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NEW SEATS MADE OF ASH WOOD – GEOMETRY AND STRUCTURE OF WOODEN SEAT FRAMES

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Abstract:

The paper aims to approach aspects of seat design according to the properties and characteristics imposed by the object of the analysis.

Capitalizing on the resources offered by the study of important contemporary furniture designed for a relaxed seating alleviates the functional and ergonomic problems arising when designing such a product.

The design approach of this furniture piece aims at an innovative and attractive esthetical attitude, and is meant to offer a high level of comfort, typical for such a product. The main focus is towards optimising the seat and back position, in close relation with the technical possibilities and material properties. Through the references brought in by current standards and functional research we can notice their influence on deciding upon the sizes and forms of the structural elements.

The analysis has provided solutions concerning economy of materials through capitalizing upon methods of joining the structural elements. The product is built up from straight and curved elements, which bring advantages of an aesthetic order, however having different production costs in relation to workability.

The proposed wood species to be used is Fraxinus excelsior – ash, which gives the product a lower weight, good impact resistance and easy processing.

The adequate use of assembly parts and joining methods has heightened the stability of the product, a factor which makes it also more viable. The usage of demountable parts offers definite advantages for both producers and consumers, such as reduction of required storage spaces, economy of transportation stemming from the reduced packaging sizes.

Keywords: *design; furniture; relaxed seating; ergonomics.*

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INTRODUCTION

IMPORTANT CONTEMPORARY FURNITURE DESIGNED FOR RELAXED SITTING

It is necessary to find references regarding the main factors and characteristics which interact towards the harmonious achieving of the proposed type of furniture. This necessity imposes an acknowledgement of the work of some designers having an early influence upon the aesthetics, functionality and ergonomics of relaxed sitting furniture.

Furniture designed mainly between 1930 - 1940 is part of the „modern classics“ category, but is appreciated and acquired due to the fact that it is still quite modern and functional even for younger people, not only as collectible items for connoisseurs. Among the pioneers who later acquired reference statute we meet Alvar Aalto, Hans Wegner and Bruno Mathsson. The following part presents short biographies, visual examples together with the contributions given by the above mentioned, having a catalysing role in achieving this paper.

The Finnish architect and designer Alvar Aalto (1898 – 1976), nicknamed “The Father of Modernism“ in the Nordic countries, known for his humanistic approach to modernism, created furniture best known for its innovative form and technology. He had a special interest in bending solid wood and plywood, obtaining several patents between 1930 and 1950. At first, the chairs he created were manufactured manually and in small numbers, later they became mass produced. Starting with 1927, in a small wooden furniture factory, he was conducting experiments of methods and work procedures with bent plywood. He tested various birch, beech and poplar species, and also various glues. Finally he reached an innovative procedure – applying longitudinal slots along the folded parts, filling them with plywood slices before gluing. This method offers the legs flexibility and resistance, allowing a curve of over 90°.

In 1932 Aalto transposed in practice for the first time the results of his research, he designed and produced the famous Paimio Armchair 41, with an „S“ shaped board, made of molded plywood, supported by a frame in the shape of a sledge runner. This armchair, revolutionary in shape and concept, offers to the patients of the Paimio Sanatorium the ideal position for breathing and taking advantage of the sunshine during therapy.

a **b** **c**

Fig. 1
Lounge chairs models designed by Alvar Aalto:
a - low-back cantilevered armchair, model #42; b - early cantilevered armchair; c - lounge chair, model #37; (online at: http://www.wright20.com/search/aalto/0/).

The chair shown in Fig. 1a represents a significant example, with a favorable support for the back and arms. The tilting and depth of the seat offer a comfortable sitting.

Hans Wegner (1914 – 2007), a successful Danish furniture designer, is best known for his chair design. Trained as a cabinetmaker, he valued the practical aspects of chair making, thus setting up a number of strict rules for the design process, which helped him find guidance for his creative potential in wood.

a **b** **c** **d**

Fig. 2
Lounge chairs models designed by Hans Wegner:
a - Dolphin Chaise; b - CH-25 Easy Chair; c - Folding Chair; d - Plank Armchair – Leather (online at: http://www.1stdibs.com/search/?q=hans+wegner+chairs/).

The "Dolphin" chair is made of oak and having thin constructive elements gains an elegant look. Its ergonomic profile is achieved through a favorable reclining of the back and a curved profile for the back and seat. This chair is also foldable.

Bruno Mathsson (1907-1988), a Swedish furniture designer and architect, skillfully used functionalist concepts, combining them with the old Swedish tradition of wood crafts. He developed a special construction technique for wooden chairs, through which the components can be bent and molded using the hot water plasticizing method. It is also worth noting that he has excelled in the technique of molded lamello wood, which helped him find a line of seating unequaled in elegance, functionality and comfort.

a b c d

Fig. 3
Lounge chairs models designed by Bruno Mathsson:
a - chaise; b - low lounge with reading stand; c - Pernilla lounge chair and ottoman; d - Eva lounge chair (online at: http://www.wright20.com/search/Bruno_Mathsson/0/).

The Low lounge with reading stand is an outstanding example for a good reclining position, its side profile reveals the simplicity of good anatomical carrying.

The contributions brought by these three exponents of modernism are mirrored in their care for functionality, the interest for ergonomics and, last but not least, the vision through which they managed to animate the composition of their designs.

It is worth noting their attitude towards the technologies through which the structural elements raised their mechanical properties, while showing their complex and harmonious structure.

Their concern for ergonomics makes their furniture to offer special properties for prolonged sitting, during which the human back, bottom and legs are in a relaxed position.

Fig. 4 highlights the main constructive elements, for the representative works created by the three designers, which give personality to the furniture through shape, ergonomics and structure.

a b c

Fig. 4
The shape of lounge chairs models designed by:
a - Alvar Aalto; b - Hans Wegner; c - Bruno Mathsson.

Their structure and composition are able to inspire and direct this paper towards conceiving and designing new shapes. The back, seat, armrests and legs for which the study has been made are able to become references for configuring a new functional identity.

Table 1 presents the relevant constructive dimensions for relaxed sitting designed by Aalto, Wegner and Mathsson.

Table 1

The main dimensions for representative chair designed by A. Aalto, H. Wegner and B. Mathsson

	Alvar Aalto (*model #42*)	Hans Wegner (*model "Dolphin"*)	Bruno Mathsson (*model low lounge*)
Height	720 mm	970 mm	770 mm
Seat Depth	600 mm	1020 mm	450 mm
Seat height	360 mm	380 max – 280 min mm	350 max – 270 min mm
Width	600 mm	720 mm	560 mm
Length	750 mm	1520 mm	1090 mm
Arm height	540 mm	580 mm	-
Back angle	24^o	34^o	44^o
Seat angle	4^o	13^o	15^o

STUDIES OF FORM AND GEOMETRY OF COMPOSITION

The expressive organizing of the sitting furniture's building parts is the starting point which can offer emotions, sensations and can satisfy the senses. The requirement to be expressive is imposed upon the compositional elements, to keep the principle of unity and to offer functional simplicity. The balance and the relaxation of the shapes are conditioned through their superposing in one plane or another, through their intersection or through the angles which are created.

The design process can start with the essential part of the concept, expressed in the sketch of the side view, in order to plan the most reasonable back and seat curve. In a first phase the rectilinear and curvilinear constructive elements are organized in a way that is expected to bring dynamism, as seen in Fig. 5a. A reconfiguration of the elements is followed and their shapes are straightened, keeping in mind the basic principles used in making a chair/armchair. The intervention was made upon the seat and back geometry, they have been given curved lines, closer to a natural sitting position (Fig. 5b). The shape of the elements is reoriented towards the meaning of the structure. Aspects of improving the relaxed position together with the interest of better visual impact are kept in view (Fig. 5c).

Fig. 5
The phases through which shapes can be structured:
a - the rectilinear and curvilinear constructive components are organized; b - reconfiguration of the components for a more comfortable sitting position; c - improvement of the sitting position.

The stages through which the geometry of the building parts has been modified lead to new relations concerning expressivity. The sitting surfaces now hold new functions and prepare the product for adapting to human necessities. This last primary shape of the chair is the starting point of expressing new aesthetical valences, in strengthening the ergonomic form and reaching the final goal of relaxation.

ERGONOMICS OF RELAXED SITTING

Sitting, respectively (back) leaned sitting, is a basic function which needs to be fulfilled properly. Sitting furniture has the most intimate contact with the human body, causing it in the same time discomfort up to incurable spinal problems. Sitting is a dynamic process, the human body stays rarely completely still. Comfortable furniture for reclind sitting has to offer more then just the possibility of varying the sitting positions, it has to adapt not only to various anatomical characteristics of the human body – depending on age category and height – but also to different target categories, as it is prolonged sitting. Fig. 6a shows the positions the human body is required to take and the basic functions the furniture has to fulfill.

While sitting, the most important stress is that of the spine. The spine has 33 vertebrae, out of which 24 are articulated through discs. Fig. 6b and 6c exemplifie the regions and the vertebrae of the spinal chord. The abbreviation for the annotation is V – vertebra, D – disc, C - cervical region, 7 vertebrae, T - thoracic region, 12 vertebrae, L - lumbar region, 5 vertebrae, S - sacral region, 5 joined vertebrae. The region of the coccyx has 4 small joined vertebrae.

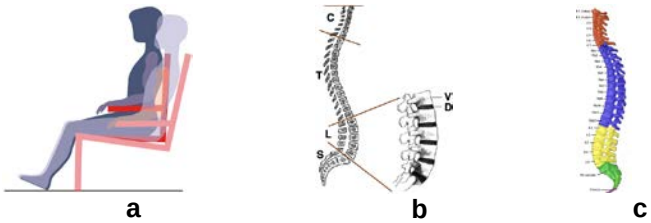


Fig. 6
Anatomical characteristics of the human body:
a - the positions that the human body required; b and c - regions and the vertebrae of the spinal chord (Cionca 2012).

The effects of wrong positions on the spinal chord are illustrated in Fig. 7a.

Fig. 7b shows, according to the Swedish researcher Bengt Akerblom, that the most favourable position for sitting is 3). The dimensions correspond to that of a small armchair.

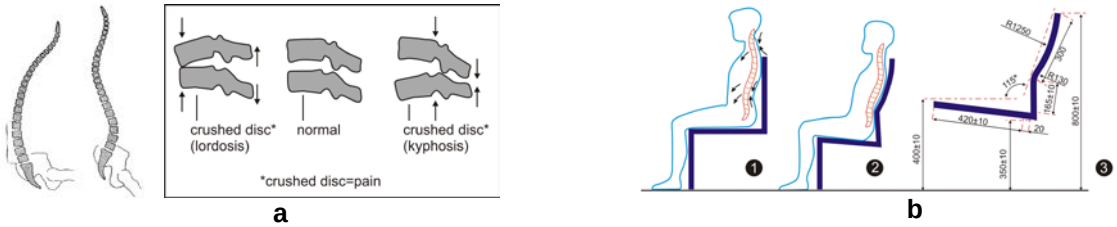


Fig. 7
Considerations of the position for sitting:
a - the effects of wrong positions of the spinal chord; b1 - the spinal chord is not freed from burdens through offering support; b2 - the spinal chord relaxes; b3 - Akerblom gives dimensions for a very relaxed sitting (Cionca 2012).

The requirements for a comfortable sitting have in view some characteristics of the seat, back and arms. The seat has to allow the frequent change of the sitting position, to assure freedom of movement, so that the leaned forward and upright positions can alternate with the supported one. The weight of the body is recommended to be distributed on the hips. The hip has to be wholly in contact with the seat. The foreside of the seat must not provoke blood circulation problems. The seat height has to provide full contact of the sole with the floor and to be correlated with the height of the table surface.

The back of the chair is the part taking over a good deal out of the effort of sitting. A too straight position (with lordosis) leads to muscle fatigue and pains. A prolonged leaned position (with kyphosis), although initially relaxed, also leads to fatigue and pain. The middle sitting position for the spinal chord is leaning the upper body forward; so that the musculature is relaxed. The optimum pressure in the discs exists mainly in the case of being supported by the back. This has to offer efficient lumbar backing, easing the back from sustained muscle effort.

The dimensional relation with the seat is one that assures utility to the armrest.

Important profiles of the back, as a result of research in the field of ergonomics are found in Fig. 8 (Cionca 2012).

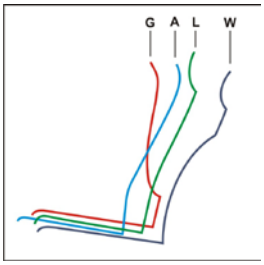


Fig. 8
Important profiles of the back:
G - Etienne Grandjean (Switzerland); A - Bengt Akerblom (Sweden); L - Stanley Lippert (USA); W-Hans Wegner (Denmark) (Ionescu and Nastase, 1970).

The components have been built without altering the ergonomic requirements, accentuating the visual impact and keeping in mind that the structure preserves its resistance at optimal parameters. Proposals for finalizing the shape of the sitting piece are shown in Fig. 9.

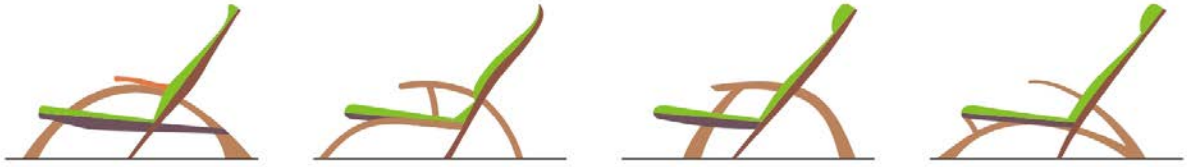


Fig. 9
Proposal for finalizing the shape.

Subject to study were the possibilities for the seat and the back to offer good relaxing effects and to satisfy in optimum conditions sitting for different activities connected with relaxing.

The proposals of varying the sitting position are visible in Fig. 10. The arrows 1 to 4 show the important positions of the human body in interaction with the supporting elements of the furniture piece, as follows: 1 – represents the region in which the pressure applies upon the legs and feet; implicitly this favours or disturbs blood circulation; 2 – is the sitting region; 3 – lumbar region; 4 – cervical region. R represents the possibility of changing the back's (or seat's and back's if they are fixed together) position through rotation or tilting.

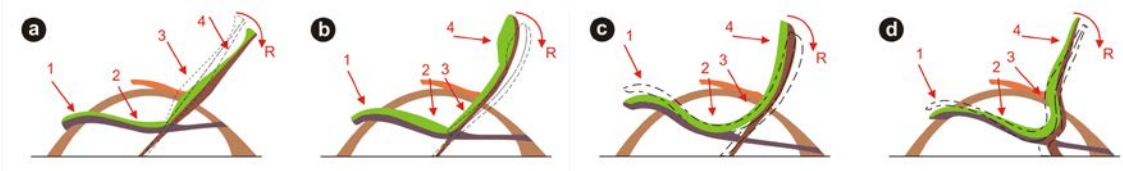


Fig. 10
The proposals of varying the sitting position.

The sitting position in a) corresponds to a prolonged one, with a maximal relaxation of all main parts of the body which are strained.

When the main activity is watching TV, as in the case of b), extra support is offered for the cervical region and the profile of the inferior part of the seat is accentuated.

In the case of c) the tilt, the shape and possibility of changing the position of the seat together with the back aimed to give a restful position. It corresponds to a situation in which the body's position can frequently change and the ergonomic characteristics remain constant.

The case of d) corresponds to an active or semi-active position and assures an adequate support for multiple body position changes.

The analysed ergonomic characteristics can be adapted, so they relay to the furniture a maximum of comfort and keep the indications given by literature (Grandjean 1973).

Fig.11 shows the finalization of the reclined sitting furniture.

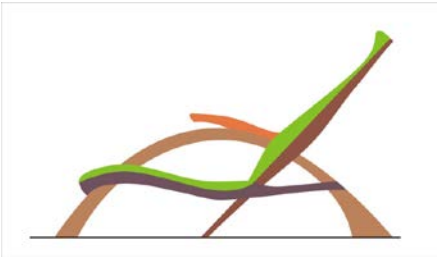


Fig. 11
Finalization of the seating furniture.

FINAL SIZING

The shape and material have an inseparable connection. Out of this comes the necessity to order the composition and to create an original product. The creative and organisational capacity leads towards measurable entities and harmony.

The recommendation for sitting and resting furniture are the following: the tilt of the back will have an angle of 100^{o} - 115^{o}, the seat 2^{o} - 8^{o}. The dimensions of the seat are 550mm for both width (l) and length (L) and 420 for the height of the seat (H1) (Lică 2003).

Fig. 12 shows the main dimensions.

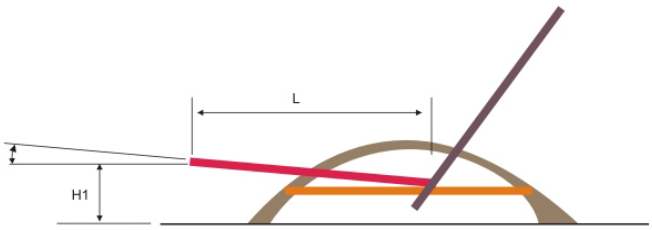


Fig. 12
Main dimensions for the lounge chair.

Worth noting is that measures of the seat height (H1) and the depth (L) are interdependent. When the seat height is small the depth gets bigger, and the other way around, in the range of the given dimensions.

The recommendation targets the sizing of the seat, where depth and height are inversely proportional – for a minimum height a maximum depth corresponds, and the other way around.

This kind of furniture does not fall strictly into any classical category of seating furniture. As a result, the basic functional measurements are kept in view, used as an example and adapted to necessities. Keeping in mind the aspects previously mentioned, together with the standardizing criteria, the main sizes for the product can be determined.

Fig. 13
The final dimensional values.

MANUFACTURING THE SEAT OUT OF ASH WOOD (FRAXINUS EXCELSIOR) AND PROPOSAL FOR A FEW INNOVATIVE SOLUTIONS

The visual effect is enhanced through differences in texture, obtained from the orientation of wood fibres. The fibre texture has to be valorised, taking into account the quality of wood and the processing technology, which may vary according to the visibility of the building parts. The visible parts are those clearly in view in the normal position, the less visible ones are still in view, but are less important in the normal position and the invisible parts are completely out of view (Lică 2003).

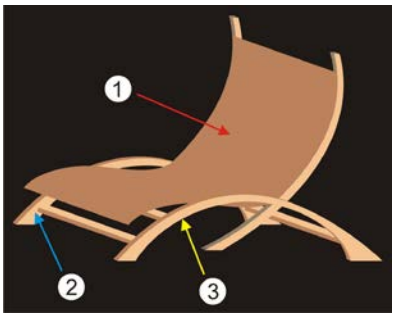


Fig. 14
Important visible and invisible parts:
1 - visible parts; 2 - less visible parts; 3 - invisible parts.

Ash is a resistant and strong wood, it dries easily and is very stable, it is shock - and vibrations resistant, well known for its rigidity. It has a cream coloured texture, with a little red, grey or brown colour and visible growth rings. It is easy to be mechanically processed, but problems can arise at sanding. When used outdoors it has to be treated. Ash wood has many uses. Due to its elasticity and strength, it can be used for bentwood furniture. Its strength and resistance to shock make it suitable for sport items and handles for various tools (Wood processing 2007). Ash wood is relatively easy to process and has good elasticity. It can be steam bent, with better results than beech wood. Thus ash is a precious species for furniture industry. Its texture, colour and cross-section are presented in Fig. 15.

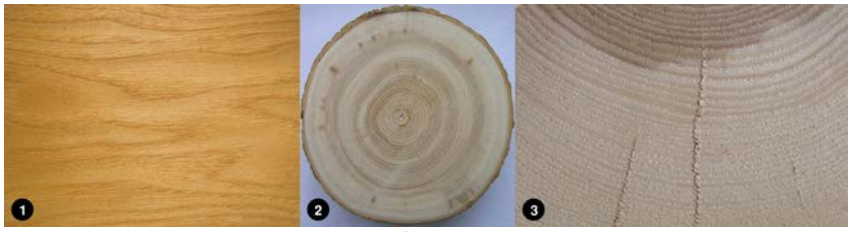


Fig. 15
Aesthetical properties of ash wood:
1 - texture and color; 2 - cross-section; 3 - zoom of cross-section.

A comparison can be made between the main characteristics of ash and other hardwood species frequently used for furniture manufacturing, such as oak and maple, by examining Table 2.

Table 2

A comparative analysis of the main characteristics for representative hardwood species (Wood processing 2007)

	OAK (*Quercus Petraea*)	ASH (*Fraxinus Excelsior*)	MAPLE (*Acer Saccharum*)
Origin	Europe	Europe	Europe, Noth America
Colour	yellow-brown/yellow-golden	white-yellowish	white-reddish
Density	600Kg/m^3-800Kg/m^3	600Kg/m^3	550Kg/m^3-700Kg/m^3
Texture	coarse	medium-coarse	fine
Fibers	straight	straight	straight
Hardness	medium	medium	medium
Oxidation	medium	very low	low
Durability	high	medium	medium
Contraction	medium	medium	medium
Mechanical resistance	optimal	medium	optimal

The proposed material to be used for reclined seats, solid wood, needs specific technological solutions in order to keep its mechanical characteristics, compared to the usage of wood bent through thermal treatment or of bent plywood. For curved pieces made of solid wood, the method is cutting-out. This minimizes the number of needed operations and also can bring advantages regarding resistance, but with high losses of material leading to higher costs. A solution which ameliorates this problem is the use of more and smaller jointed elements, which would spare the raw material, but holds the risk of lowering the resistance of the elements.

As a first measure for rising the resistance of these components is overdesigning their dimensions in the assembly zones. Another solution is the reinforcement with metal parts, on the invisible parts, in a way that is not visually disturbing. Figure 16 presents the zones with higher risks with regard to resistance.

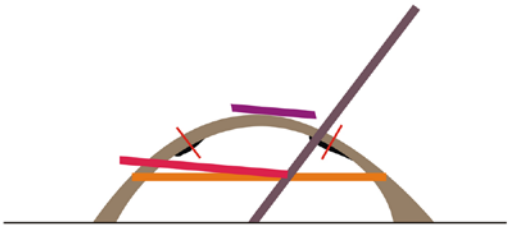
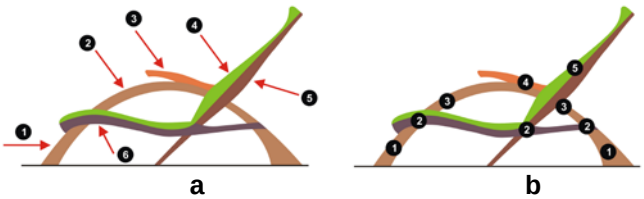


Fig. 16
Zones with higher risks with regard to resistance.

STRUCTURING: THE JOINERY ELEMENTS

The furniture piece is made out of parts that, through joining and assembling, offer to the product stability and high resistance to stress. Figure 17a shows the building parts, as follows: 1 – frontal leg binding (invisible from the sides), with the function of consolidating the structure; 2 – leg; 3 – arm; 4 – the elements which define the ergonomic line; 5 – back; 6 – transversal binding.

The elements need assembling in order to form a structure of resistance. The assembling zones are found in Fig. 17b.



a **b**

Fig. 17
The joinery elements:
a - building parts; b - assembling zone.

In the case of assembling number 1, the option of a stretcher made of solid wood can be used - or, as an alternative, a metallic rod to strengthen the legs. In the case when solid wood is used, the joining can be made by mortise and tenon, as seen in Fig. 18a.

The joint marked with 2 is made with metal assembly parts. A specific method of assembling solid wood frames is the use of M6 coupling screws, with threaded bolts. Fig. 18b presents this type of assembly.

The longitudinal joint, marked with 3, for making of the leg, as noted in the previous chapter, is made out of three parts, in order to maintain economy of material. The jointing of curved elements is made longitudinally, by gluing.

Finger joints and mortise and tenon joints are used, with wedged cuts. Out of these types the finger joint is the most adequate regarding the longitudinal jointing of the massive wood remains. (Curtu 1998)

Fig. 18c shows the types of finger joints (1) and mortise and tenon joints (2).

The mounting of the armrest, noted with 4 is made by cylindrical dowel. Fig. 18d shows an example of this type of assembling.

The side elements (Fig. 18e), are the ones that play also an aesthetic role. The chosen solution for construction, which helps maintaining the ergonomic line, is the use of transversal solid wood elements with various heights, which follow the proposed ergonomic line. They are distributed at distances equal with the height of the elements. They are assembled with the seat and the back with cylindrical dowels. They can be individually re-profiled and re-dimensioned if needed, in order to keep the ergonomic profile. Variants of the section are found in Fig. 18e.

Fig. 18
Solutions for assembly:
a - mortise and tenon joinery; b - M6 coupling screws, with threaded bolts; c - leg joinery, finger joints (1) or mortise and tenon joinery (2); d - armrest joinery, cylindrical dowel; e - side and back elements, various sections.

The constructive, dimensional, ergonomic and design aspects which lead to the carrying out of this study led to the design of a furniture prototype adequate for relaxed sitting. The final version is shown in Fig. 19. This model satisfies the necessities which are specific to this category of furniture, facilitates the phases of the design process and constitutes a helpful source for dimensioning.

Fig. 19
The final version.

CONCLUSIONS

The purpose of this paper was to present the complexity and interactions of the factors that arise during the design process which need to be taken into consideration when conceiving furniture for reclined sitting.

The design phases had in view a group of furniture under less standardizing rigors. Innovative ways had been found for approaching the design concept of relaxed sitting furniture, together with constructive solutions which would bring the product to a higher performance. The design generated challenges in the choice of technical solutions, which should not alter the aesthetical considerations.

Also some perspectives are opened for a deeper study of the aspects regarding resistance calculations for the jointing of the parts. The method of analysis using finite elements, through approximate numerical calculus, can solve problems regarding the evaluation of deformations and tensions that arise under external forces and stress. The result is a higher viability for the product.

The furniture for relaxed sitting for which this study has been made is intended not only to be integrated into the human habitat, but to become itself an attractive object, satisfying in optimal conditions the comfort necessities and enhancing the visual qualities of the solid wood texture.

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