity, leading to a fundamental rethink of modeling practice. (Evans, Wallace, Cheshire, & Sener, 2005) The engineering origins of digital modeling can still be seen in the current state of CAD. Even though development of CAD-capabilities evolve quickly it is important to recognize when analogue methods are more efficient and produce better results. (Alcaide-Marzal, Diego-Mas, Asensio-Cuesta, & Piqueras-Fiszman, 2013)

A study by Milincu & Feier (2015), motivated by the increased usage of digital solutions and number of unrefined furniture designs, points to problematic behaviour among students. A clear preferance for digital methods lead to moving into CAD as quicly as possible, at which point the development of the designs stagnated drastically. Once a certain level of detail was exceeded, students were reluctant to make any changes. It was also apparent that design concepts and changes in design were adapted to suit the modeling capabilities of the individual, confining exploration within the limits of the chosen software. Serriano (2003) identifies similar behaviour among architects, comparing different designs made using one of three softwares. The software is found to have a significant effect on the result, defined by how tools are made availible in the graphical interface, creating a noticable slant in the manipulation of form.

Dorta, Pérez, & Lesage (2008) points to the difference between design ideation and design modeling, arguing that the current state of CAD is only suitable for the latter. Digital modeling provides efficiency for final detailing, accurate representation and documentation, but forces the designer to adapt to specific interfaces and workflows. The paper claims inability to support a nonlinear development process makes CAD unsuitabble for design ideation, commenting: “In the design process, computers have become, in fact, instruments of rhetoric left to represent anew already designed ideas.” (Dorta, Pérez, & Lesage, 2008, s. 123)

5.2 Materiality

The quality of furniture design has fluctuated over time with alternating periods of peak and decline. Periods of decline, such as the industrial revolution and the modern overproduction period, are associated with designers’ disengagement from material and materiality. This phenomenon is also observed to become more pronounced in the digital age. While complete digitalization is considered productive in many fields, it is problematic in furniture design, where materiality is an important

part of the end result. (Milincu & Feier, 2015)

Dorta, Pérez, & Lesage (2008) presents the ideation gap, a interruption of workflow when working with digital design. The lack of a proper haptic feedback creating problems in the dialog with the computer. Evans, Wallace, Cheshire, & Sener (2005) evaluated in their paper the possible use of a haptic feedback system with CAD-modeling, attempting to introduce materiality to the digital modeling process. However, they found that existing technologies did not perform sufficiently, meaning they would not be able to replace the functionality of physical prototypes.

The use of physical prototypes are essential to the process of industrial product design. Several case studies into new adaptations of CAD-modeling show that the materiality of physical prototypes have yet to be recreated digitally. Physical prototypes also remains unrivaled in speed of implementation, adjustability and real time verifying, allowing for early discovery of problems and better design flow. (Alcaide-Marzal, Diego-Mas, Asensio-Cuesta, & Piqueras-Fiszman, 2013; Dorta, Pérez, & Lesage, 2008; Evans, Wallace, Cheshire, & Sener, 2005; Yang & Epstein, 2005)

6. INTERVIEWS

3 Interviews were performed with groups of students who had utilized the prototype. The focus of the interview was not on the prototype itself, but rather the method of using it and how it affected their process.

6.1 Implementation

The construction of the prototype consisted of two large sidewalls, made of MDF, with several horizontal and vertical slots for adjustment. Metal rods were placed between the walls, positioned in the slots. These had nuts on each end that when tightened would lock the position. Plates placed onto the metal rods acted as the seat and back of the prototype. This allowed a large degree of adjustment in height, depth, and angle of both seat and back.

The prototype was made available for the previously mentioned students. After a couple of weeks, they were interviewed about their experience.

6.2 Execution

The interviews were performed as loosely structured conversations with four points of interest:

- How did they experience that the efficiency of the process was affected by the method?
- How did they experience that their workflow was affected by the method?
- How did they work with sketching, CAD and other designing methods in relation to the method?
- How did they experience that design validation and quality assurance was affected by the method?

6.3 Interview findings

All the groups interviewed reported a very positive experience with the provided tool and method. All three groups designed lounge chairs for their projects, but with significantly different design languages. Two of the groups had first gotten

measures from existing chairs with the desired sitting position and they used the tool for validation of the chosen dimensions as well as final adjustments. The last group collected some dimensions from average chars, but had a design that required testing to get the right height, width and angle for the back of the chair. They stated that the testing performed with the tool was critical for the project and had a very significant effect on the projects efficiency, as they did not have time to construct such a tool themselves within the time limit of their project. The other two groups suspected a moderate increase in efficiency.

The groups were unsure whether their workflow had been affected, but interestingly, all groups waited until after testing before moving the design into CAD. It was stated that they then only produced one 3D-model, having more or less finalized the design beforehand. Being able to define all important dimensions prior, resulted in more efficient modeling than they have experienced with previous projects.

Having the tool provided without having to construct in direct relation to the project was considered as very important. The ability to validate the design in the very early stages of the concept, while also reducing overall time usage was seen as the biggest contribution. One interviewee pointed out that such a validation is critical for quality in furniture design regardless of time usage.

7. DISCUSSION

In the digital age, it is important for designers to have a conscious relationship with different methods and the effect of how and when they are used. “Industry 4.0 is about to become reality. Examples of previous technological revolutions shows that the transition towards the smart factory will be a rapid, irreversible, disruptive and destructive process. In order for designers to have a chance of succeeding in the new environment it is necessary for them to develop a new set of skills, concentrated especially in the interface between environments (real and digital).” (Milincu & Feier, 2015, ss. 1796-1797)

Digital solutions and increased efficiency are critical in the modern profession of industrial product design. A complete digitalization does however not seem viable considering current research into materiality and CAD-software. Digital solutions are steadily being improved upon and seem to now become more relevant for ideation. Digital solutions are highly productive in the late stages of the design process, but the chosen software has an effect on the outcome. Different solutions are geared towards specific types of design creation. “If these built-in slants are ignored, embracing technology for its own sake could lead to an uncritical stance both on the behalf of the users as well as on the critical assessment of those designs.” (Serriano, 2003, s. 204)

In industrial product design, and perhaps particularly furniture design, physical prototypes appear to be essential. Several studies show results that favor the approach over the alternatives. However, results also show that for this to be the case, prototyping needs to be done with specific intent and simplicity tends to correlate with creation of quality.

The proposed method of prototyping sitting position takes into important principles presented in this paper, using physical prototyping when digital solutions are not appropriate and testing a very

specific aspect. Assuming an ergonomic prototype is made sufficiently adjustable, it could also be considered a tool rather than a project-specific prototype, usable for any future project as well. This was the experienced by the interviewees, who could test what they needed straight away. In avoiding delays or stagnation, flow is maintained in the project, further leading to a maintained productivity and efficiency.

8. CONCLUSION

For an industrial designer to work efficiently and produce quality, they need to be familiar with the methods and tools available to them. Different stages of the design process benefit differently from different approaches. In the current situation, analogue solutions are more flexible and thus more productive for ideation, while digital solutions are much more efficient for finalizing, representing and documenting. CAD-software is becoming more and more capable for ideation, but it is important to assess the slant of software and how it will affect the process.

Working with physical prototypes is essential for industrial product design and ergonomics, defining the main function of furniture design, needs to be tested properly in a design process. The proposed method shows great promise for productivity and efficiency, and a generalized tool able for reuse, potentially even more. It is however necessary to test this on a larger scale to see the extent of the effect, as interviews in this paper were performed on a low number of projects.

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