The Glass Chair

Competence Building for Innovation

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http://in3.dem.ist.utl.pt/glasschair/

This paper tells the strange tale of a glass chair. Creating a glass chair might seem a perverse – maybe impossible – enterprise. After all, chairs are normally held together by moment connections, such as those joining the legs to the seat. Glass is a notoriously bad material for forming moment connections; it is brittle, and quickly snaps if you subject it to bending. But there are advantages to such startling formulations of design problems. They force you to challenge conventional wisdom, to ignore standard prototypes, and to ask interesting new questions. How might you design a chair without moment connections? How might you do so without making the result impossibly heavy? How would you built it? And what interesting qualities might such a chair have? These were questions investigated in the design project pursued jointly by students at an American and a Portuguese school, in collaboration with glass and molding fabricators. The students explored many possibilities, and in doing so learned a great deal about chairs and about the properties and potentials of glass. The final project is a particularly elegant outcome of their investigations. It is created from just two curved pieces of glass, which held together by metal tie-rods. In the end, the finished glass chair looked just like the initial computer visualizations.

***Keywords**: Design education: remote collaboration; glass; innovation.*

Introduction

The project described in this paper refers to a collaborative teaching experience undertaken by two universities and two factories aimed at designing and making a glass chair using state-of-art design, production, and communication technologies. The goal of the project was to show how technologies can be used both as a medium for creation and as a mediator between professional experts. The project evolved within the context of the MIT Design Studio of the Future (DSOF), which is an interdisciplinary effort that focuses on geographically distributed electronic design and work group collaboration (http://loohooloo .mit.edu/people/WJM/DSOF.htm). Since the first project addressed the design of new houses to replace the structures without historical value in the Kat Hing Wai walled village in Hong Kong, (Wójtowicz 1995) several other collaborative projects have been carried out (Yee et al 1998), more recent projects have addressed the design of housing for teleworkers in an old section of Lisbon (Duarte et al 1999), the use of shape grammars for generating Siza's Malagueira houses (Duarte in prep.), and the use of grammar interpreters for designing new housing (Celani 2001), to name just a few of the DSOF projects. The current project was the first to involve participants from the industry, and to provide the students with a design problem in a “real-world” context.

Problem

The problem given to students was to design a glass chair within the production constraints imposed by the technology available at two given factories. Why a chair? As George Nelson points out: “every truly original idea – every innovation in design, every new application of materials, every technical invention for furniture – seems to find its most important expression in a chair” (1953). Moreover, “the chair offers a glimpse into our collective ideas about status and honor, comfort and order, beauty and efficiency, discipline and relaxation” (Cranz, 1998). A chair is a symbol of modern western civilization; as life becomes more sedentary, we spend more time sitting on chairs than standing still or walking. A chair is a symbol of authority; at meetings we defer to the chairperson, academics hold chairs, and kings sit on thrones. Chairs have evolved throughout the centuries, and their function and design are usually linked to social habits and constraints. The invention of new materials and the discovery of new properties have long played an important role in stimulating the creativity of chair design, which can be considered an interplay between the importance of function and aesthetics. Regardless of whether the preference in approach has been weighted towards utility or aesthetics, the primary object of chair design remains the same—making connections. (Calado 2001)

But why glass? Glass is a notoriously bad material for forming moment connections such as those usually required to join a chair’s legs to the seat. Glass is both an appealing cool material and an aggressive one. It can break into a million fragments, all ready to wound and hurt. Glass is unique: fragile and yet strong. It is not the first time that glass has been used as a material for chair design. Jacques André and Jean Prouvé designed a glass garden chair in 1937 in Paris. More recently, the Italian glass manufacturer FIAM presented two glass chairs.

In summary, the creation of a glass chair represented a challenge to conventional wisdom. It also represented an opportunity for creating a bridge between architecture and engineering students, thereby testing the idea of creating distributed, multi-disciplinary teams for approaching complex design problems.

Participants

Two schools and two fabricators participated in the project. The Massachusetts Institute of Technology school of architecture (MIT), USA, contributed adventurous design thinking, and skill in use curved-surface modeling and visualization software to represent possible designs. The *Instituto Superior Tecnico* school of engineering (IST), Portugal, brought their own design sensibilities to the task, made useful practical suggestions, and provided essential expertise in the technical properties of glass and in the finite-element analysis of glass structures. Agiltec—a molding factory—and Infusão—a glass factory, both located in Portugal, were active participants throughout, and contributed their special knowledge of glass fabrication equipment and process, particularly the limits of these processes.

At MIT, graduate students in architecture were organized into two teams of three members each. They were in charge of designing the chair and they were told that only one design could be produced due to budget constraints. Their designs would be assessed from several viewpoints, including aesthetic and ergonomic, but particularly the manufacturing and economic ones, and the fittest would be produced. This put pressure on them to work within the manufacturing limitations. At IST, fifth year students enrolled in professional civil and mechanical engineering programs formed a single team of three students. This team had to analyze the MIT designs in terms of structural stability, to comment on their manufacturing feasibility, and to mediate the dialogue with the fabricators. For instance, they would discuss the design proposals with the fabricators, and transmit their feedback to the design teams.

Communication tools

The remote collaborative process encompassed presentation sessions involving all the participants and informal working sessions among team members. The project included presentation sessions at the outset, in the middle, and one at the end. The primary form of communication in these sessions was PictureTel—a videoconference system that included room and document cameras, computers and a VCR. The working sessions were booked at the pace and convenience of design teams. The forms of communication in these sessions included Netmeeting—a web-based videoconference application with camera, voice, chat, whiteboard, and application sharing features—and e-mail. Due to budgetary constraints, PictureTel was used only occasionally. With Netmeeting, image and voice did not work very well due to the quality of transmission on the Web. This caused students to use a combination of whiteboard and chat. E-mails were used extensively for summing up the results of the working session and for asynchronous communication when teams had difficulty booking synchronous sessions, due to the time lag or schedule conflicts.

Design tools

Various design tools were used for drawing, modeling, and rapid prototyping. In addition to common hand-drawing tools such as paper and pencil, students used the Netmeeting whiteboard for conceptual sketching during videoconferences. They also used Autocad 2000 for accurate 2D and 3D modeling, 3D Studio for producing photo-realistic images, Rhino for modeling complex free forms, and SAP2000 for structural analysis. In addition, they utilized a three-dimensional printer (FDM by Stratasys) for making small-scale physical models when they needed to gain a better understanding of shape of their designs, and a laser-cutter (X-Class by Universal) for producing full-scale models when they needed to test its ergonomics.

Production techniques

The final design is composed of metal and glass parts. A 5-axis milling machine was used for producing the aluminum feet from the CAD model. The production of the glass parts required first to produce the moulds and then to slump the glass. The moulds were produced using metal forming techniques, namely bending by pressworking. The slumped glass process consists of melting a sheet of flat glass onto a mould, inside a high temperature oven. Through gravity, the melted glass acquires the form of the mould and then hardens during the cooling process. This process presents several limitations. (Bento et al 2001) First, there are limitations set by the size of the available oven. Second, there are limitations in the radius and angle of the deformations. Some deformations that cannot be obtained by gravity can be achieved with the use of mechanical arms that push the glass while melting, but there are many technical difficulties in using such a mechanism in high temperatures. Third, the melting temperature of the mould's material must be higher than that of the glass, which reduces the range of possible materials. A steel mould needs to be shaped against another mould, but manufacturing two moulds increases the cost. The students had to consider such limitations in the design of their chairs.

Design process

Both design teams followed similar processes to develop different designs. Due to space limitations, we only describe the design process of the manufactured chair. The students started by considering different materials and production techniques. Their initial idea was the design of a non-standard piece of furniture: a bench that could sit against a curved wall and would be custom-made to fit (Fig. 1-1). They thought of producing this bench by extruding a seat profile along a flat curve but later found out that extrusion applies only to straight pieces. Then, they thought of forming sheets of plastic materials like metal against a mould, or molding some melted material like plastic or glass against the same mould (2).

At this point, they were asked to consider the available glass technology and had to change the design to avoid manufacturing problems. They proposed a kernel idea consisting in a single-piece curved glass chair obtained from a flat sheet, supported at the front and rear ends (3) and they considered two designs: a side chair and a beach chair (4). The structural analysis of these designs revealed that high tension would develop, mostly in the seating area (5). Interpretation of this result concluded that excess bending stresses were due to direct loading over the seating area reinforced by the displacement of the feet in opposite directions. Structural analysis also showed that it was better to avoid cuts and narrow strips.

The following proposals consisted in a simple rectangular sheet of glass melted into a curved shape. The side chair required a special mechanism to push the glass inwards while melting (6), but the beach chair was much simpler to produce. Nevertheless, its shape was not self-supporting. They considered corrugating the surface to add resistance (7), but abandoned the idea because it was not comfortable. It also had a big tendency to open up, which was solved with the use of tie-rods (8). Structural analysis revealed that the metal ties absorbed the forces that pulled each end out, but that the stress in the sitting area was still a problem (9).

Then they realized that glass works better when subjected to compression, and used this principle to develop the final design. First, they considered supporting the torsion forces in the sitting area by using vertical, flat pieces of glass to absorb the weight of the person and to transfer it to the ground. They proposed a solution that had a glass part under the seating area (10) and a side-supported solution that required the water-jet cutting of two side plates following the chair's profile (11). Structural analyses showed that both designs worked, but they rejected them based on aesthetics considerations. Finally, a counter curved sheet of glass was placed under the chair, carrying the weight to both ends of the top shell, where they were neutralized by the tie-rods (12). The analysis of this solution revealed that it was satisfactory from all points of view: aesthetical, structural and, above all, fabrication.

Production process

The chairs were fabricated from 12mm-thick flat laminated sheets of glass, which were used both for the upper shell and the bottom, supporting arch. The double curve of the upper shell required a two-phase heating process, and two moulds were produced and used (Fig. 2-1 through 4), while the single curvature of the bottom arch only needed a one-step heating phase to produce a single mould. Final assembling of the upper shell and the bottom arch was achieved with the aluminum feet positioned with tie-rods, thereby obtaining the final chair (5 and 6).

Conclusion

This paper reports a collaborative teaching experiment by two universities and two factories with the goal of designing and making a glass chair using state-of-art design, production, and communication technologies to show how they can foster innovation in design. Results and an interview with the students showed that "the possibility of making

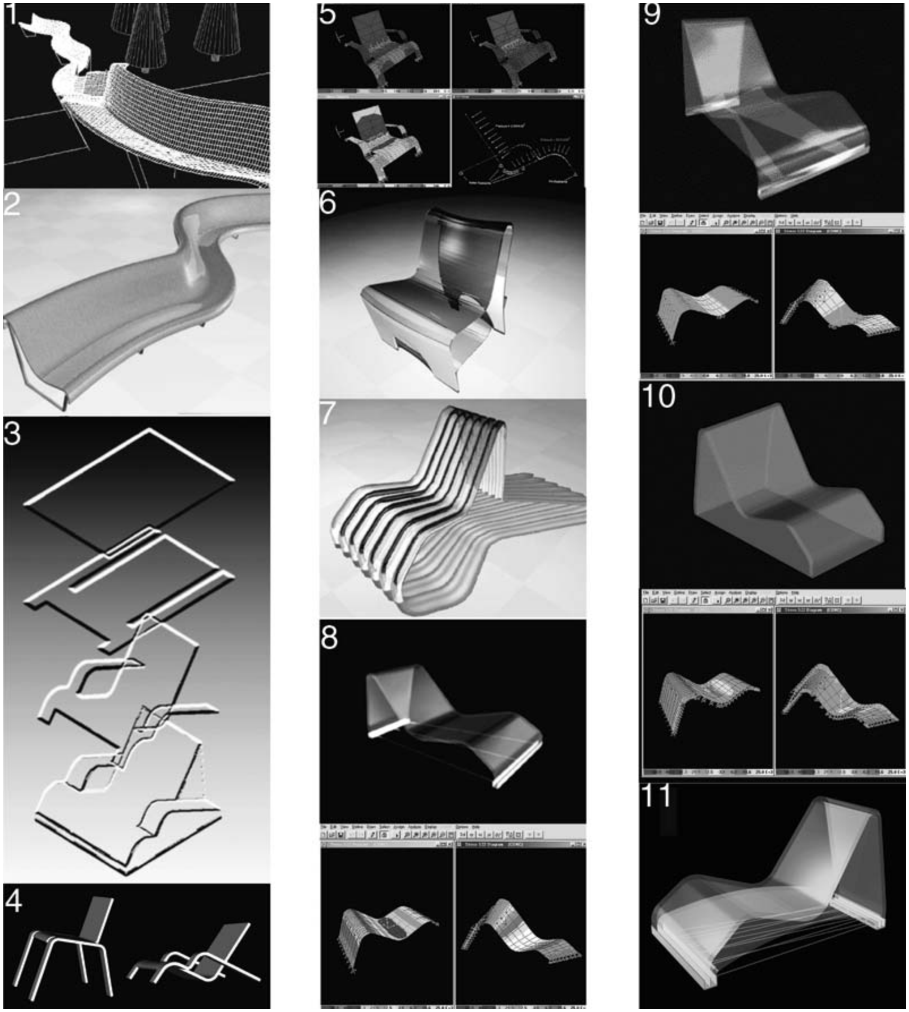

Figure 1. The evolution of the manufactured chair design. (Please, refer to the text.)

quick sketches on line while talking or writing to our overseas team was very important for the development of the basic design and structural concepts." They realized that some ideas were very hard to transmit by verbal descriptions only and a graphic tool was very important in the process. Results also revealed some language constraints: "even though the Portuguese team was fluent in English, some concepts were hard to explain in a non-native language." However, students admitted that the "long path followed to reach the final product allowed them to learn about many different materials and production techniques by exploring all the different possibilities for creating an unusual shape." They

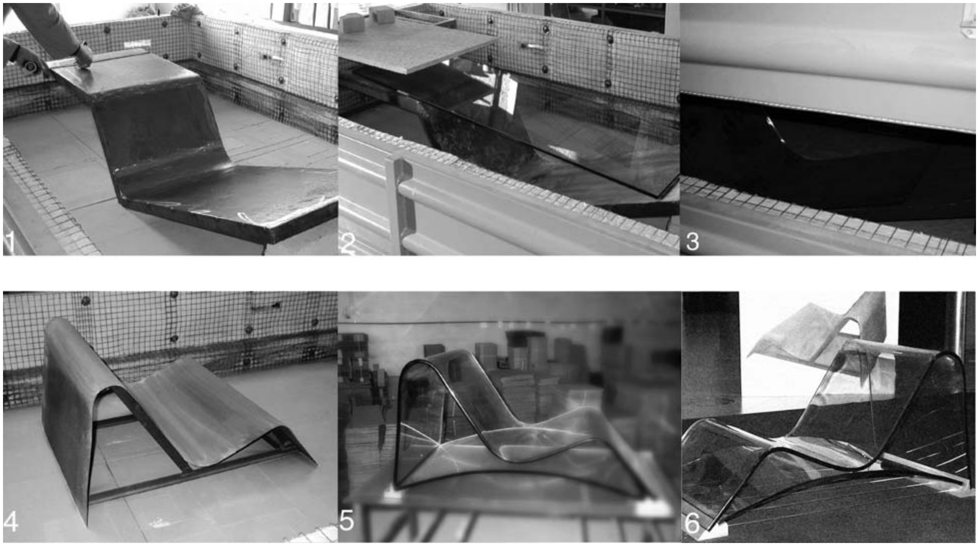

Figure 2. The manufacturing process. (Please, refer to the text.)

also mentioned that "the interaction with teams in different locations made the experience even more interesting, by showing that different techniques can be used for achieving similar results." The final design is the result of aesthetic and functional requirements, as much as the result of production and structural limitations. It is a triumph for communication across borders between disciplines and cultures. It is less important whether the final object is economically viable, or even comfortable. More important is that an innovative idea has been turned into a reality – a palpable object, good to sit on.

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