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INNOVATIONS IN CONCCURENT FURNITURE ENGINEERING

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ABSTRACT

Basic aspects and innovations in concurrent engineering and its major place in the production of furniture in our days are represented. The main advantages and the main differences between concurrent and traditional furniture engineering are analyzed. Examples of using 2D and 3D models made by CAD-based programs in the production of furniture, with the help of CNC machines and 3D printers are considered. The new technology for 3D printing and its using for production of wood elements and furniture are presented, which leads to establishing the idea for „Smart wood materials". The opportunities to use these technologies to make easier the work of designers and adapt them in everyday life, which make them more available to the customer are discussed.

Key words: concurrent engineering, furniture design, 3D modelling, CAD, 3D printing, "smart wood".

INTRODUCTION

1.1. CONCURRENT ENGINEERING

Concurrent Engineering represents a key trend in product development, which has changed academic and industrial approaches of looking at the product development process. Some elements of CE were recognized in the first half of the XX century, however ,they were not adopted until the 1980s. CE became popular in the literature with the work by Imai et al. in 1985 and Takeuchi and Nonaka in 1986 (Loch, C. and C. Terwiesch, 1998).

Several *definitions of concurrent engineering* are in use. One of the first is this of R. Winner: Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements (R. Winner et al, 1988).

Another more extended definition is this of J. Cleetus: A systematic approach to integrated product development that emphasizes response to customer expectations and embodies team values of cooperation, trust and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life-cycle perspectives, synchronized by comparatively brief exchanges to produce consensus. (J. Cleetus, 1992).

In summary *Concurrent engineering* is a modern engineering and manager concept – one nonlinear group approach to designing and manufacture, which combines the inputs, processes and outputs needed to produce a product. Basic characteristic of this method is the multi subjected team consisted of designers, technologists, marketing personnel and managers, who work together to solve the problems of creating a new product. In concurrent engineering different stages of designing and developing products, run simultaneously (Loch, C. and C. Terwiesch, 1998; Bartoline, G. and E. Wiebe, 2005). The main idea of this method is creating new products as quickly and efficiently as possible.

While concurrent engineering is somewhat of a new production business strategy, it offers four main advantages - maximizes quality, faster development, reduced costs and happy customers.

1.2. CONCURRENT ENGINEERING DESIGN

One of the basic process of the concurrent engineering is the engineering design. The key feature of *concurrent engineering design* of products, including *furniture* is *3D modeling*. The concurrent nature of this design is based on three key activities – Ideation, Refinement and Implementation (Bartoline and Wiebe, 2005) – Fig. 1. These key features are further divided into smaller segments: problem identification, preliminary ideas, preliminary design, modeling, design analysis, design visualization, servicing, financing, marketing, producing, planning and documenting. 3D modeling and graphics knowledge have great importance in engineering design and production (Staneva, N., 2008). With the use of a modeling approach everyone can have access to the current design through a computer database. This database helps to improve the financial aspect of the production process along with planning, managing and marketing phases. For achieving these optimization processes concurrent engineering uses two main databases – CAD and CNC programing.

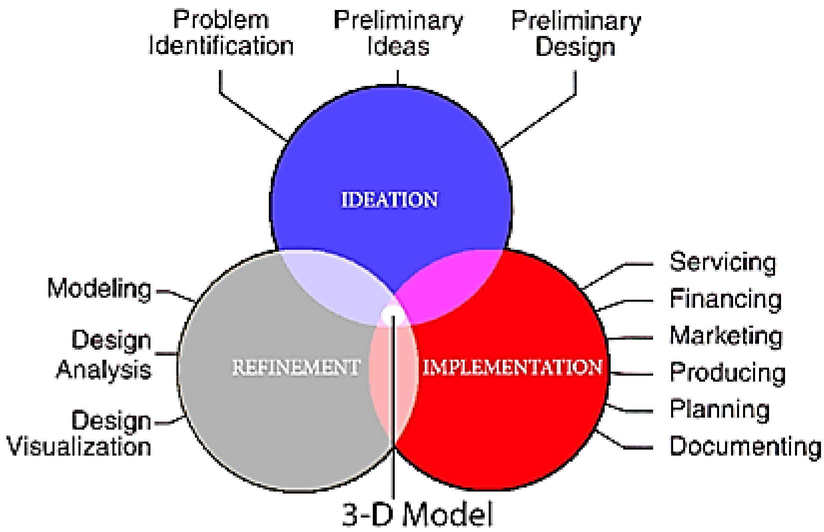

Figure 1: Concurrent engineering design

2. INNOVATIONS IN CONCURRENT FURNITURE ENGINEERING – 3D PRINTING TECHNOLOGY

The concurrent possibilities and differences between traditional and concurrent furniture engineering were discussed in our previous paper (Kitchukova, M. and N. Staneva, 2014), based on original scheme developed by Wang C., 2011. In *concurrent furniture engineering*, the engineering process is paralleled with the mock-up process which saves a lot of time – Fig. 2. Engineering could response to any error caused by a design flaw based on daily production feedbacks. In this case by the end of engineering process, the mass production engineering documents are ready by using the same amount of time while in *sequential furniture engineering* only preproduction documents are completed. In the *traditional furniture engineering* process the preproduction engineering happens first then the documents will distribute to production to trigger the mock-up process. Production associates provide feedbacks in the process of making mock-ups. Engineers cannot start the compilation of mass production documents until all the feedbacks are collected from production.

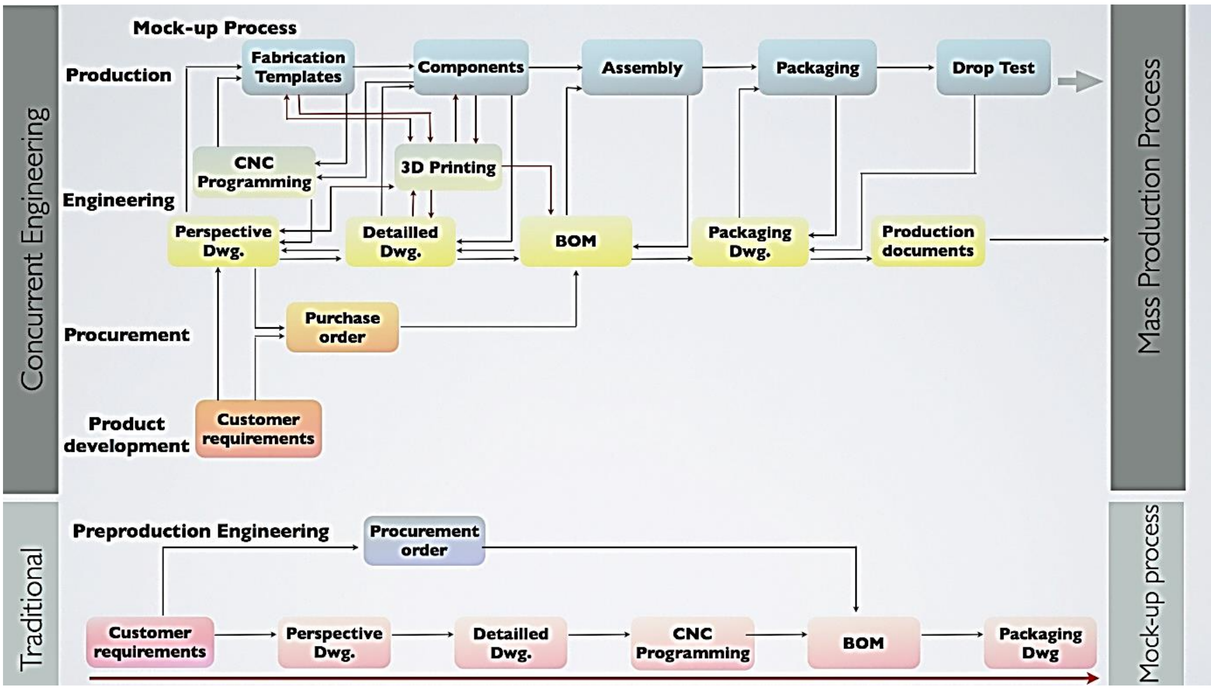

Figure 2: Concurrent-traditional furniture engineering

In this research the scheme of concurrent furniture engineering is updated with 3D printing technology – Fig. 2. The latest key process in *concurrent engineering – 3D Printing* is compared head to head with the CNC programming machines – Fig. 2. Clearly, each of these methods can serve a purpose in the furniture industry. For low-volume functional products made of production-equivalent materials, rapid CNC machining is ideal. And for larger numbers of products and mass and serial production is perfect choice also. 3D printing is a revolution in this industry which makes the future process of designing and producing furniture more cost efficient in term of materials, time and people. It is one level up than CNC programming because it combines in itself more processes, which give it future key part in the concurrent engineering.

The first commercial 3D printer was based on a technique called *stereolithography***.** It was invented in 1984 by Charles Hull. 3D printing is a product of Autodesk CAD software and the computer printer. Autodesk and other CAD programs, first in 2D and then in 3D dimensions, allowed designers to create a virtual model fully defining a solid object on a computer. The concept of 3D printed furniture might look like completely new innovation in the industry but in fact it is not. In 2012, was created the first 3D printer, which can work with wood based material and print furniture and since then such kind of a printer has been passing the radar.

Although 3D printers use a variety of very different types of additive manufacturing technologies they all have one thing in common: they create a three dimensional object building it layer by layer, until the entire object is complete. Each of these printed layers is a thinly-sliced, horizontal cross-section of the eventual object. To create an object a 3D printer needs a CAD file created with the use of a 3D modeling program. It can be created from scratch, 3D model or by a 3D scanner.

Since the first 3D printer was developed this technology is constantly developing and updating. That is why there are different *methods of 3D printing*: Stereolithography (SLA); selective heat sintering (SHS); Direct metal laser sintering (DMLS); Selective Laser Sintering (SLS); PolyJet photopolymer; Syringe Extrusion and the most used method is Fused Deposition Modeling (FDM).

Fused Deposition Modeling (FDM) is additive manufacturing process that uses a reel of plastic filament. This method is used by popular desktop 3D printers like MakerBot and Ultimaker to fabricate parts. Build process is shown on Figure 3. Fused Deposition Modeling works by extruding a thermoplastic polymer through a heated nozzle and depositing it on a build platform (Hellebrand, M., 2014). The deposition tool draws cross-sectional slices of a 3D model with the thermoplastic “model material” one layer at a time, stacking layers until a 3D part is formed. Support material can be deposited to allow the fabrication of overhanging structures.

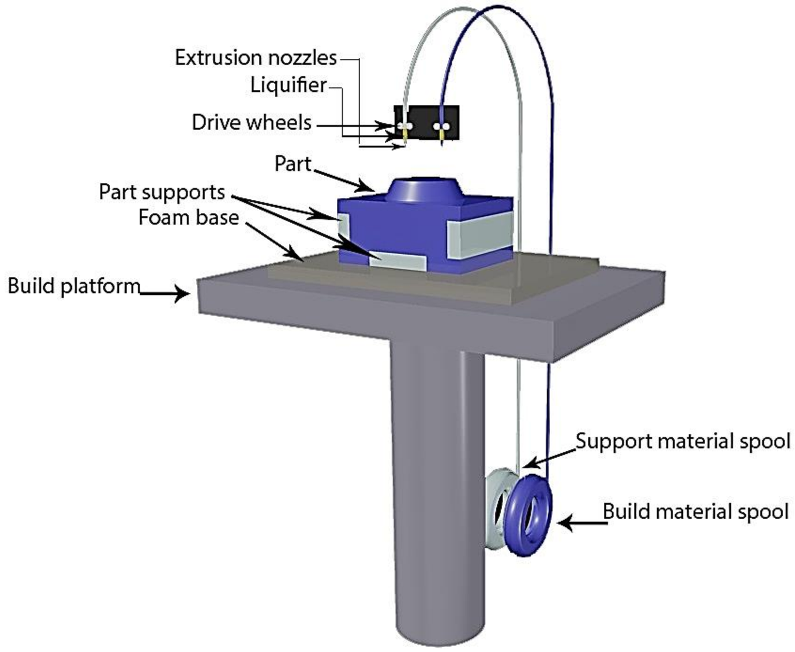

Figure 3: FDM (Fused Deposition Modeling) method

Usually *materials* that can be used in 3D printers are substances like plastic, resin or metal. Some of these materials are made from renewable resources as corn, tapioca roots, chips or starch or sugarcane. But now the 3D printing community is experimented with wood, which is a more natural material with a unique aesthetic. More and more exotic uses of 3D printers are being researched, but wood-based materials are very attractive because of its organic and eco-friendly characteristics. And in a world where 3D printers are printing tons of plastics, wood-based materials could be the next revolution in 3D printing.

Company that provides high-speed, large-format 3D printers is currently developing new material sets, including additional sands, ceramics, cement and wood powder. That new printers use powder binding technology, which involves chemical binding agents used to bind together the material being printed.

The new technology will enter the furniture business through 3D printing wood. First wood material for desktop 3D printer called LAYWOO-D3 [9] (Fig.4) is made up of 40 percent recycled wood fiber, combined with a polymer binder. It can be melted and extruded like all of the other commercially available 3D filaments on the market. The printed wood will appear rough, similar to MDF (Medium-Density Fiberboard). In addition to its obvious application of creating natural looking objects, things made with the material can be painted, ground or cut like wood.

Figure 4: 3D wood printer and printed models from Laywoo-D3.

The development of wood material enables more applications in design and furniture industry. Also 3D printers can deliver custom, affordable wood furniture within days of order. This process minimizes the high labor cost and offers consumers an affordable way to get customizable furniture. Consumers would have a choice to use different material, different color. Using these technique designers would be allowed to tweak, change, modify their design simply in the CAD software. It would be much easier for interior designers to customize furniture orders.

With the possibility of printing wood there is a new revolution option - to print "smart wood" for home automation. This smart wood technology is based on developing energy efficient smart furniture that can change their color in response to light. This will be possible with embed electronics directly in wood – Figure 5. This electronic chip has sensors capable of detecting people and atmospheric or temperature change.

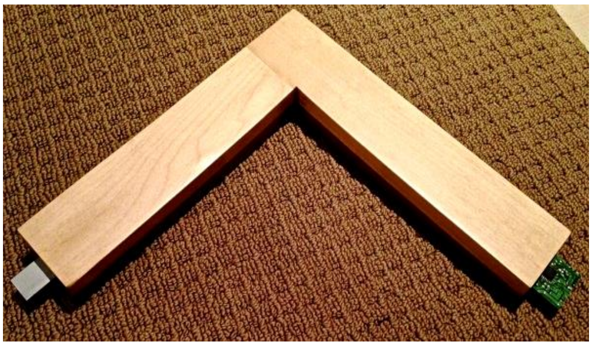

Figure 5: Electronics & metal cased in insulating wood.

3. EXAMPLE OF USING OF CONCURRENT FURNITURE ENGI-

NEERING WITH 3D PRINTING TECHNOLOGY

Modern complex shapes and details of the furniture are product of combining CAD created 3D models, CNC machines and 3D printers. The possibility of achieving exact radiuses in designing furniture details using CAD based systems and 2D and 3D models is illustrated with Figure 6. From generated 3D model of a table was created scaled model using a 3D printer.

This process contains the next steps:

- Make a 2D model of the wanted shapes.
- Make a virtual design of the table. This virtual design is made in a CAD file using a 3D modeling program AutoCAD.
- A stl. file is exported so it can be loaded into 3D printer.
- To prepare the digital file created in a 3D modeling program for printing, the software slices the final model into hundreds or thousands of horizontal layers.
- Uploaded the prepared file in the 3D printer.
- The printer creates the table layer by layer. The 3D printer reads every slice (or 2D image) and proceeds to create the table blending each layer together with no sign of the layering visible, resulting in one three dimensional object - scaled model of the table.

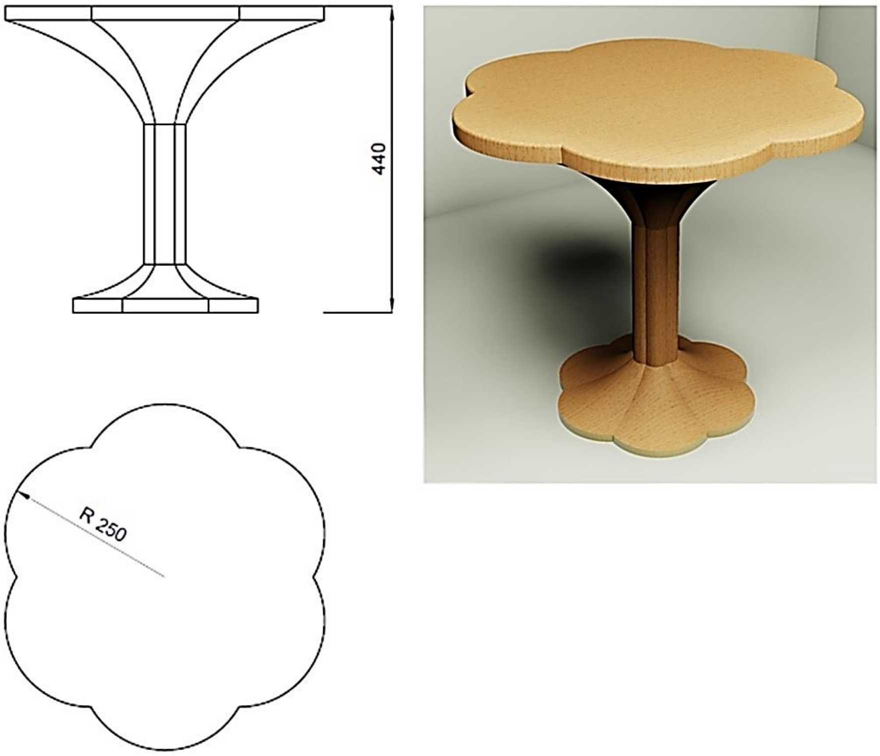

Figure 6: 2D and 3D model of the table

The printed scaled model of the table is shown on Fig. 7. It is printed on a *Makerbot Replicator 2* using FDM method as described above. The printed scaled model of the table is made from material named *PLA* (Poly(lactic acid) or polylactide) which is a biodegradable thermoplastic aliphatic polyester.

Figure 7: 3D printed scaled model of table

CONCLUSION

The conception of concurrent engineering has increasingly wide application in furniture engineering. The last innovation in concurrent engineering – *3D Printing technology* could revolutionize and re-shape the world. Advances in 3D printing technology can significantly change and improve the way of manufacturing products. It opens a new horizon for companies and individuals to create products of any size or scale limited only by their imagination. This industrial revolution brought mass production and the advent of economies. 3D printing could bring mass manufacturing back a full circle - to an era of mass personalization, and a return to individual craftsmanship.

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Acknowledgments

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