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Chair design for CNC manufacturing – Skeleton Chair

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Abstract

The goal of this project is a chair design, manufactured by CNC router. Plywood is used as a basic material. No additional fittings are used and joints are not glued. All parts fit together and support each other - interlocking jointing system. Construction is able to be assembled and disassembled without use of tools. Design reflects used technology, material and construction principles. No energy is spent for manufacturing of metal or plastic parts. The cost for transport is reduced. After routing parts are finished and ready to be assembled. Whole chair is stable and solid enough. Solution of antagonisms between design, construction, material and technology is highly important background of the project. The solution was developed for 3 axis CNC and plywood material. Results of project are different chair prototypes. The CNC technology offers many advantages and can help manufacturers of all sizes to attain global competitiveness. Thanks to the combination of CNC technology, ready-to-assemble (RTA) furniture concept and new wood composite materials, a contemporary advanced manufacturing concept is brought up. So far this new "design for CNC manufacturing" is being developed in educational courses and very rarely produced by furniture companies. Even though it could be highly popular technique for small manufacturers, who are looking for new products and own CNC router. CNC furniture is simple for use and user friendly. No fittings, no queries, just slide parts together.

Keywords Chair design, CNC technology, ready-to-assemble furniture, joint

Project brief

Basic goals are the study of flat pack furniture methods, design and construction. The second part deals with the construction for CNC machines and manufacturing.

Aim/Vision to develop
- Universal chair.
- Flat pack construction.
- No additional fittings will be used.
- Contemporary design.
- Based on traditional joints adapted for CNC machine.

Material
- Plywood, MDF for prototypes.

Machine
- CNC router

The chair has to be easy to assembly and fully functional. It means that we will be able to use it as chair of classic construction. Chair will be able to be disassembled. Design will be specific because of using new approach to construction.

Front and side view of the finalized product is in the Figure 1 and Figure 2.

Fig. 1 – Final design – front view

Fig. 2 – Final design – side view

Why to develop this type of furniture?

There are four main reasons for designing this type of CNC furniture. Extension of CNC machining possibilities, ecology (efficient usage of material, one machine, flat pack), development of competitive solutions which are applicable on current manufacturer technology, possibility for quick manufacturing for everybody with a CNC machine. Because of the innovative approach and technology, the chair is interesting and feedback is positive. In the market there is recognizing the trend of development of this type furniture. It is ecologic, widely applicable and modern. The chair could be sold as chair for different

kinds of interiors, as children furniture, or last but not least for advertising purposes. Also the technical solution aspect is appreciated.

Skeleton chair development

1. Theoretical research and evaluation of possibilities.
2. Market research.
3. Ergonomics, material, shape, machining and mechanical properties research.
4. Paper sketch.
5. Sketch in CAD.
6. Decision about construction type.
7. Decision about suitable design with appropriate construction.
8. Drawing of parts in CAD.
9. Assembly in CAD.
10. Design and construction improvements.
11. Finalized 3D of Skleton 1 – Figure 3.
12. Using of analyzing and simulation tools for design evaluation.
13. Calculation of stability.
14. Conversion into 2D format.
15. Decision about tooling and manufacturing (machine, clamping) strategy.
16. Adjustments in CAD.
17. Import into CAM/WOP.
18. Setup of position on working plane; setup of tooling; adjustments in tool approach.
19. Manufacturing.
20. Prototype evaluation.
21. Improvements in design and construction.
22. Testing of plywood properties.
23. Manufacturing of second prototype – Skeleton 2.
24. Improvements in design and construction.
25. Decision about new machine and adjustments of programs for a new machine.
26. Manufacturing of third and fourth prototype – Skeleton 3 and Skeleton 4 – Figure 4.
27. Drawing in other furniture design software, visualizations.

Fig. 3 – First prototype

Fig. 4 – Final design

Construction and design

Construction of the chair was designed for a 3 axis machine (Smid, 2006) and plywood (or similar material). The construction used, is influenced by CNC furniture philosophy. Final construction is fully functional, but it is also important to consider it as a case study of different techniques. Construction is suitable for manufacturing in batches.

Chair design is tightly connected with construction. From first sketches, look of the chair was visibly improved. The look of the chair is one of the most noticeable benefits. Even opinions on design are highly individual. Shape is highly interesting and in connection with specific construction and details I assume, that chair has got appropriate and representative form – Figure 5.

Main parts of the chair are:

- 2 legs
- 13 ribs (seat and backrest, all ribs are similar)
- 4 rods
- 2 footrests
- 1 back cross

Ecology

Effectiveness of process and subsequently lower consumption of energy and material is one of main contribution to the ecological principles. CNC furniture reduces material spent. Another influence is no use of metal or plastic fittings. This reduces spent energy. Because we can develop furniture as flat pack, less space is needed in transport. This is also important ecological aspect.

Fig. 5 – Final design – perspective view

On the market is a recognizable trend of a "Sustainable marketing" (sustainablemarketing.com) and of development of CNC furniture. It is ecologic, widely applicable and modern.

Material

Material choice has an influence on every step in the manufacturing process. This choice is important, because a few main aspects have to be considered. These aspects are the materials physical/mechanical properties together with structure of the material and the second aspect is material dimension.

Physical properties, mainly moisture, and their influence are similar as for traditional furniture. Mechanical properties are important due to its influence on construction and machining. For clarification of material strength I carried out basic testing of the plywood.

Important mechanical property as well as the strength of the material is the material structure. Influence of grain orientation is important due to design and mechanical properties. Usage of laminated materials is possible. Material hardness is important due to router speed. Surely, there is a question of tool wear and it is important to find a compromise between time, quality and tool wear.

Technology

For Skeleton chair has been used two different machines during the development. On each of these machines, two prototypes were manufactured. Both machines had 3 axes.

Tooling of machines was similar. For the Skeleton chair only two tools are necessary – an 8 mm drill and a 10 mm routing bit. Tooling has influence mainly on chair construction and look. Apertures in corners are drilled. This is not necessary if a smaller mill dimension could be available. Advanced possibilities could be provided by machine and by tools. Important is number of machining axes. Construction possibilities are wider, when drilling and routing under an angle is possible. Special tools could be used for specially shaped joints.
Also use of machines such as inverted router or drum sander could be eliminated with use of appropriate clamping technology.
Input data are made as 3D models with export into 2D drawings. Therefore manufacturing is available on different types of machines.

Results of the project

Results of the project are four successfully manufactured prototypes. Different constructions and designs were developed. From initial sketches to final designs it is 6 designs with important changes and over 60 designs with minor changes.
During the process issues were solved in all areas and successful manufacturing on two different machines was done. On different prototypes was tested influence of new parts, tooling and machines. Testing of material has been done and different types of materials have been used. Also ergonomics was considered and stability of the chair was calculated. The project is complex with a theoretical base, which is applied to a developed solution. The chair was exhibited on two important Czech exhibitions: WoodTec and Mobitex. The chair has been well appreciated by the public and also by furniture industry authorities.

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