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Do it-yourself furniture: Part A - Designing fittings for an easy-to-manufacture hybrid chair

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Abstract

Traditional productions of goods are being changed by technological advances. Furniture production also takes its portion from this either positive or negative manner. Because either traditional wood material preparing ways or design and manufacturing of fittings are being changed by the technological software and hardware. The do-it-yourself perspective of additive manufacturing applications emerges as a reflection of these advances and changes. Different types of connectors were designed and manufactured for a specific joint of a chair by previously published studies. However, in this study, four different connector types were designed for properly assemble of a chair instead of element joint in accordance with the do-it-yourself perspective. CATIA software was used for three-dimensional modeling and assembly. Dowels were applied to each joint for strengthening chair construction. Wooden elements were designed without curves to provide easy-to-manufacture chairs for end-users who have limited knowledge about wood joinery. Views and sections were included for presenting the assembly details. Some construction add-ons such as an upholstery seat and a backrest with a proper slope were offered to improve the comfort issue that arises from the straight-line design approach.

Keywords: CATIA, Chair, Connector

Kendin yap mobilya: Bölüm A – Kolay imal edilebilir melez sandalye için bağlantı elemanları tasarımı

Öz

Teknolojik gelişimlerle birlikte ürünlerin geleneksel imalat şekilleri değişmektedir. Mobilya imalatı da bundan olumlu ya da olumsuz anlamda payını almaktadır. Çünkü gerek geleneksel ahşap malzeme hazırlama gerekse de bağlantı elemanı tasarım ve üretimi teknolojik yazılım ve donanımlarla değişime ve gelişime uğramaktadır. Eklemeli imalat ile kendin yap anlayışı da bu gelişim ve değişimin yansımalarından biri olarak karşımıza çıkmaktadır. Önceki çalışmlarda genellikle sandalyenin belli bir bağlantısı için farklı tip elemanlar tasarlanıp üretilmiştir. Fakat bu çalışmada, kendin yap anlayışı doğrultusunda bir sandalye montajının tam olarak yapılmasını sağlamak için dört farklı bağlantı elemanı tasarlanmıştır. Üç boyutlu modelleme ve montaj için CATIA yazılımı kullanılmıştır. Sandalye konstrüksiyonunu güçlendirmek için herbir bağlantı noktasına kavelalar uygulanmıştır. Ahşap parçalar, ahşap doğramacılığı hakkında kısıtlı bilgiye sahip olan nihai kullanıcıların bir sandalyeyi rahatlıkla imal edebilmesi için herhangi bir kavis olmadan tasarlanmıştır. Sandalye montaj detaylarını göstermek için görünüşler ve kesitlere yer verilmiştir. Uygun eğimlere sahip takılıp çıkarılabilir döşemeli oturak ve sırtlık gibi bazı konstrüksiyon eklentileri düz hatlı tasarım yaklaşımı nedeni ile ortaya çıkan konfor meselesini iyileştirmek için önerilmiştir.

Anahtar kelimeler: Bağlantı elemanı, CATIA, Sandalye

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1 Introduction

Sitting on a floor, carpet, stone, tree trunk, or modern thing such as a chair is a relaxative and vital activity for the human being from past to now. In the past, it was not as comfortable as now due to material variety, and improvements in transformation abilities such as using machines to manufacture goods that are effectively designed using software considering ergonomics and other human-related scientific data. Furthermore, emerge of the engineered materials for the production which made goods (such as chairs) available to the community instead of notable historical figures or people who had high purchasing power in the past. Moreover, material and production method innovations appeared in all fields of design along with the industrial revolution (Uludüz and Aydın 2022). Changes and transformations are an inevitable part of history not only for humans but also almost for everything. For example, advances in technology made changes in the design and production style of chairs. However, firmly in contact with the body for comfort and health, utilization ability in lots of places and moments are the main features of a chair (Kim et al. 2011). Furthermore, chairs are the furniture that has prearranged and personal seating spaces (Çevik 2010).

Personalization of the production is not untouchable in recent years due to technological developments such as additive manufacturing (AM) or in other words three dimensional (3D) printing. The AM or 3D printing is not a new-sprung method for production, indeed 80's are the years of emerging technology but nowadays they have become actual. Because, the basics of production were reformed by AM due to some outstanding properties such as speed, the ability of complex geometry production, and economy (Bandyopadhyay and Heer 2018). However, most 3D printers are being used for rapid prototyping instead of manufacturing although significant improvements were made,. It is because, limited building volumes and material features, and long printing durations are the essential limitations of 3D printing to overcome (Hajash et al. 2017). But, by producing new innovative materials, furniture production took place in AM and Cellular loop, a cantilever chair based on biomimetic using 3D printer, is one of the rapid prototyping examples for furniture (Peters and Drewes 2019).

Software, 3D printers, and innovative materials can be assumed as game-changing advances that have impacts on traditional carpentry and, day by day, the number of researches that focused on the evaluation of these three factors in furniture production increases. Followings are some recent studies dealing with chair properties; Chair design (Sperling et al. 2006), prototyping of a chair using 3D printing (Bhooshan et al. 2017; Yulvan and Sunarmi 2019), use of 3D scanners and printers for the renovation of damaged round element used for joining the veneer laminated chair and metal legs (Akkaş and Andaç Güzel 2021), comfort evaluation of Office chair (Maradei García et al. 2017), office chair design according to ergonomic-anthropometric approaches (Noshin et al. 2018), user-oriented chair design (Kim et al. 2011), design and evaluation of mechanical behavior of low-cost school chair (Začal et al. 2016), and finite element analysis of chair (Aydın and Yılmaz Aydın 2017; Yılmaz Aydın et al. 2016).

CATIA is the software that includes computer-aided design (CAD), manufacturing (CAM), engineering (CAE), and product lifecycle management (PLM) modules and is known lesser in the wood science and technology field. Therefore, there are limited studies that evaluated wood or wood-based products using CATIA, and the followings are some of them. Stress analysis of poly-urethane (PU) armchair seat (Butnar et al. 2016), ergonomics evaluation of chair (Ansari et al. 2018; Binti Mohd Ali 2010; Mahantesh et al. 2021; Sarı and Şahin 2019; Paloma 2018; Yusuff et al. 2008) and office furniture (Top 2019) by RULA,

modeling the scanned chair of Thonet (Barros et al. 2011), 3D modeling and finite element analysis (Haraga and Goantă 2017), and parametric design of furniture (Buna et al. 2015).

Providing uncomplicated structures including joints to decrease the unforeseeable expenses of an intricate design to avoid material losses (Valiyousefi and Alihedarloo 2019) and designing a furniture assembly components using CATIA which the end-user can produce using AM and using these components to assemble a chair or stool is the main motivation of this study. When the literature was reviewed, it can be seen that studies on chair assembly using additively manufactured connectors focused on just one specific joint of the chair elements such as the front leg and stretcher. However, this study presented a complete connector set for a chair assembly.

2 Materials and Methods

CATIA v5 R17 software was used to design and 3D modeling of connectors. Part and assembly design modules were used for element modeling and joints, respectively. As can be seen in Figure 1, four different connectors were designed to make a chair or stool construction available. The wall thickness of the connectors is 2mm. At the core of the design, there is a 29x29 hollow cube with 2mm thick walls and it has a 31mm extension to provide connections of wood parts. The Acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) material properties were applied to connector models. Moreover, the default material library was used for wooden elements.

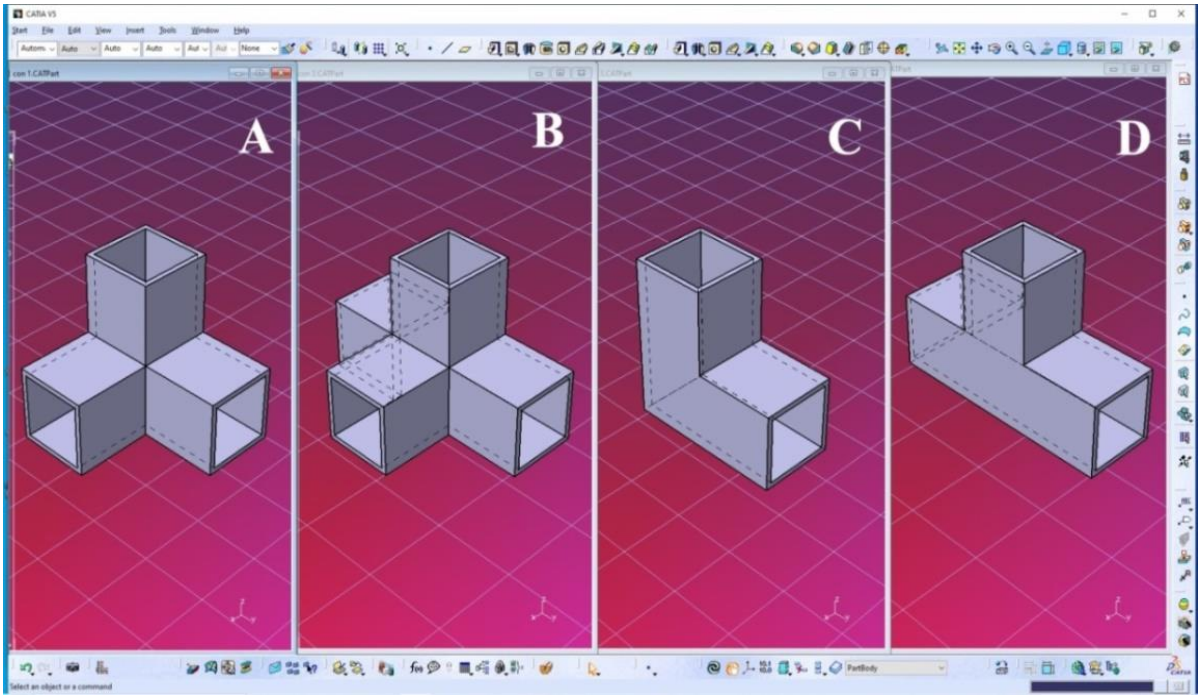

Figure 1. Four different connector designs

Wooden elements, seen in Figure 2, were designed without any curve according to easy-to-manufacture criteria. Cross-cut size of all the wooden elements is 25x25mm. Seat height without seating element (40cm) and depth (42cm), and backrest height (90cm) are in the range of typical values reported in (Home-Douglas 1994). Therefore, inner parts are sized according to these values and joinery details. For the exact positioning of the wooden elements and connectors, constraints such as contact (directed surfaces) and coincidence (element alignment) were defined. At the end of the assembly, exploded view was presented (Figure 2 right) to demonstrate the assembly details.

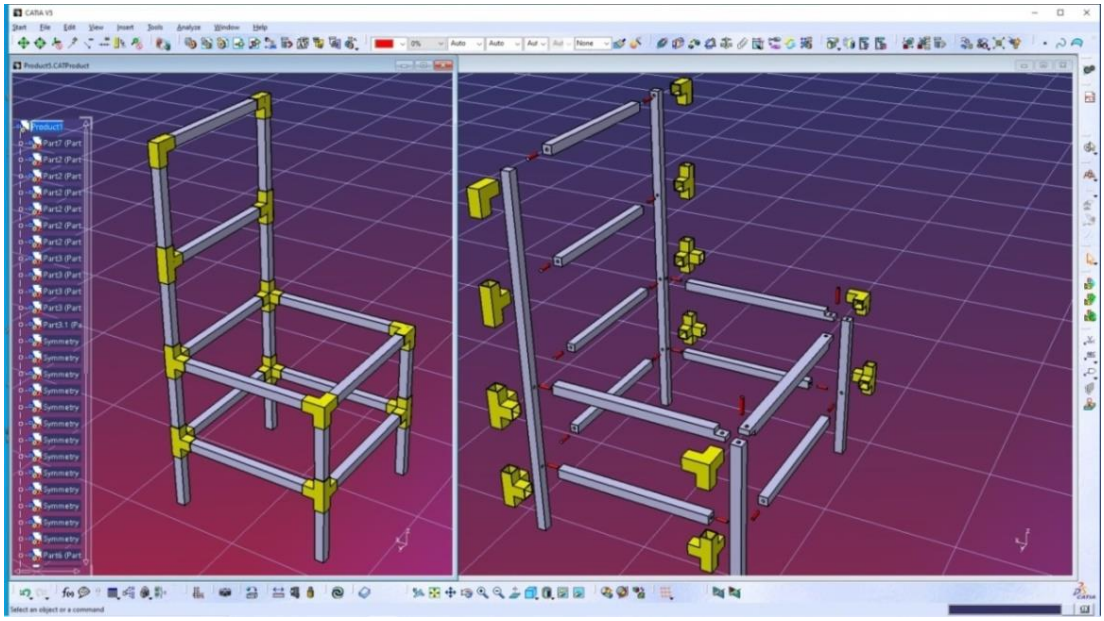

Figure 2. Assembly details

3 Results and Discussion

A total of 12 connectors (2xA, 6xB, 2xC, and 2xD) are needed to assemble the chair frame. As can be seen in Figure 2, dowels were used to fasten chair elements to one another. Furthermore, an end lap joint was used to fasten the apron (also seat or front rail) and side rails together. Moreover, as can be seen in the E, G, K, and M section views projected from Figures 3 and 4 are presented in Figure 5, the apron and side rails were connected to the front leg using a dowel. These two joinery tricks improve the rigidity of the construction. As can be seen in Figure 2, all the chair elements were designed as flat or straight instead of curved or else. It can be thought that a sense of aesthetic is regarded but in this study, the main motivation was to provide a design for producing a chair by performing a few production processes not only for the simplicity of the do-it-yourself perspective but also to minimize production cost and easy to the accessibility of straight-line simple wooden element if the person does not have woodworking tools such as circular saw, etc. Furthermore, in the design phase, some of the ergonomic criteria such as backrest slope were overlooked, and the chair may fail to satisfy comfort. Furthermore, it may shorten the sitting duration due to discomfort. These disadvantages are not related to fittings and discomfort arises due to reduced contact area between person and chair. Because, when the angle between the back of the chair is higher than 90°, load distribution changes and the backrest undertakes some of the load by improving the contact area of the upper body. On the other hand, the slope of the seat is another factor that influences the load or pressure distribution. Therefore, elements, particularly for the backrest of the back leg and side rail, should be designed with proper slopes. Such slopes also cause design changes for the fittings A and B. However, there is no slope between the legs and stretcher which are fixed together using fitting B. Therefore, in addition to these, A and B fittings with proper slopes should be produced. In this case, dowel holes should be drilled at a specific angle which may make production difficult for the regular users for the do-it-yourself process.

Stretchers were fixed to front and back legs using but-joints reinforced by dowels. Back legs were assembled on top and cross rails with dowels. A seating element was not designed because a seat with a cushion, laminated seat, or else can be applied according to consumer perceptions.

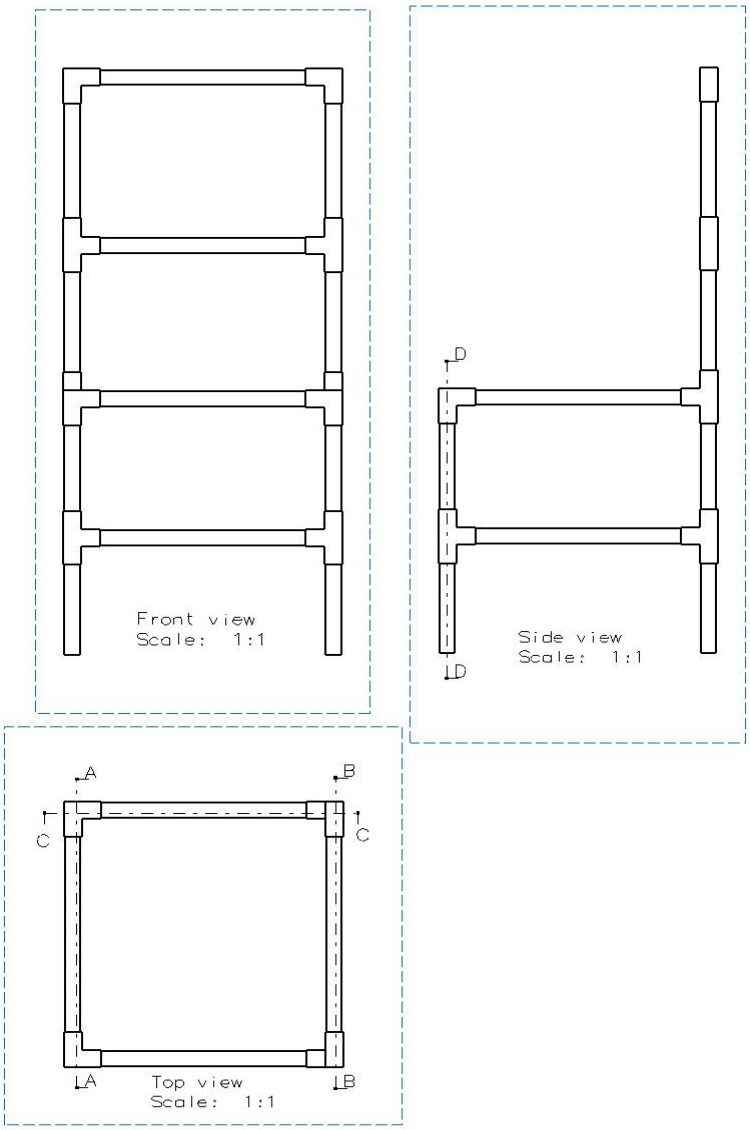

Figure 3. Top, front, and side views

The structural durability of the assembly is crucial and should be evaluated considering the related standards. For example, Uysal et al. (2015) evaluated the cyclic front-to-back load of four different stools assembled by screw, bed bold, mortise-tenon (pinned and glued), and dowel. Chen et al. (2022) evaluated the mechanical behavior of commonly used detachable and novel joints. Demirel and Kalaycı (2020) and Demirel and Bas (2021) evaluated the mechanical characteristics of furniture joints with staples. These are some of the traditionally produced furniture examples but, digital joinery for hybrid carpentry (Magrisso and Zoran 2019) is not a fiction indeed is a reality due to developments in the fields related to manufacturing technologies such as 3D printing. Furthermore, 3D printed furniture such as chairs, tables, and fittings at local shops of the consumers does not take long (Eti Proto and Koç Sağlam 2021). Therefore, a pilot study is going to figure out the mechanical behavior of assembled chairs with 3D printed connectors including numerical analysis to exemplify the hybrid carpentry. Performing destructive tests is important for determining the design failures and mechanical behavior which may provide essential feedback for size, shape, and topology improvements to meet the requirements. This issue is going to be figured out by the second phase of this study.

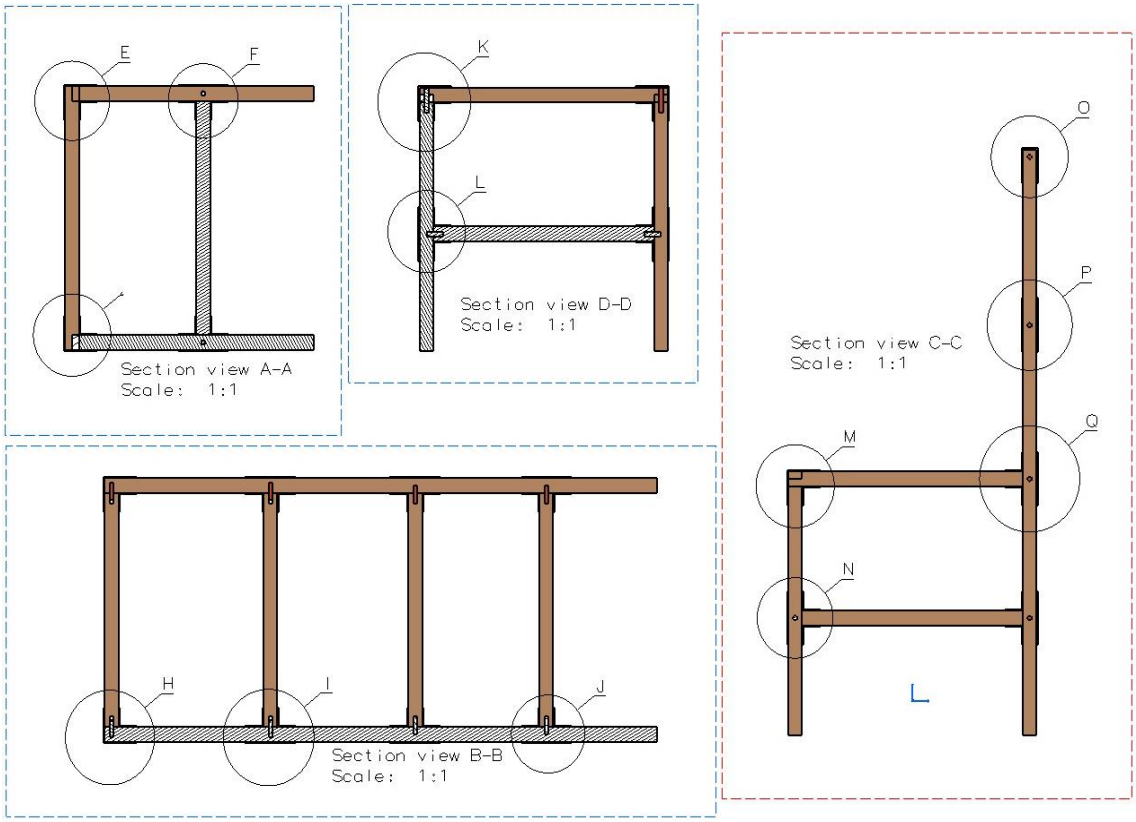

Figure 4. Section views

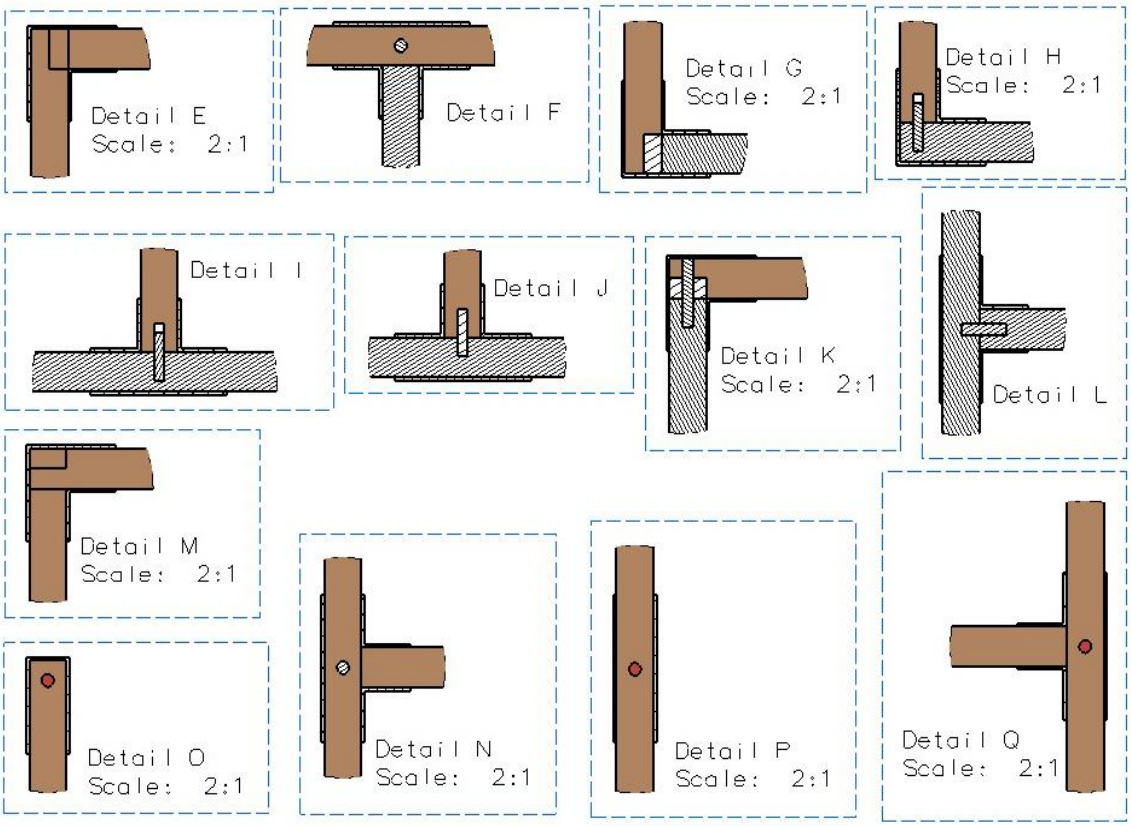

Figure 5. Details for the section views

A similar connector, seen in Figure 6, was designed by Nicolau et al. (2022) for comparing the mechanical behavior of mortise and tenon and 3D printed connector (fiberglass-reinforced PLA) connected chair leg and stretcher. As can be seen in Figure, one of the essential differences is the curved edges and support extensions.

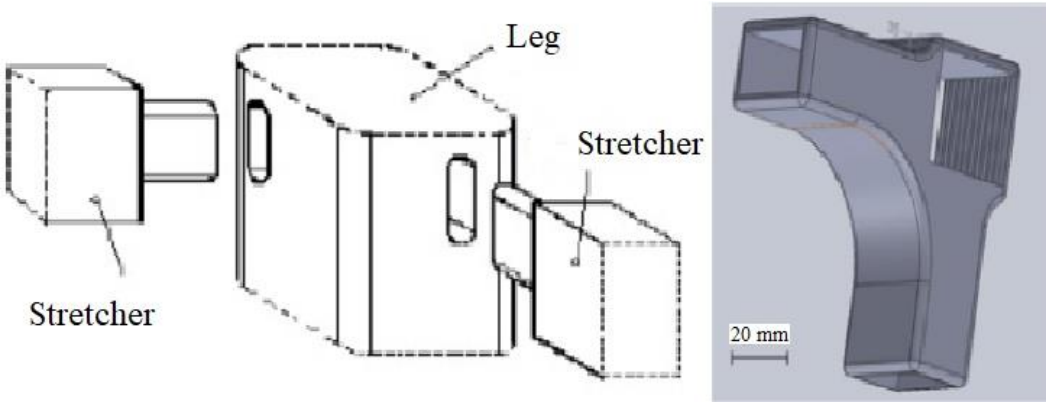

Figure 6. Mortise-tenon jointed chair leg and connector design for leg and stretcher (Nicolau et al. 2022)

As well-known, wood has a porous and hydrophilic nature and polymeric materials used in 3D printing for furniture applications are generally hydrophobic. Due to the opposing behavior of these two materials, fixing them using chemicals requires attention to provide sufficient bonding strength as Kariz et al. (2017) noticed for bonding ABS and beech lamella.

Plainness, weightlessness, and packing ability in relatively small volumes for personal or commercial shipments are some of the prominent properties for achieving the title of the most sold chairs globally (Barros et al. 2011), and it can be said that chair design of this study is able to meet all of these requirements while comfort is questionable. The designs of the majority of the chair produced even now are not as they should be and the bulk of the chairs is comfortless (Malik et al. 1984). Indeed, instead of aesthetics, ergonomics is basic for the comfort of a chair (Dainoff et al. 2007). Therefore, without reducing the easy-to-manufacture perspective, some improvements should be added to eliminate such adverse effects of the straight-lined elements used in this study. For example a detachable back support and cushion seat with the proper angle. Further information on a scientifically designed chair that meets the ideal seating is reported by Malik et al. (1984).

Typical seat and backrest angles are 0° to 5° and 10° to 15°, respectively (Home-Douglas 1994). In this study, the angles of the seat and backrest are 0°. For this study, straight lines were chosen due to provide easy-to-manufacture parts for end-users who have limited knowledge about material and complex production ways for joints. For seating angle, 0° seating angle may cause front sliding of the user. However, a 0° backrest angle may cause sitting disorders or discomfort. Therefore, for the users who are willing to produce do it yourself (DIY) chair, angle and height are two important parameters that should be taken into consideration to minimize neck strain and adequate support.

Two mm wall thickness of the connectors may look unaesthetic due to the difference in the surface levels. Therefore, elements should be prepared as presented in Figure 7 (rendering with wood texture does not reflect the proper surface views corresponding to the log cuts such as quartersawn, flatsawn, or riftsawn) to equalize the surface levels. However, this modification is applicable only for the outer sections of the elements and requires cutting capabilities that a regular user cannot do.

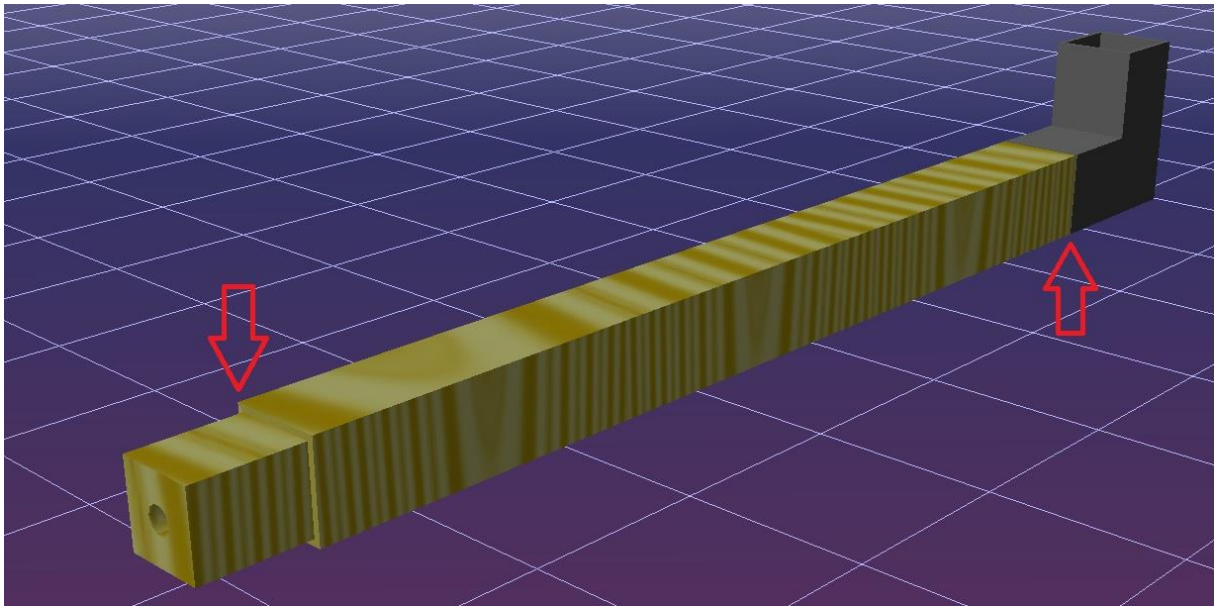

Figure 7. Modification of the element to equalize the surface levels

Footstep of the AM in furniture production on the increase and some dramatic changes run up on us. Traditional professions such as furniture production would be adversely influenced by AM if all the production activities begin and finish between the designer and printer (Aydın 2015). Recent developments in manufacturing technologies and related fields are steering traditional processes through advanced methods such as AM. The AM may play an essential role in the hybridization of carpentry with the utilization of advanced 3D modeling software and printing processes. This can be assumed as a potential disruptive side of the AM for traditional business.

4 Conclusion

In this study, four different connectors with 2 mm wall thickness were designed to assemble straight line wooden elements for making available DIY chair production.

- Besides providing joinery for the chair, just two of them (Figures 1-A and B) can be used to assemble a stool.
- The weak sides of the connectors are going to be re-designed after performing the mechanical testing and numerical comparison by a pilot study.

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Author Contributions

Tuğba Yılmaz Aydın: Research idea, planning and conducting studies, obtaining data, writing the manuscript, publishing the manuscript.

References

Akkaş, G., Andaç Güzel, T., (2021), Strength of a chair renovated with additive production systems and reverse engineering approach. *European Journal of Science and Technology*, *32*, 1150–1155. https://doi.org/10.31590/ejosat.1054613

Ansari, S., Nikpay, A., Varmazyar, S., (2018), Design and development of an ergonomic chair for students in educational settings. *Health Scope*, 7(4), 1-9. https://doi.org/10.5812/jhealthscope.60531

Aydın, M., (2015), Additive Manufacturing: Is it a new era for furniture production? *Journal of Mechanics Engineering and Automation*, *5*(6), 338–347. https://doi.org/10.17265/2159-5275/2015.06.002

Aydın, M., Yılmaz Aydın, T., (2017), Finite element analysis of chair frame using CATIA. In A. Aytin, S. Çiftçi, and İ. Baykal (Eds.), 4th International Furniture and Decoration Congress (pp. 22–32). Düzce: Düzce Üniversitesi.

Bandyopadhyay, A., Heer, B., (2018), Additive manufacturing of multi-material structures. *Materials Science and Engineering R: Reports*, *129*, 1–16. https://doi.org/10.1016/j.mser.2018.04.001

Barros, M., Duarte, J. P., Chaparro, B., (2011), Thonet chair design grammar: A step towards the mass customization of furniture. Designing Together: CAADFutures 2011 - Proceedings of the 14th International Conference on Computer Aided Architectural Design, 181–200.

Bhooshan, V., Fuchs, M., Bhooshan, S., (2017), 3d-printing, topology optimization and statistical learning: A case study. *Simulation Series*, *49*(11), 88–95. https://doi.org/10.22360/simaud.2017.simaud.012

Binti Mohd Ali, N. A., (2010), Risk of muscula-skeletal disorders and the development of ergonomic furniture for primary school children in Malaysia. Universiti Putra Malaysia.

Buna, Z., Badiu, I., Eles, A., (2015). On using parametric modeling in furniture design. *Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering*, *58*(2), 239–244.

Butnar, L. A., Basarman, A. P., Tranisan, D. I., Cioban, H. A., (2016), Von mises stress anallysing of the polyurethane armchair seat. *Materiale Plastice*, *53*(4), 678–680.

Çevik, G., (2010), American style or Turkish chair: The triumph of bodily comfort. *Journal of Design History*, *23*(4), 367–385. https://doi.org/10.1093/jdh/epq028

Chen, B., Xia, H., Hu, W., (2022), The design and evaluation of three-dimensional corner joints used in wooden furniture frames: Experimental and numerical. *BioResources*, *17*(2), 2143–2156.

Dainoff, M., Mark, L., Ye, L., Petrovic, M., (2007), Forget about aesthetics in chair design: Ergonomics should provide the basis for comfort. *Lecture Notes in Computer Science* (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 4566 LNCS, 19–25. https://doi.org/10.1007/978-3-540-73333-1_3

Demirel,S., Bas, S., (2021), Evaluation of creep characteristics of singlestaple furniture joints made of different wood species. *Drvna industrija, 72*(2), 179-186.

Demirel,S., Kalayci, G., (2020), Measuring and estimating shear force of one stapled and one-row multi stapled wood joints. *Maderas ciencia y tecnología, 22*(3), 395-404. https://doi.org/10.4067/s0718-221x2020005000313

Eti Proto, M., Koç Sağlam, C., (2021), Furniture design education with 3D printing technology. *Lecture Notes in Networks and Systems*, *240*, 97–105. https://doi.org/10.1007/978-3-030-77040-2_13

Hajash, K., Sparrman, B., Guberan, C., Laucks, J., Tibbits, S., (2017), Large-scale rapid liquid printing. *3D Printing and Additive Manufacturing*, *4*(3), 123–131. https://doi.org/10.1089/3dp.2017.0037

Haraga, G., Goantă, A. M., (2017), FEA analysis and design optimization for a multifunctional piece of furniture. *MATEC Web of Conferences*, *112*. https://doi.org/10.1051/matecconf/201711206009

Home-Douglas, P., (1994), *The art of woodworking: Building chairs*. Richmond, Virginia: Time-Life Books.

Kariz, M., Kuzman, M. K., Sernek, M., (2017), Adhesive bonding of 3D-printed ABS parts and wood. *Journal of Adhesion Science and Technology*, *31*(15), 1683–1690. https://doi.org/10.1080/01694243.2016.1268414

Kim, G. H., Choi, K. R., Sung, Y. J., (2011), A study on versatile chair design reflecting users' behavior. *Journal of the Korea Furniture Society*, *22*(3), 151–159.

Magrisso, S., Zoran, A., (2019), Digital joinery for hybrid carpentry. *Lecture Notes in Civil Engineering*, *24*, 441–461. https://doi.org/10.1007/978-3-030-03676-8_16

Mahantesh, M. M., Rao, K. V. S. R., Mandal, J., (2021), Human digital modeling and RULA analysis for an office chair user in computer work environment - A case study in Indian context. AIP Conference Proceedings, *2316*. https://doi.org/10.1063/5.0036414

Malik, S. L., Jurgens, H. W., Helbig, K., (1984), Designing a chair: A scientific perspective. *Indian Anthropologist*, *14*(1), 41–61.

Maradei García, F., Galindo Estupiñan, Z., Castellanos Olarte, J., (2017), Comfort testing in office chair design. *Revista UIS Ingenierías*, *16*(1), 69–74. https://doi.org/10.18273/revuin.v16n1-2017007

Sarı, M.İ, Şahin, İ., (2019), Ergonomic analysis based on digital human modelling: adjustable school furniture design for secondary school students. *Journal of Polytechnic*, *0900*(4), 1097–1110.

Nicolau, A., Alin Pop, M., Coşereanu, C., (2022), 3D printing application inwood furniture components assembling. *Materials*, *15*(2907), 1–15.

Noshin, L., Sen Gupta, H., Kibria, M. G., (2018), Office chair design: a systematic approach of ergonomic design based on the anthropometric measurement of Bangladeshi people. *International Journal of Research in Industrial Engineering*, *7*(2), 224–234. Retrieved from http://www.riejournal.com/article_63512.html

Paloma, M. F., (2018), *Redesign of a classroom chair from the campus of Parma*. Universita di Parma, Italy.

Peters, S., Drewes, D., (2019), Additive production and 3d printing. In S. Peters and D. Drewes (Eds.), *Materials in Progress: Innovations for Designers and Architects* (pp. 158–193). Berlin: Birkhäuser.

Sperling, L., Kristav, P., Olander, E., Eriksson, J., Lekeberg, H., (2006), Exploring emotions for design of your future chair. Proceedings from the 5th Conference on Design and Emotion 2006.

Top, N., (2019), Ergonomic analysis and redesign of operational office furniture design by RULA method. *Gazi Mühendislik Bilimleri Dergisi*, *5*(3), 290–299.

Uludüz, Ç., Aydın, Ç., (2022), Machine as the designer of generative solutions in chair

design. *Journal of Computational Design*, *3*(1), 81–104. https://doi.org/10.53710/jcode.1070450

Uysal, M., Haviarova, E., Eckelman, C. A., (2015), A comparison of the cyclic durability, ease of disassembly, repair, and reuse of parts of wooden chair frames. *Materials and Design*, *87*, 75–81. https://doi.org/10.1016/j.matdes.2015.08.009

Valiyousefi, M., Alihedarloo, A., (2019). Study the impact of 3D-printed joints on the complex wooden structures. International Congress on Science and Engineering. Tokyo: University of Tokyo.

Yılmaz Aydın, T., Güntekin, E., Aydın, M., (2016), Finite element (FE) analysis of chair frames constructed with Turkish red pine (*Pinus brutia* Ten.). 1st International Mediterranean Science and Engineering Congress, 1919–1925. Adana: Çukurova University.

Yulvan, Y., Sunarmi, S., (2019), Technology of 3D Printing in the creation of design by Interior Design Students, In: SEWORD FRESSH 2019, 27 April 2019, Surakarta, Central Java, Indonesia. https://doi.org/10.4108/eai.27-4-2019.2286938

Yusuff, R. M., Ny, Y. S., Aziz, F. A., (2008), Ergonomics evaluation of school furniture design for primary school children in Malaysia. The 9th Southeast Asian Ergonomics Society Conference, (1992), 1–9.

Začal, J., Dostál, P., Šustr, M., Barboutis, I. A., (2016), Design and testing of low cost chair with round mortise and tenon joints. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 64(2), 567–572. https://doi.org/10.11118/actaun201664020567