

Furniture structural joints made of cardboard and/or plywood

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Abstract: The article describes and explains current trends in cardboard and plywood furniture that is produced by a combination of laser technology and a plotter. The main material is a cardboard sheet made of recyclable raw materials. The aim is to re-utilize raw materials that end up in waste and have no further use today, once they serve as packaging material. Cardboard boards are sandwiches that have sufficient strength and rigidity if properly oriented on the product and for specific applications, such as starting furniture for young families or new businesses, they can save both raw materials and costs.

Our project deals with the development of the technology for processing furniture made on the basis of corrugated and coated cardboard and plywood. It is expected that the furniture will be primarily intended for final assembly by the customer, based on the Ready-to-Assemble (RTA) principle.

This is an experimental project using cardboard as the main construction material. Cardboard furniture as a theme that recurs repeatedly with the requirements for recyclability of consumer furniture has been elaborated by students, designers and architects many times during the last half century (Alvarado, Davies, Jacobs, Gehry, Cuiomar). However, cutting cardboard furniture always entails considerable wear of the cutting tools, which is further increased if the panels are composed of multiple layers of cardboard or paperboard glued to each other.

Testing of material behavior and experimenting with shape possibilities will result in design and prototype of chair intended for interior, working chair. The prototype will be subsequently tested in the furniture testing room according to the European standards.

In order to lighten and strengthen the whole structure, the structure will be conceived as combined with the supporting part of the structure consisting of plywood, seat part and decorative backrest of cut, engraved cardboard. The following structural joints are considered to be used in project: insertion, bending, grooving, eventually tenon and mortise or dowel. For the production of furniture samples and joint testing a new combined universal CNC machine will be used (laser, plotter and router).

THE AIM OF THE WORK

Our goal is to develop and test in practice 2-3 construction joints for cardboard furniture made of cardboard waste. The reason is that designing and producing cardboard furniture from newly made cardboard sheet solves the problem with recycling only partially.

The challenging part of the work is to use really used boxes and by laser cut out of it shapes, that can be bent, thread and slide in together to form a furniture for seating, writing, etc.

Using the corrugated cardboard of 5 layers, that forms the most common packaging gives us good and stable constructional material for specific use indoors.

There is no typical dimension of cardboard box from waste, but for the purposes of our task is necessary to specify, that seating furniture of typical width of 45cm, height of 80 cm and depth of 50 cm gives the assignment for search of the most suitable formats.

Suitable formats can be found as a part of packaging material of household equipment like refrigerators, tv sets, domestic furniture, larger light fixtures, or technical equipment of the building used in the construction and equipment of the house. It is mainly 5 layer corrugated cardboard thick between 4 to 7 mm.



Ways of joining cardboard furniture

Joint

The basic link of any structure is the joint. The properties of the joint result from the type of construction and the purpose of use and production technology. As cardboard is mainly used as a packaging material, the joints are based on the production of boxes, fixing fillings, liners and other products from this material. When joining, it is primarily ensured that its physical and mechanical properties of the joint are proportional to the mechanical properties of the joined materials. If this is not achieved, the joint is the weakest link of the jointed material affecting its resulting physical and mechanical properties. The correct choice of the connection method and the quality of the connection is very important, and therefore they must be given due attention. (Machán 1998).

Cardboard furniture can be produced in demountable and non-disassemblable design

Removable joint

A detachable joint is one that can be disassembled and reassembled at any time without damaging the joint or connecting part. It is based on the principle of two counterparts that fit together. It is a connection without the use of any connecting means. In this way, flat cardboard blanks are formed from flat cardboard blanks by simply inserting, lowering or folding the part into the blank. Folding joining enables the transport, storage and handling of the product in a flat state (Machán 1998).

It is therefore possible to speak of a so-called homogeneous connection. The strength of the joint depends on several factors, especially the chosen technology, material properties (Jožák, 1999). The only force that holds the joints together is caused by the tightness of the joint. In the case of carton joints, this statement is doubly valid, as it is an easily wearable material.

non-detachable joint

Unlike a demountable joint, it is a permanent joint of the material. In the case of cardboard furniture by gluing.

An overview of demountable connection types

Insertion

A typical method of joining for cardboard furniture. The construction is based on the principle of notches or counterparts that fit together. In the case of cardboard, its edge strength is used.

An example of this design is furniture by David Grass. The notches in the parts form the rib structure of the whole product. The width of the notches corresponds to the thickness of the material. In his work, he uses the advantages of the packaging properties of cardboard, when the packaging itself becomes one of the functional parts of the product.



Kids chair and coffee table by David Grass

Another alternative to this connection can be a pin and groove connection, in which it is possible to use a larger thickness of the honeycomb board material in pressure on the surface compared to corrugated cardboard.



Pin and groove used in cardboard furniture

Bending

Another large group are products made by bending and folding cardboard. These are often folding products made from a single piece of cardboard or products inspired by the Japanese art of origami.

Joining by folding is performed without the use of joining means. These replace the various threading or sliding tabs formed on the cardboard blank and the slits on the opposite flaps into which the tabs are inserted. Thus, the flat blank is joined at the edges and a three-dimensional shape of the package is created. Careful design solutions are used for this purpose, which allow easy and firm connection (Machán 1998).

These operations are used to achieve the bending of the cardboard:

Slicing

Technological process in which a bending line is created by cutting the outer layers of cardboard. The depth of cut is between half and three quarters of the thickness of the cardboard (0.5 s to 0.75 s). Cutting facilitates the bending of the cardboard by the fact that the outer layers, which would crack in irregular lines when the uncut cardboard is bent, are cut in a straight line up to the middle layer. By cutting, the cardboard largely loses its original mechanical properties (tensile strength and compressive strength). Therefore, this process is only used if the reduced strength is sufficient (Machán 1998).

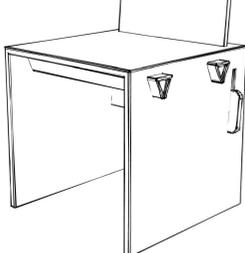
Grooving

Technological process which creates conditions for easy bending of corrugated cardboard (cartons) in a small bending radius without cracking the outer layer, which is stressed by tension during bending. In practice, grooving is the most common and in the production of cartons the most common way of preparing bending lines. A groove is embossed into the cardboard in the bending line. The task of the tools that create it is, on the one hand, to compress the cardboard layers into the groove relay so that during bending there is a reserve in their length proportional to the stretching requirement during bending, and on the other hand so that they do not apply tough resistance on the inner side of the bend during compression and easily bulge (Machán 1998).



Cardboard is distinguished according to the dimensional proportions of the corrugated layer:

Joint



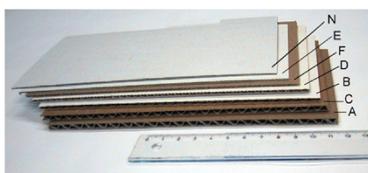
with coarse wave (marked A)

with medium wave (marked C)

with fine wave (labeled D)

with very fine wave (microwave marked E)

with miniwave (labeled F or N)



Advantages and disadvantages of current cardboard furniture constructions

Basic characteristics of cardboard furniture

Cardboard furniture is a specific category of furniture, which cannot fully replace furniture made of wood or wood-based materials from the base of the input material. It is mainly stylish furniture that has its specific clientele. A typical feature is its lightness compared to other materials and structures used in the production of furniture. A common feature for all the constructions described above is the fact that the material from which they are made is intended mainly for the packaging industry. This is the advantage and disadvantage of cardboard furniture:

Benefits:

Light and strong at the same time

Demountable

Flexible

Simple

Ecological

Original

Disadvantages:

Service life

Endurance

Weather resistance

From the available information and research of current products on the market, it is not possible to completely determine which type of connection is the best and which, on the contrary, the worst. The most important advantages and disadvantages in relation to the construction are described below:

Construction

Insertion

Bending

Gluing

Benefits

Simplicity of production

Lower material consumption

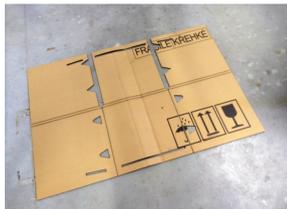
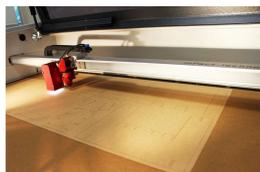
High strength

Disadvantages

Strength

Production of bends

Material consumption



DISCUSSION AND CONCLUSION

During this project, we came across a number of design details that repeatedly influenced the design retroactively. The main targets were met, but the work on the furniture family will continue, as we want the joints to be as small as possible but robust at the same time. This target will be met after testing prototypes and bringing their inputs back to further stages of design process. The prototypes will be tested due EN 581-2 Outdoor furniture - Seating and tables for camping, domestic and contract use - Part 2: Mechanical safety requirements and test methods for seating - This European Standard specifies the minimum requirements for the safety, strength and durability of all types of outdoor seating for adults, without regard to materials, design/construction or manufacturing processes. The test requirements contained within this standard are based on use by persons weighing up to 110 kg.

Our furniture meet the RTA rules, but we would like to focus on simplifying the folding and disassembly, because in the temperate climate where our country and University is located, the outdoor furniture is often held in storages during winter periods. From this point of view, we want to simplify the base construction so that the dovetail corner joints will be fully dismountable. Another goal after testing will be the overall weight reduction of individual elements while maintaining sufficient stiffness and stability.

Due to the quarantine circumstances (Covid-19) and the closure of the University's workplaces, we were unfortunately not able to produce a sufficient number of samples to test all their parameters in the testing room according to applicable standards. This work related to the author's dissertation will take place in the rest of the year 2020 and its goal is to design seating and storage furniture in the category of NTR furniture (noi-tools-required). At the same time, we will focus on the of bends on of furniture edges to avoid possible injury to the operator and end users. The reason is the laser cuts are very sharp and from the point of view of repeated production it is not appropriate for furniture to be surface treated at the edges after assembly. We focus on cost-effective, light furniture with optimal use of recycled inputs, without fasteners made of other materials.

Designing and manufacturing cardboard furniture is a popular topic, that brings with it many interesting issues. This kind of furniture can be placed almost in any room, perhaps except for the bathroom. There is a wide range of cardboard furniture on the market, ranging from professional designers to home-made production

From the point of view of furniture production, it offers a wide range of joints and structures without the use of fittings or other connecting materials, which has recently been the subject of interest for the use of CNC machines.

Recycled paper

From an economic and ecological point of view, recycled fibers obtained by regenerating old paper are now used in paper production. Waste paper is an important secondary raw material that re-enters the production process.

Fibers differ morphologically (shape and size of fibers), chemical composition, mechanical, optical and other properties that affect the resulting properties of the paper.

However, they have one thing in common, namely the ability to form a sufficient interfiber bonding system after milling during molding, which connects the originally separated fibers into a flat system of paper, cardboard or paperboard and affects its quality.

Recycled fibers tend to be a 100% replacement for primary raw materials in the production of cardboard, cardboard, packaging, writing and printing papers.

Basic terms and definitions of paper technology

In practice, we can meet with three basic types of materials, whose composition is similar, divided mainly by basis weight in g / m²

Paper is a cohesive layer of predominantly vegetable fibers, usually of cellulose origin, bound together by interfiber bonds, most often hydrogen. The paper sheet is formed on a fine mesh by flooding a dilute aqueous suspension of fibers, felting it, dewatering it and drying it. It is a sheet material with a basis weight of up to 150 g / m².

Carton, a stiffer material with a basis weight of 150 to 250 g / m² produced as a single or multi-layer, one layer is usually formed on a longitudinal sieve, others are formed on former or from a secondary inlet and the individual layers are joined by wet pressing.

Cardboard, a material of a higher basis weight, usually above 250 g / m², formed from several layers, usually of different fiber composition. Up to an area weight of 1000 g / m², it is produced on a cardboard machine with several longitudinal sieves or cylindrical sieves or on multi-sieve formers, and the individual layers are joined by wet pressing. Cardboard with a higher basis weight over 1000 g / m² is produced by gluing several layers of paper, cardboard or board on gluing machines.

Paper as a material for furniture production

Paper (cardboard) furniture is made of flat materials used in the packaging industry, such as corrugated cardboard or honeycomb boards. In addition to these basic materials, paper tubes, for example, can be used. The vast majority of cardboard furniture is made of corrugated cardboard. Recently, paper honeycomb has become more widely used. These materials offer great possibilities in construction and joining compared to paper tubes.

Corrugated cardboard it is formed by joining one or more layers of corrugated paper, which are alternately glued between the layers of flat paper. Corrugated cardboard combines the good properties of smooth cardboard and at the same time eliminates their shortcomings. The physical properties of different types of corrugated board are precisely determined, depending on what material properties are required. The functionality of corrugated cardboard is determined by the geometry of the wool, the most common is the sine wave shape.

The main reasons for corrugated packaging are among the most important packaging in packaging technology are:

- Corrugated board differs from other cardboards in its characteristic construction and the properties provided by the corrugated layer;
- Has very good packaging functional properties, especially damping ability and flexibility with relatively high stability, good strength in the strut (compressive strength at the edge), which are important packaging functional properties of boxes;
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Input materials for the production of corrugated cardboard

In order to produce corrugated cardboard, it is necessary to glue the cover paper with the corrugated paper. In the conventional packaging industry, these papers are divided in qualitative order as follows:

Corrugated papers, types:

- Fluting - unbleached semi-tissue paper from leaf wood with min. 65% primary fibers
- Wellenstoff - mostly made of sorted old paper
- Gray - paper from a mixture of ordinary old paper such as printing waste, gray cardboard, cardboard tubes, etc. .

Cover papers:

- Kraftliner - sulphate, cellulose paper in natural brown color or with bleached bleaching layer (white top) of coniferous wood with min. 80% primary fibers
- Testliner - mostly two-ply papers of different fibrous paper materials, wherein the cover layer may comprise a high-quality fibrous material. The fiber composition is not determined, therefore the strength properties are defined and not also guaranteed
- Gray - paper from a mixture of ordinary recovered paper

Types of corrugated cardboards:



CNC technology for carton cutting

The category of these machines includes all technology that uses a series of characters for its control, which correctly form the control code (Computer Numerical Control). A computer with a keyboard is connected to the CNC machine, which enables the creation, editing and saving of programs directly on the machine. Production is thus flexible, faster and more versatile. It is also possible to easily repeat production automatically. Benefits and disadvantages of CNC technology are described below:

Benefits

Increase work efficiency

Automation of the production process

Increased accuracy and quality of cutting

Speed up the processing process

Production flexibility

Disadvantages

High acquisition and operation costs

The need of professional staff

High demands on auxiliary equipment

CNC technology for cutting cardboard can be divided according to the cutting tool into:

- cutting by knives
- laser cutting

So-called CNC plotters are used for cutting flat materials. From the point of view of CNC machines, it is a simpler device (2.5 and 3 axes), which use a unit with a replaceable cutting head equipped with various types of knives for cutting or laser. We have decided to use laser cutting for more exact cut lines and edges, rather than knife be its inaccurate inner corners of cuts.

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