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USING MATERIAL EXPLORATION AND MODEL-MAKING AS AN APPROACH FOR THE DEVELOPMENT OF CONCEPTS IN DESIGN PROJECT COURSES

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ABSTRACT
One of the most used methodologies for project development in engineering consists of starting with a market necessity, developing a concept, materializing it, and designing details in order to enter the productive phase. These stages go in hand with the selection of materials, which is done at the end of the design process phase. However, in some cases selecting the material at the beginning of the process can be a source of innovation in product development. This paper describes a methodology used in "Project II", a first-year Product Design Engineering (PDE) course at Universidad EAFIT in which students initially select and explore non-conventional materials for furniture and then, through scaled models, develop concepts, culminating in a final product. This exploration helps students approach materials intuitively, develop their own creativity and boost their learning process of the creation and development of new product concepts.

Keywords: Material exploration, design methodology, rocking chairs, model making, design concepts

1 INTRODUCTION

The opportunity to explore materials and discover their potential is constantly evolving. An inquisitive and curious mind is needed to ensure that materials continue to push creative boundaries while still remaining functional [1].
Traditional materials can turn into a source of inspiration by transforming them and exploring their possibilities in the first stage of the design process [2]. PDE students take advantage of this method to develop projects in their first year.
The academic exercise this paper describes consists of developing a rocking chair by selecting a non-conventional material in the field of furniture and using it in an innovative manner to create a dynamic structure that can stand the weight of a person. Because the designers do not know beforehand the properties of the materials, selection is done initially in an intuitive way, relying on visual attributes and resistance. However, this experimental approach introduces the student to solving the problem of reconciling the selected material with the design exercise's requirements: the chair must be built with simple technologies, it must achieve a resistant and light structure, it should be ergonomic, and – thanks to the initial research on materials– a final prototype with a differentiating element should be possible. Starting with the material is an approach that shows great potential for today's furniture designers. When materials are removed from familiar applications and techniques and experimented on by different methods, exciting proposals can emerge and potential new markets identified [1].
Section 2 describes the methodology used in "Project II" courses to design a rocking chair from a chosen material, using scaled models to arrive at a final prototype. Section 3 describes a case study that illustrates this methodology with products developed by first-year PDE students as an example. Results are discussed in Section 4, while Section 5 presents the paper's conclusions.

2 METHODOLOGY

Ashby, Brechet, Cebon & Salvo [4] consider that the design process goes through various stages (market need, concept, embodiment, detail and production) and that necessary information on

materials and processes can be more general during the concept stage, and more detailed in the final one. In turn, Ashby [5] cites four methods of material selection: analysis, synthesis, similarity, and inspiration. This last method explains the way in which design materials are selected via inspiration and defines a design process which is different to the one initially described, as the material is a previously given element, opening up a large number of entry points to the design exercise.
In *Dutch Design meets Bamboo*, Pablo Van der Lugt [3] explains to us that: "learning more about bamboo was to us a true exploratory expedition as we didn't know the material at all, we always try to find something new and turn it into beautiful objects." In a project titled *Design Cork*, Ana Mestre [6] manages to incorporate cork as an innovative factor and starting point for the development of new products.
Figure 1 illustrates the methodology developed in the "Project II" course for first-year PDE students. In this course, students are asked to design a chair with movement (a rocking chair), using a material in an innovative way and in minimal quantities, in order to achieve high mechanical resistance and ergonomic characteristics.

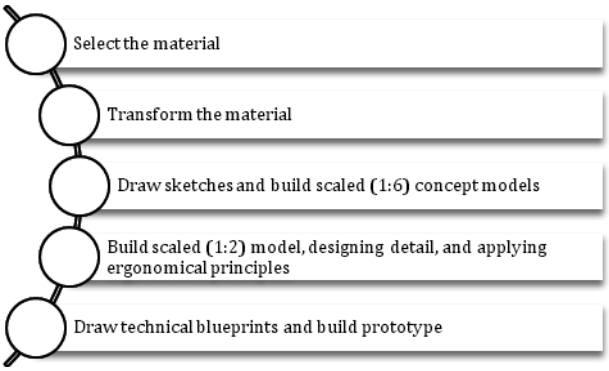

Figure 1. Rocking chair design methodology

The design process starts in stage 1 by searching for a material from other contexts and that is alien to furniture. The main reasons behind the student's choice are its visual and physical characteristics. Some of these materials are: coaxial cable, recycled tires, ribbed pillow foam, electric scythe cable, polyester ropes, polyethylene tubes, rubber soles, polyethylene foam used in floors, polyethylene mesh, EVA foam, Thera-Band®, MDF, cork, bamboo, and corrugated cardboard. These materials are classified (plastic, composite, metallic, or natural) and students determine their commercial dimensions and prices, and ways in which they can be used to create structures. This information is registered in a technical card.
Stage 2 consists of working the selected material and transforming it by using a *principle of design*, or action, on it: knitting, stitching, perforating, knotting, packing, and folding are some of these principles. They are presented to students via randomly-distributed creative cards that explain graphically and theoretically the concept. This class session is dedicated to exploration and creativity, thus permitting students to understand the nature of the material, manipulate it and propose a transformation that allows its use in a rocking chair in the upcoming stages. The material's appearance, assembly possibilities, and resistance are evaluated using a 200 x 300 mm sample.
Once every student has transformed the sample, they advance into the conceptual stage. During this stage, students draw three chair proposals that may use the selected material as a seat, back or both, and then build the necessary models in a 1:6 scale. Some authors such as Elvin Karana consider that, during this stage of the design process designers are more interested in the intangible characteristics of materials [7]. Sensory aspects turn into the reason for selection and allow the development of new concepts. David Bramston [1] explains that "materials need to be subjected to different attitudes, approaches and feelings. They need to be thrown into the unknown and allowed to survive, materials need to be held and understood, captivating and absorbing the imagination, before they are rejected or ignored".
These proposals are evaluated by teachers in the classroom using criteria such as innovation, the use of the material, structural resistance, and ease of production. The 1:6 scale model makes it possible to

visualize the chair's form, check if the design has implicit movement, and think about how the material will be used.
Stage 4 seeks that students be capable of clarifying (through renders and a 1:2 scale model) the characteristics and dimensions of the chair, its assembly methods, the type of structure and the rules of ergonomics that allow it to be comfortable. This scaled model is crucial to the development of the project because it brings the student face to face with deciding how he is going to build the piece of furniture and with defining final details. Product design engineers have used physical models to create, test and implement their academic ideas [8].
The student's models are evaluated using an acrylic model specifically built for this course. Called an *ergonomic test model*, it consists of two acrylic sheets, engraved with the ergonomic diagrams of a rocking chair and its minimum and maximum measurements. The diagrams correspond to the lateral and front view of the chair; the sheets can be put a 90° angle so that the scaled model can be inserted between them, as Figure 2 shows. This way, by comparing the student's model to the test model, corrections and adjustments can be done to the final prototype's measurements.

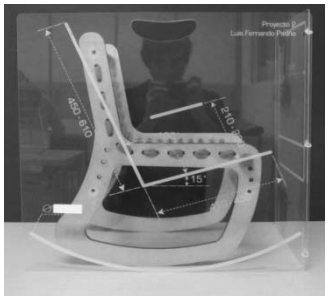

Figure 2. Ergonomic scaled (1:2) test model

Stage 5 consists of drawing the general and detailed blueprints once all corrections are made. Now, the student is ready to build the final prototype and decide aspects such as colour, adjustments in the assembly and measurement confirmation.
This method is designed so that the student can develop skills with each stage of the process: drawing, rendering, building and using creatively models in various scales, using the laws of ergonomics, and exploring materials that are conventional in other contexts, so that they can be used creatively in the production of a chair. This approach allows students to develop design concepts and materialize them in a product that can be used, to experiment, and to evaluate the possibilities of production of said concepts in a certain context.

3 CASE STUDY

This section describes one of the exercises developed during the second semester of 2011 by PDE students. In stage 1, students chose a foam used in orthopaedic pillows known as "contour pillows" and a conventional polyurethane foam which was chosen for its tactile qualities, its appearance and the comfort it offers when coupled with other products. At the same time, they did research on the general qualities of a similar material to polyurethane called Eurofoam deflammo FF. Through its subscription to the *Material Connexion* database, the University's materials library allows students to observe materials that call their attention because of their visual and tactile characteristics (see Figure 3).

Figure 3. Materials selected for the project

During stage 2, students worked at the University's design workshop and were assigned a creative card. These cards consist of an image of a product and a word or action that describes how the material was transformed to get to that product in the front, plus a definition using synonyms on the back. Students had to alter the material they had chosen, using the action in the assigned card. In this case, they sewed the polyurethane foam, as seen in Figure 4. The objective was that students found a way to develop a more resistant structure with a common material and showcase its possibilities.

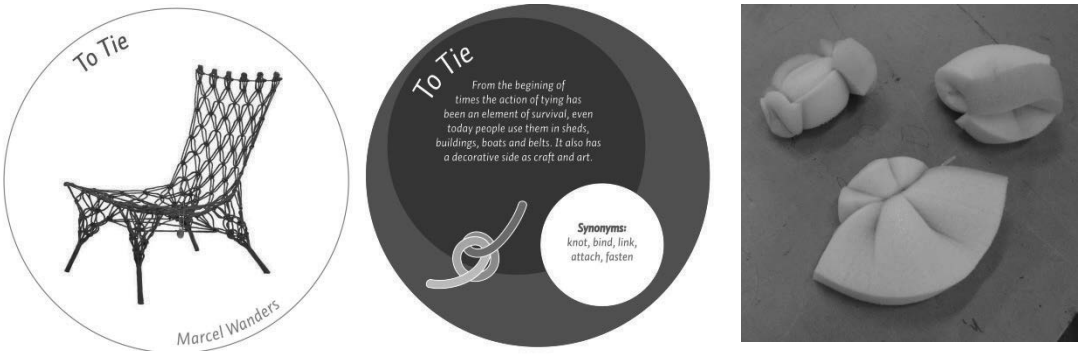

Figure 4. Material modified by a design principle and creative cards

The first sketches and the 1:6 models were presented during stage 3. Students drew the design concepts taking into account that the chairs should move and applying knowledge from another first-year course ("Conceptual Physics") in order to reach a safe and resistant structure. The evaluation of the group proposal was done weighting the degree of the chair's innovation –be it because of its shape or because of the material used–, the implicit movement in the design, and the comfort the material could generate. This class session is shown in Figure 5.

Figure 5. Group session and proposal evaluation

The stage in which the 1:2 scale model was built with the selected materials (stage 4) sought to put the students face to face with determining details in the chair's assembly, adjusting its dimensions, and defining its ergonomics. In this case, a tool called "*Ayudas*" (literally, aids), consisting of class presentations authored by the teacher, is used to explain the concepts of ergonomics to students. (This tool is published in an online platform called "*EAFIT Interactiva*"; see: *http://interactiva.eafit.edu.co/ei/contenido/listar.do?menu=S.*). These concepts are used later for the technical plans and building the 1:2 scale model, which is verified with the ergonomic test model. In the case of the foam chair, the test model's dimensions showed that the student had understood the "*Ayudas*" and applied the necessary angles for the chair to have ergonomic qualities. The model also showed required assembly types, chair proportions, and the process by which the final prototype could be built (see Figure 6).

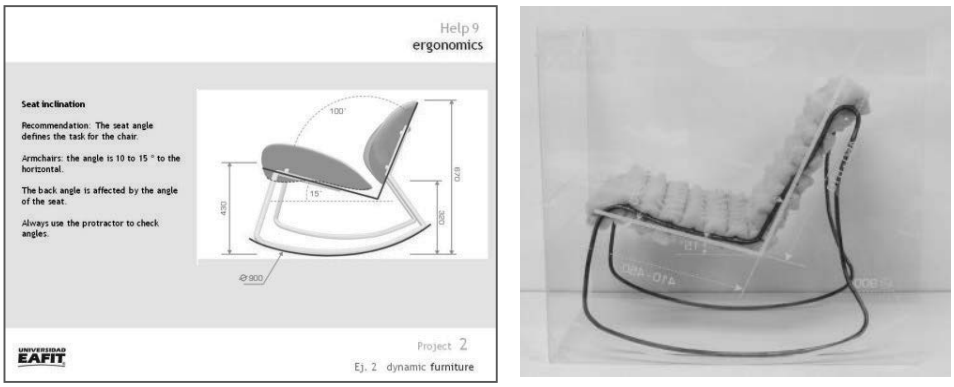

Figure 6. Ergonomics "Ayuda" and the ergonomic test model

In the final stage (5), the students built their prototype. Trials were then made with users in order to evaluate comfort, appearance, possibilities of mass production and their place in the market. This was done during an exposition at the end of the semester, in which the students' work was socialized with the rest of the University (see Figure 7).

Figure 7. Public presentation of the project and its results

4 RESULTS AND DISCUSSIONS

Through this exercise, first-year students developed the following abilities:

- They approached materials intuitively because they sensed, by similarity, that they could obtain ergonomic characteristics.
- The material's morphology was changed through sewing and was turned into a source of inspiration for designing and developing creatively a chair with a material from another context.
- The need to change the colour was one of the design requirements that called for experimentation with dyes that could be used in the final product and deliver the needed performance. In the case shown, the foam had to go through a washing process after dyeing in order to stabilize the colour.
- The preparation of scaled models that materialized ideas made the development and communication of concepts easier for students that had difficulty drawing in the first stage.

- The 1:2 scale model was an excellent tool to clarify the building of the final product, while ergonomics were verified with the ergonomic test model, which showed that the dimensions were correct.
- Building the prototype in a 1:1 scale allowed students to prove that the material did indeed work for the chair. People could sit in it, rock, test its comfort, express their aesthetic views about it, and consider if it could be a marketable product, among other variables. In this way, students faced the design process in every one of its stages and developed abilities for future projects based on self-criticism and feedback from other people.

5 CONCLUSIONS

This papers proposed a method for design concept development for first-year PDE students. It focuses on selecting materials in the first phase of design and developing the project until the end with the help of scaled models.

One of the methodology's most important aspects is that it makes it easier for designers to develop their skills in different areas: drawing, model-building, the use of the laws of ergonomics, physics, and knowledge of materials applied to a furniture project.

Overcoming an engineering student's difficulty of expressing ideas through drawing, coupled with building models, helps students develop their design concepts in a way in which a tangible result can also be produced. Chairs are a product that commonly requires drawing abilities and skills that are not inherent to PDE novices. This methodology can increase these abilities and skills and relate them to models.

The results registered in this paper can be a source of inspiration for demonstrating that students can have good results in a design process through the use of creative tools that help them in their learning process. It all depends upon how students are stimulated and how the information necessary to develop a project is shown to them. Designing by starting with the material can turn into a strategy to develop design concepts.

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