
Jeng-Neng Fan • Daniel Schodek

Personalized Furniture within the Condition of Mass Production

Received: date / Accepted: date

Abstract Manufacturers producing ready-to-assembly furniture are experiencing an increasing demand from customers, who expect products to be individual and unique. Transformable Furniture, a new type of ready-to-assembly furniture, is made of carbon fiber reinforced shape memory polymer (SMP) composite panels to provide the consumer a new way of instant customization for fabricating one-off furniture with curved surfaces in their home environment. It offers users the cost-free customizability to obtain non-serial artifact under the condition of mass production and enables the efficiency of compactness in transportation. The standard SMP composite modules provide almost endless variations determined by the user's creative assembly

Keywords, Personalization · Shape Memory Polymer · Flat Packed Furniture · Customization

1 Introduction

Current manufacturing industry is undergoing a major paradigm shift that is taking traditional manufacturing of standard products into a world of product variety. Most of the manufactured products, with many replications, are still standardized and owned by thousands of us, although product variation is becoming a dominant trend in every industry now. On the other hand, for manufacturers like IKEA, ready-to-assembly furniture exhibits complexity in terms of the characteristics of this particular product. First of all, manufacturers typically maintain broad product offerings with a consequent large and diverse part population. Secondly, the fashion nature of furniture sales creates pressure to introduce frequently new product offerings and redesigns. Lastly, there are considerable competitive pressures to reduce lead-times to help ensure rapid delivery to the customers.

Jeng-Neng Fan
Department of Industrial Design, National Taiwan University of Science and Technology
Tel: +886-2-27376302
Fax: +886-2-27376303
E-mail: rcamagica@gmail.com

Daniel Schodek
Graduate School of Design, Harvard University
Tel: +1-617-4955453
Fax: +1-617-4958949
E-mail: dschodek@gsd.harvard.edu

Over the past few years, many efforts have been made in the industrial design practice to explore the possibility of different types of furniture variations. Within the condition of mass production, the one-off furniture is still problematic and unaffordable to the public. Since furniture has to be mass-produced, the end result of variation inevitably leads to replications that make the nature of uniqueness disappear. The idea of mass producing one-off or limited edition furniture, entirely using CNC or RP technology, has been realized by many designers. It allows us somehow to mimic the craft quality and create the non-serial artifact. However, adopting CNC technology or rapid prototyping to produce one-off furniture is not feasible. Considering the condition of high speed production, it is not economical in terms of its time and cost for mass producing large volumes.

We argue that, with user's participation and creative assembly, the transformable furniture can generate the one-off furniture with single curved surfaces without the maintenance of broad product offerings. In order to lower the large and diverse part population and enable the provision of non-serial product within the condition of mass production in ready-to-assembly furniture, transformable standard shape memory polymer composite modules can be the key to furniture with single curved surfaces for fabricating the one-off artifact.

2 Related works in furniture variations and Shape Memory Polymer

In furniture industry, the modular design approach enables product variety by mass-produced standard modules. Most storage and office furniture product group are based on system concepts, a dimensional system and a unit assembly approach that permits modular grouping [1]. Gaetano Pesce challenges standardization and inserts randomness into the industrial process to produce unique furniture [2]. Furniture manufacturer, like Herman Miller, has employed 3-D visual design software to facilitate the customization of furniture. [3]. It allows products to be tailored for individuals on a one-to-one basis and gives customers the opportunity to design furniture which conforms to their personal requirements and tastes. Bookworm designed by Ron Arad [4] leaves the configuration of a standard product to the end user and beneficially reduces the complexity of diverse part population. By offering reconfigurable choices, consumers can make design decisions normally made by designers.

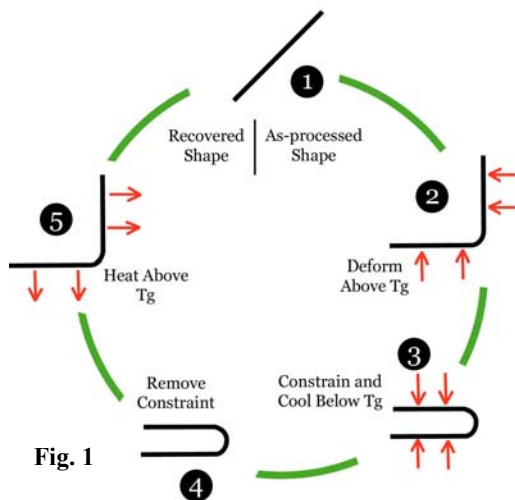


Fig. 1

Shape memory polymer (SMP) can be reshaped or returned quickly to its memorized shape and subsequently cooled into a rigid plastic. Below glass transition temperature (T_g), 45 degrees C, SMP is in solid state. While above T_g , SMP is in rubber state and very easy to be bent. The shape recovery thermo-mechanical cycle of SMP consists of 5 steps as shown in the figure 1. A significant drawback of unreinforced shape memory polymers for structural applications is their relatively low strength and stiffness. Liang et al. [5] have proposed a solution to the stiffness and strength problem by introducing shape memory polymer composites, whereby continuous or discontinuous reinforcements are dispersed throughout a polymer matrix. Composite Technology Development (CTD) explores the potential of Elastic Memory Composites in the application of deployable hinge [6]. It mainly focuses on its recovery behavior of SMP composite while bending with certain radius.

3 Approach

In this paper, smart materials in the form of shape memory polymers implemented by composite material technology has been proposed to pursue the uniqueness of mass-produced furniture with single curved surfaces. This type of tailorable furniture is flat packed and very efficient in transportation (Figure 2). Depending on the user condition and preference, the consumer can transform/bend the heated SMP composite panels (at 45 degrees C) to the desired curved shape and joint panels together by aluminum connectors. The user can easily transform a rigid flat sheet panel to a single curved surface with undercut feature without the assistance of any extra tool. The standard panels provide almost endless variations determined by the user's creative assembly. If the user needs to re-tailor the furniture, he can "reset" the furniture to its original flat sheet form and reshape the panel to desired shape again by repeating the same process. Thus, owning one-off furniture within the condition of mass production can be realized by the marriage

of SMP composite technology and the random quality of human operation.



Fig. 2

4 Implementation

The standard transformable SMP composite module is a sandwich panel using plain type woven fiberglass reinforced SMP laminate as facing and solid SMP as core. KaptonTM flexible heater coated with thermochromic materials is bonded on the panel and used for heating up the panel above T_g . Panels with panel joint at the edge can be jointed together by aluminum connectors. Figure 3 shows the cross section of the panel and Figure 4 shows how the panels are jointed together.

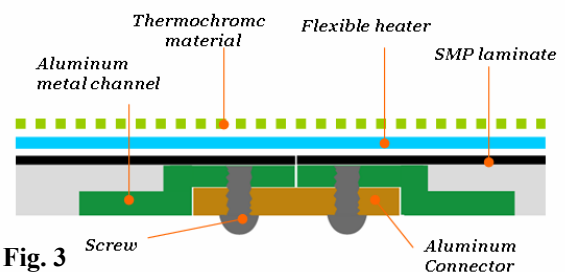


Fig. 3

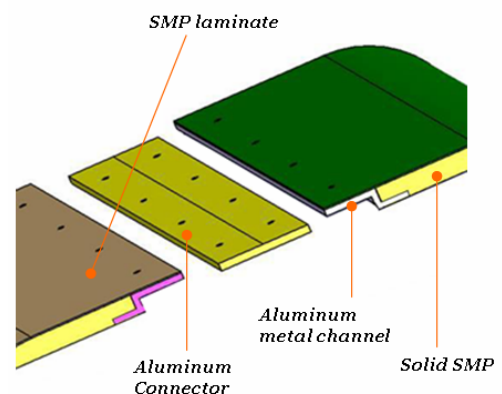


Fig. 4

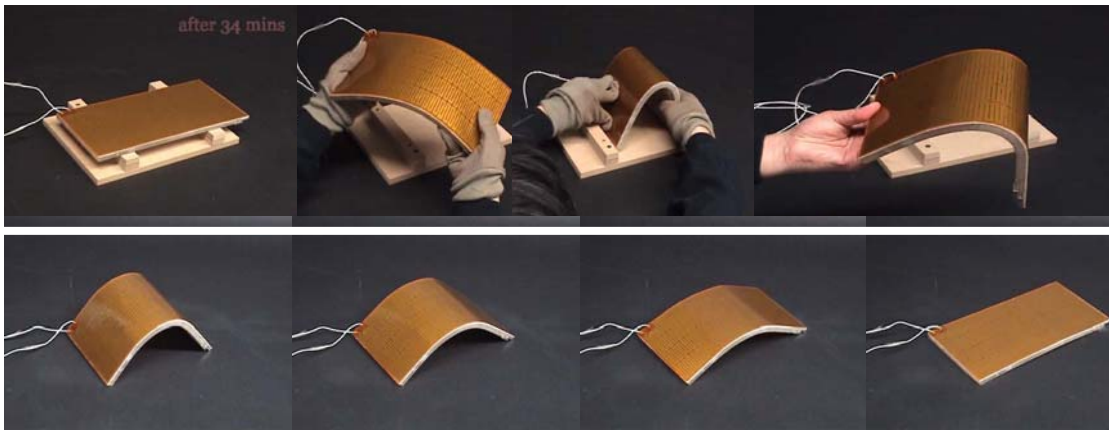


Fig. 5

4.1 The Sandwich Concept

The transformable SMP panels for customizable ready-to-assembly furniture adopt the concept of sandwich panel to obtain a large bending stiffness without sacrificing its feasibility in bending. When a SMP laminate with excessive thickness is bent around a mandrel with small radius, the out of plane buckling will expect to occur on the compression side of a bent SMP composite laminate. The strategy of using a sandwich structure can partially avoid the problem. By placing the SMP composite laminate in the face from the neutral axis, a large bending stiffness can be obtained without significantly increasing the thickness of SMP composite laminate.

4.2 Reinforcement for SMP Laminate Facing

The plain weave type S-glass woven fabric is chosen based on the desired function, strength, stiffness, and cost. Because the weave is stable and has reasonable porosity, it is usually left moderately open so matrix resin penetration and air removal are good. Experiments (Gall et al., 2000) have shown that utilizing the plain weave fiber architecture improves the bending performance of SMP laminates, and severe subsequent damage at low bend ratio (the ratio of bend radius to laminate thickness) can be avoided. Its value can be as low as 20. The plain weave provides more dispersed equivalent sites for buckling rather than a few highly favorable buckling sites that occur in the other types of weave.

4.3 Heating System and visual alert

A critical aspect of the successful design of a SMP sandwich panel is an efficient system for heating the structure above T_g during the thermo- mechanical cycle of SMP sandwich panel. For heating method, etched foil flexible heaters in resistive heating system offer the most versatile heating solution and are found in a diverse range of applications. With the characteristic of low thermal mass leading to fast response in both heating and cool down, the etched foil heater encapsulated with Kapton film is the ideal element for heating. It is surface-mounted on the facing of SMP sandwich panel. Since there is no spare space in the sandwich panel for installing sensor components and electric circuit board, the visual alert informing user the proper moment to bend will be more feasible and promising.

The thermochromic material with color changing property can be coated on the flexible heater and acts as a signal to inform the user to bend the sandwich panel. It eliminates the need for installing temperature sensor and electric circuit board in the heating system.

5 Performance of Prototype

A portion of the prototype as a proof of concept was made with the selected material and through the proper manufacturing process. The intention of prototype building was to test and prove the feasibility in user bending. Prototype was plugged into 120V AC for roughly 30 minutes until the temperature of the panel reached above its T_g . The panel was bent by hand without the help of mandrel. It was hold by a wood-made steady until the temperature of the panel was below T_g . Experiments (Figure 5) show that the prototype can perform satisfactory thermo-mechanical cycles without visible out of plane buckling, if the bend ratio larger than 35.

However, there is an issue needs to point out. Ideally, the heat-up and cool-down time has to be short. Unlike using convection oven to heat up the sandwich panel, it takes approximately 30-34 minutes to heat up the SMP panel at room temperature and 4 to 5 minutes to cool down the SMP panel in the performing test. From the user point of view, both of them are too long for the user operation. Longer cool-down time also means that users have to spend more time and hold themselves a still position to fix the shape of SMP panel. Although the ramp-up time of flexible heater can be shortened by adding more power to heater, it does not shorten the heat-up time for the panel reaching above its T_g significantly. Both of the problems are subject to the thermal conductivity and thermal contact conductance of SMP panel. A strategy has to be made to deal with this issue in future study.

6 Conclusion

It is concluded that the open-ended user customization of ready-to-assembly furniture can be technically achieved by adopting the use of SMP laminate/ SMP core sandwich panels. Compared with ready-to-assembly furniture, this type of standard sandwich panel allows a much greater range of furniture form, due to the flexibility and shape changing

properties of shape memory polymer. The fiber reinforced sandwich panel improves the stiffness of shape memory polymer and its resistance against load. Consumers are free to immediately customize and assemble the furniture according to their personal preference. This research gives the user the tools to create their own objects and discard the notion of design as a way of addressing specific preferences and instead. Therefore, a unique object can be personalized without extra cost within the circumstance of mass production.

References

1. Pile, J. F., Furniture: Modern + Postmodern: Design + Technology, Wiley, New York (1990).
2. Bartolucci, Marisa, Gaetano Pesce, Chronicle Books, San Francisco (2003).
3. <http://www2.hermanmiller.com/zaxispromo/>
4. Collings, Matthew, Ron Arad talks to Matthew Collings, Phaidon, London (2004).
5. Liang, C., C. A. Rogers, et al.. "Investigation of Shape Memory Polymers and Their Hybrid Composites." Journal of Intelligent Material Systems and Structures 8(4): 380-386 (1997).
6. Campbell, D. and A. Maji, "Deployment Precision and Mechanics of Elastic Memory Composites". Proceeding of 44th Structures, Structural Dynamics, and Materials Conference, Norfolk, Virginia (2003).