INNOVATIONS IN SITTING DESIGN WITH A USE OF CNC TECHNOLOGY

Milan Šimek, Jiří Tauber, Václav Šprdlík

Department of Furniture, Design and Habitation, Faculty of Forestry and Wood Technology, Mendel University in Brno, Czech Republic

Key words
Chair design, CNC Technology, Flat pack, Nesting, Experimental construction.

Abstract
The main goal of this study is to prove and demonstrate two experimental chair constructions together with its manufacturing. Both flat pack chairs are designed to be manufactured on CNC machines with nesting processing. Used material for this experimental sitting is plywood, which allowed us to test new joint designs. Especially flexibility of the plywood was the main factor for its usage. First presented design is fabricated with laser CNC and the second one with classic CNC router. The results of this contribution are two shown chair prototypes, functional and esthetic, meeting ergonomic and safety demands.

1. INTRODUCTION

CNC routers are widely used nowadays in wood machining processes e.g. furniture manufacturing. These machines are numerically controlled with ability to perform numerous operations. They are usually equipped with automatically changing toolbox therefore they can work without assistance. CNC routers could be found in all woodworking companies, form small to large plants. Great advance is versatility and universality of these machines. (Marek and Blecha, 2010)

Laser beam machining of wood technology belongs to unconventional methods used to machine wood and composite wooden materials. When cutting wood with laser, chemical degradation occurs. „It results from influence of high temperature and inhomogeneity of material composition. Some phases of material show chemical changes. After cutting the edges are straight and surface is smooth but covered by a layer of residual carbon dust.“ (Maňáková, 2000) Singed cut areas can increase esthetics of every machined part to a certain extent, if the natural appearance of material remains in existence after surface finish. On top of that, the singed areas provide some level of wood preservation.

When using classic tools or laser to machine wood, it is important to take into account some factors which can influence the cut quality. These factors include density, thickness, humidity and a type of material, but also a type of glue used when producing wooden composite materials. (Marek and Účeň, 2010) The higher the thickness and humidity are, the lower the cutting speed is, which results in deeper carbonization of machined areas. Due to this fact, it is fit to machine wooden material not thicker than 50 mm. (Barcal 1989) The cutting speed is influenced by the density of wood too. Compared to wood with low density (pine, poplar), the speed of cutting high density wood (oak, walnut) reaches lower values.

Milan et al. (2015). “Innovations in sitting design with a use of CNC technology”
Laser cutting technology used to mill wood and wood based composites does not produce sawdust, the cut is thin and precise. Using more-axis CNC machining centers increases machining productivity and enables cutting in different directions and under different angles. On top of that, it is possible to start and stop the cut anytime, the cut is smooth and sharp angles can be produced. (Chryssoulouris, 2013)

2. DESIGN OF THE CHAIRS

Manta chair
The goal was to produce a chair using a joint which is rigid and stable enough when the final product is completed. Functionality, esthetics and simplicity were considered as well. It was decided to create a knock-down joint which can be used to fold the furniture without glue or other joining parts (metal fitting), and easily disassemble it back. There was also another demand. The final joint should not have any visible apertures after inserting and securing all parts, i.e. it should look compact and undivided. A working model was made from paper and paper cardboard. However such a model is suitable for checking tightness and composition of the joint only. To verify the toughness, load capacity, the joint was manufactured from oriented strand board as well as working model. Final visualization if shown in Figure 1.

![Figure 1. Visualization of Manta armchair](image)

The above mentioned joint is the basic component used when designing a folding armchair. To bring attractive design and prevent accidental dismantling it is necessary to unify all components. Ergonomic knowledge was taken into account when the real design was prepared. The aim was to meet all requirements for comfortable sitting. Since the product includes springy parts it was necessary to adjust basic parameters to prevent situation which causes discomfort when using the armchair (e.g. unwanted reclining causing increased stress on muscular and skeletal system).
Performe chair

In the beginning of this study was an idea of bending plywood and use it to design of a chair. Bending is performed on the rigid plywood plate thanks to a specific pattern of perforations. Demand from our side was to design more elegant chair than common flat pack chairs and to achieve the smallest possible number of parts. As a base material 10mm thick beech plywood plate was chosen. Our challenge was also not to use glue or other metal fittings.

The design was based on bending detail. The goal was to join seat, back and legs into one piece. Various shapes, intervals and patterns of perforations were tested to achieve most flexible and tough enough part where plywood could be bend for almost 90° without damage. Two patterns were chosen as a best for a chair design. First one is with open ends, second one has every 2 perforations connected together on the end. Both are depicted in the Figure 2. Crucial parameters for bending were width of the perforation and length and distribution of the bridge between each perforation.

![Figure 2. Open and closed ends of perforation samples](image)

Main part of the chair is designed as one piece of plywood, 4 other parts secure the structure. Perforations are located between seat and back and between seat and legs. It was decided to use dovetail joints to assemble whole chair. They are located in the front and on the back part. Two remaining parts are supporting the back in the right position. Dovetail joints are placed only in flat parts of the shape, in bend part there is no joint. In Figure 3 disassembled chair is shown. This distribution was also used during the manufacturing process in order to save material.

Milan et al. (2015). “Innovations in sitting design with a use of CNC technology”
3. DEVELOPMENT

Manta chair
Development of the armchair resulted in two models. To make the final product as simple as possible, only one construction joint was applied to the second model. In both cases the armchair is composed of two legs, two aprons, two armrests, one backrest part, one seat part and dowels. To provide a potential customer with product variability several versions of the seat and the back were prepared. The customer can choose a component which suits his/her preferences, taste, mood and esthetic feelings the best.

Performe chair
Manufacturing of perforations and dovetail joints on regular CNC router is not easy. For both details a parametric program was designed. Paths for the tool were generated according to defined parameter of a shape. During the perforation development various design were tested on one detail samples to achieve the best properties. Dovetail joins are very complex and require precise manufacturing and they are highly dependent on flat surfaces that fit together. Quality of plywood and setting of final milling process are most important issues in achieving best possible result.

Testing of dovetail joint was performed in study of Šimek et al. (2013) and therefore wasn’t needed. Combination of dovetail joints and perforations give great mechanical parameters to the construction. As mentioned before, distribution on the plane was designed as economic as possible. At the end parts for 2 chairs were fitted on one plywood plane - dimensions 2500x1250mm.
4. MANUFACTURING AND ASSEMBLY PROCESS

Manta chair
Lower and upper part of the aperture is cut off under a certain angle to secure that the basic part fits in as good as possible after it is inserted. In the upper part of the apron there is a carved joint. The third part of the puzzle fits in this joint. The seat and the back consist of the third part of the final construction joint. In the edge part of this third component there is a T-shaped aperture. Vertical cuts are straight, horizontal cuts are skewed to fit in the apron part properly. It is very fast and easy to fold and dismantle the whole joint. The part of the joint with the T-shaped aperture is taken and the apron component is inserted into its upper vertical part. Afterwards both joined parts are slipped into the basic part and turned slightly (resp. a free area of the third part). Both parts are tightened and after they fit in indent sites of the part in the shape of a disrupted logarithmic spiral the whole structure of the final construction joint is finished. It is necessary to secure free areas from accidental dismantling when using this type of joint to make an armchair. In Figure 4 the variation of Manta armchair is shown.

![Figure 4. Assembled variant of Manta armchair](image)

Performe chair
Before manufacturing itself it was necessary to create model and program for CNC router. Development of construction was done in DXF file in TurboCAD and BricsCAD and connected with OptimCabinetV2. For CNC machine SCM program was translated using TaskCAD and for CNC Homag WoodWOP DXF import was used. Simulations were done by AlphaCAM. Manufacturing was performed on 5-axis CNC router Homag Venture. Problems occurred during the manufacturing of perforations due to small width between each perforation and vibrations of the ends. First layer of plywood was splitted on several spots. Speed of tool shift was adjusted and new tool was used in order to avoid splitting of plywood. The whole process of milling took about 45 minutes; most of the time took manufacturing of dovetail joints.

Milan et al. (2015). “Innovations in sitting design with a use of CNC technology”
Essential part of the assembly is precise manufacturing of dovetail joints which guarantee the stability of whole structure. Assembly starts upside down, at first back parts is bent and 2 supporting parts are placed into prepared apertures. Next step is placing rear part and connect dovetail joints together. Last step is placing front part under the seat and legs and connect dovetail joints. In Figure 5 assembled construction of the chair is presented.

Figure 5. Design of the chair using perforations and dovetail joints

5. CONCLUSIONS

In this study two similar approaches of flat-pack chair design were presented. Goal was to design chairs with basic joints and easy to assemble without using glue or metal fittings. Both presented prototypes fit well in flat pack category and they are innovative in design and also used technology. For Manta chair there are several types of seat and backrest fitting together which allows the user to choose best color and shape. Performe chair uses perforations as a technological and esthetic element and shows innovative approach for furniture design.

Acknowledgement
This study was kindly supported from Internal Grant Agency of the Faculty of Forestry and Wood Technology, Mendel University in Brno – project id LDF VT 2015008.

References

Milan et al. (2015). “Innovations in sitting design with a use of CNC technology”


Corresponding author:
Šimek Milan

*Department of Furniture, Design and Habitation, Faculty of Forestry and Wood Technology, Mendel University in Brno, Czech Republic*

© Author(s) 2015. This article is published under Creative Commons Attribution (CC BY) license.