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Strength properties of furniture corner joints constructed with different wooden connectors and wood-based materials

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Abstract: *Strength properties of furniture corner joints constructed with different wooden connectors and wood-based materials.* The aims of this study were to determine the influence of the type of invisible wooden connectors on the strength in glued corner joints for chipboard and MDF, the most popular boards in box furniture. Three variants of connectors arrangement were considered: variant I - with the use of 4 wood grooven beech dowels, Variant II - with the use 2 beech Domino pins, Variant III - connectors mixed arrangement. Experiment results indicated that samples prepared using joining with dowels provided the highest strength values of all variants (F=1169 N for MDF panel, F= 617 for chipboard panel). Moreover, it has been observed that the corner connection with Domino pins is the type of connection with the lowest strength. It is worth noting that the above tendency was observed in both types of wood-based panels. The influence of the material also turned out to be a statistically significant factor in the analysis of joint strength. The use of MDF panel increased the strength values ,by 47% of the dowel joint, by 36% of the Domino pins and 34% of the connectors mixed arrangement, compared to their use in chipboard.

Keywords: furniture corner joints, dowel, Domino pin, strength, wood-based materials, cabinet furniture

INTRODUCTION

The box furniture used in kitchens, bathrooms, offices and other rooms for storage are essential elements of home furnishings. They is largely made of board elements (chipboards, MDF, etc.), where the dimensions of the thickness of the elements are relatively small compared to the overall dimensions (Smardzewski 2019). There are the relatively large number of various factors in the furniture design process, that should be taken into account that have a significant impact on the load-bearing capacity (strength) of these structures. The most important of them are: type of corner joints, engineering fits, type of material (wood and wood-based material), type of glue, accuracy of production, dimensions, humidity etc. (Wilczyński et al. 2000). Knowledge of their impact on the strength of a piece of furniture is a key aspect at the furniture design stage. However, testing the entire large-size box furniture is often problematic, costly and long-lasting. It's know that, one of the most important is definitely the strength of corner joints in furniture, which has a direct effect on the durability of the product (Altinok et al.2009).

According to researchers joints are the weakest parts of furniture and they are the primary cause of failure; thus, their design is very important. Even though furniture components have enough strength to carry the loads that the furniture bears, joint failure can negatively affect the whole furniture structure (Smardzewski et al. 2002, Smardzewski 2019, Eckelman et al. 2011). Therefore when designing wooden (or wood-based material) structures and furniture, it is very important and usually sufficient to consider joints (Zaborsky et al. 2018). Consequently, the selection of the proper joint is of great importance, because it affects the design, the strength and the total quality of the furniture. The selection of the type of joint and its properties is one of the most important design stages

Generally, furniture corner joints are located so as to close a certain space, using five or six elements that can be connected to each other in two ways: by means of hidden joints (like like dowels, lamellas or Domino pins) or by means of visible, connectors (like confirmat screws or eccentric connectors).

There have been many studies that have aimed to determine the mechanical properties of furniture corner joints. Among the factors influencing the durability, the most important are such as wood species (Zaborsky et al. 2018, Aman et al. 2008, Kasal et al. 2012, Uysal et al. 2018), type of wood-based panel (Tankut et al. 2009, Imirzi 2013), type of furniture connector (Tankut et al. 2009, Chen et al. 2019), type of glue (Altinok et al. 2009, Zaborsky et al. 2018, Bardak et al. 2017, Abdolzadeh et al. 2015), size of joiners (Zaborsky et al. 2018, Smardzewski et al. 2016, Chen et al. 2018, Langová et al. 2019, Kasal et al. 2020), the number of fasteners (Smardzewski et al. 2016, Hao et al. 2020).

For the user of furniture, aesthetics is an important issue, along with high mechanical properties. Furniture connections should contain fasteners that have beneficial features both for users and for furniture manufacturers. The user wants to obtain aesthetic, functional and reliable connection values while the manufacturer expects low production costs, versatility of use, load-bearing capacity, durability and easy assembly (Branowski et al. 2020, Smardzewski et al. 2016). In furniture joints, internal stresses are caused by external forces, most often compressive, which are transferred from one element to another (Zwerger 2012). The contact surfaces at the joints must be tightly adjacent to each other so that the acting forces can be transferred through the structure. According to Sydor (2005), the stiffness of connections and their strength in elements made of chipboard and MDF depends, among others, on material features of the main plate elements, geometric features of the connector and technological features (clamping force, sequence of assembly of individual joints etc.).

The fasteners should be exactly matched to the holes made in the joined elements. Even a small mutual displacement of individual elements of the structure caused by inappropriate fitting of the joints can significantly affect the deformation of the entire structure. The arrangement of the fasteners is presented in various standards and the strength of a given furniture structure depends mainly on it. In non-detachable joints, the elements are connected with each other by means of various fasteners, most often made of wood, and then permanently with the addition of glue

Dowel joint are one of the most commonly used in corner joints of cabinet furniture structures. Their advantage is simple structure, availability, price and high aesthetics (invisible from the outside). Therefore, most global furniture manufacturers have been somewhat favored to dowel joints other than rectangular tenon joints in the furniture production (Chen et al. 2018). There have been many studies that have aimed to determine the mechanical properties of furniture corner pins joints. Most of them focused on comparing the strength of the dowels joints with other joints such as Rastex (Kowaluk et al. 2011), screw (Imirzi et al. 2013) butt connections, biscuit connections, splined connection (Tankut et al. 2009, Altinok et al 2009,), double-cone connector (Smardzewski et al. 2016), Minifix fasteners (Simek et al. 2007, Saar et al 2014), spiral-groove dowel (Chen et al. 2019) etc. Futhermore, the influence of dowel connection parameters such as dowel spacing (Chen et al. 2018, Norvydas et al. 2005, Simek et al. 2007), dowel size (Chen 2018), its embedment depths (Edril et al. 2000) and type of adhesive (Bardak et al. 2017, Abdolzadeh et al. 2015). on the furniture structural properties such as bending and tensile strength was examined

A great alternative to a dowel connection is the invisible Domino joint. It is a specially invented by Festool company type of connection that uses a properly designed pin or tenon having the appropriate shape (flattened prism with rounded edges and oval sections.) and grooves into which the Domino joint is inserted. Domino pins are made from solid beech and are slightly compressed so that the plates can absorb moisture from water-based glue, causing them to swell in the slots for a tight fit and strong bond. The Domino system is used for connections used in furniture, interior design, for the production of window structures, joining frames and much more. The grooves on Domino pin can be easily prepared using a special milling machine designed for the DOMINO system by Festool, a classic milling machine or a CNC machine (Festool 2016).

The mortise and loose tenon joint has been used in furniture industry in joints requiring high strength for many years [Aman et al. 2008]. There are some studies devoted to this topic. Aman et al. made a comparison of loose tenon with conventional mortise and tenon (M&T) joint and dowel joint strength for tree wood species (cherry, maple and oak wood). From the obtained results it was concluded that M&T joints generally outperform dowel joints. For the wood species studied loose tenon joint perfotmance falls somewhere in between that of the traditional mortise and tenon joint and the dowel joint. Derikvard et al (2014) studied the effects of bottom shoulder width, tenon depth of embedment, tenon width and tenon wood species on the bending moment capacities of T-shaped mortise and loose-tenon furniture joints. All of these factors turned out to be significant.

However, only a couple of published papers have considered the strength of Domino fasteners. However, the results of studies also carried out on solid wood (beech and spruce) by Zaborsky et al. (2018) show the influence of various factors (wood species, type of stress, type of adhesive, size of Domino connector) on the stiffness of the Domino joint. The wood species, type of stress and thickness of the Domino were found to be important. The samples made of beech wood showed noticeably greater strength to the stiffness of the joints.

It turns out that few research has been performed on wooden connectors arrangement such as Domino pins and dowels on strength parameters. The research studies cited above focused primarily on the factors as various species of solid wood only (therefore they mainly concern frame structures of furniture). There are no reliable studies comparing the strength of Domino pin, dowel and their mixed arrangement in furniture corner joints made of wood-based material for box furniture. Although Domino pin connectors are now increasingly used in the construction of furniture cabinets, there is no many information available that can be used in design

The paper describes the results of an experiment aimed at comparing strength of the type of invisible wooden fasteners as Domino join, dowel join and their mixed arrangement version for such the wood-based material as MDF and chipboard, the most popular boards in box furniture

MATERIAL AND METHODS

For the experimental two type of wood-based panels: 18mm three-layer chipboard and 18mm thick medium density fiberboard (MDF) were tested. When choosing the material, the main consideration was its wide and common use for creating furniture with a box structure. Each L-shaped specimen consisted of 2 principal structural members, forming a right angle with each other after joining. The dimensions of the two pieces were: the Group A element 150mm in width, 150mm in length and 18mm in thickness, the Group B element 150mm in width, 132mm in length and 18mm in thickness. The dimensions were selected so that the length of the sample was identical after gluing (Fig. 1). In preparing the specimens, full size 18 mm thick sheets of chipboard and MDF (2070 by 2800 mm) were cut using a panel saw SAWTEQ B-300.

Two types wooden beech connectors, which most often used to create strong hidden joints, were used in the research: Domino pins with rounded edges, oval cross sections and grooved surfaces, and grooved dowels, the most commonly used furniture fasteners (Altinok et al. 2009].

Suitable markings were made on the face sides and edges of the Group A and B wood-based panels to be joined. The holes of 8 mm diameter and 12 ± 1 mm depth were drilled using a vertical drilling machine on Group A components. An electric drill and a special drilling template were used to make holes with a diameter of 8 mm and a depth of 24 ± 1 mm in the Group B components. In the experiments, 8 mm in diameter 34 mm long, grooved beech wood dowels were used. The total length of the drilled holes for the dowels was 2 mm longer than the length of the connector for excess glue.

The mortises were prepared using a DOMINO milling machine patented by Festool, in which the mortising depth is adapted to the respective tenons size. According to the recommendations of the milling machine manufacturer, the appropriate size of fasteners for box furniture made of wood-based panels is the catalog dimensions 5x30 mm (real dimensions are 5x19x28 mm). The depth of the grooves was set using the depth stop on the machine. Festool recommendations (Festool 2011, 2016) were used to select the appropriate depth. The appropriate width and thickness of the mortise were also set by the milling machine, according to the dimensions of the selected Domino tenon connector. Correspondingly, their depths were 12± 0,5 mm (the accuracy was estimated on the basis of own measurements) the Group A components and 20± 0,5 mm in the Group B components.
The arrangement of joints and a detailed view of the samples with all dimensions is shown in can be seen in Figure 1.

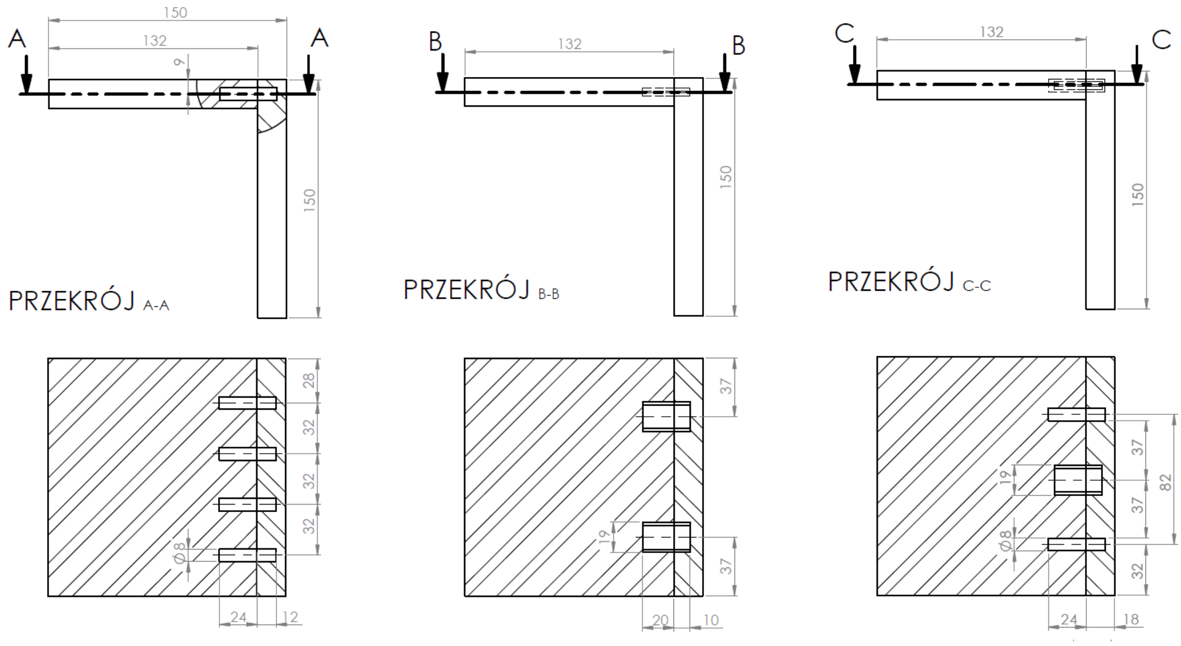

Fig. 1. The detailed view of the joints (from the left side: dowel joint, Domino pins joint and mixed joint)

In this way, holes and grooves were made in all elements for three different configurations of connectors. As a result, 3 variants of corner joins were created:
- Variant I - corner connection with the use of 4 wood beech dowels, the spacing of which was determined on the basis of generally accepted principles and amounted to 32mm (it is the standard distance resulting from the spread of tools on multi-spindle machines);
- Variant II – corner connection with the use 2 beech Domino pins, the spacing of which was determined by the by the positioning method in the case of the milling machine with the use of special stop pins (the distance from the edge of the element is 37 mm);
- Variant III - connectors mixed arrangement with the use of 1 Domino pin of the above-mentioned dimensions and 2 standard dowels (the fasteners spacing from each other and from the edge were 37 mm, like in variant II).
The geometry of the corner wall samples with 3 variants of connectors is displayed in Figure 2.

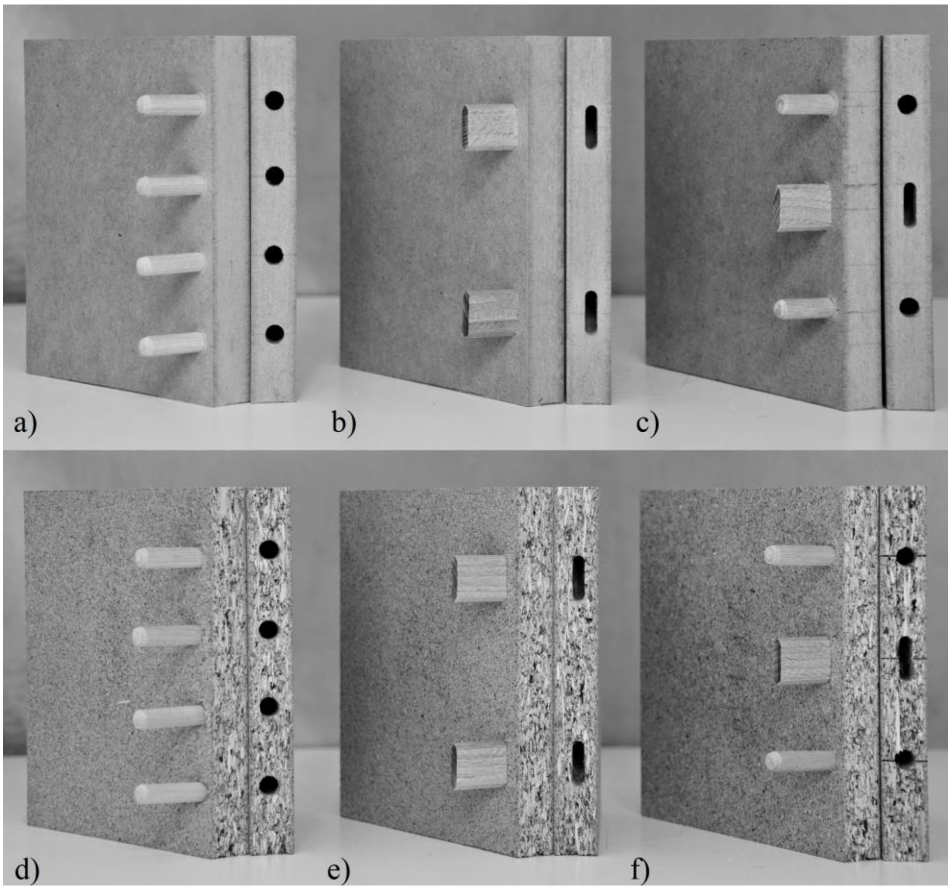

Fig. 2. Some samples before joining in three variants: a), d) Variant I b), e) Variant II; c), f) Variant III (respectively for MDF – on the top, and chipboard – on the bottom)

In this way, 60 sets of samples were created, 30 for each type of wood-based board (10 samples with pins, 10 samples with dominoes, 10 samples with mixed arrangement).

In the next stage, the prepared elements were glued with the use of RACOL polyvinyl acetate glue. The choice of glue was dictated by the convenience of applying to the material, quick drying, universality of use, availability and sufficient strength (the type of glue most often used in industry). Before assembling, the holes and grooves in the face and edge members were cleaned with compressed air to remove dust in order to promote good bonding of the pieces. After 24 hours of sample seasoning in the laboratory a double spread technique was used, in which adhesive was applied to both the walls of slots and the surfaces of the dowels and Domino pins. The samples joints were pressed together using a clamp and left to harden.

The methodology of testing the mechanical properties of corner connections is not standardized. On the other hand, the literature provides for various methods of fixing and methods of loading the samples. In studies of box furniture corner connections, the most popular methods of mounting the samples in the testing machine are:

- pieces of the sample formed an angle of 45 degrees in the direction of the loading force (Langova et al. 2013, Norvydas et al. 2005, Simek et al. 2007, Chen et al. 2018);
- the arrangement of the sample resembled a “gable roof” (the ends of the element rested on supports, a loading force acted on the top of the top) (Smardzewski et al. 2016, Kowaluk et al. 2011, Joscak et al. 2014, Majewski et al. 2020, Tas 2010).

Namely, a sample made of wood-based panels was placed on a testing machine in a manner similar to a “gable roof”. The samples of corner wall connections were tested on typical testing machine which is the equipment of the Department of Technology and Entrepreneurship in the Wood Industry in Institute of Wood Sciences and Furniture Warsaw

University of Life Sciences. In order to carry out the strength tests, a specially constructed device was used to fasten the samples in the testing machine. It was built of trolleys mounted on bearings that ran freely on metal rails, minimizing unnecessary resistance that could affect the results of the experiment. The trolleys have been constructed to the samples do not move, and the force is evenly distributed over the entire length of the elements and exactly in the symmetry axis of the "gable roof" (Fig. 3).

Fig. 3. The test stand with the use of a special equipment for fixing the samples on the testing machine

The load speed to destroy the connection was equal 10 mm / min. The maximum force value was registered as a result of the connection strength measurement.

After carrying out strength tests of furniture joints, small 50-mm square specimens were cut from the MDF and chipboard samples to determine the vertical density profiles across panel thickness. The density distribution within a wood-based panel is one of the most important panel quality attributes which largely determines panel end uses. Of particular interest is the control of the density distributions within the panel as they have a significant effect on the strength properties of these panels (Wang et al. 2006). An electronic wood X-ray machine was used to generate X-ray profile of samples used in the experiment

The analysis of variance (ANOVA) performed with Matlab was used to determine the effect of type of connectors and wood-based board on the maximum force.

RESULTS

The maximum strength were determined as the force applied to each experimental sample at the time of failure. The result for each of the samples was displayed by the computer to which the test device was connected. The distribution of forces during the experiment was also recorded (Fig. 4).

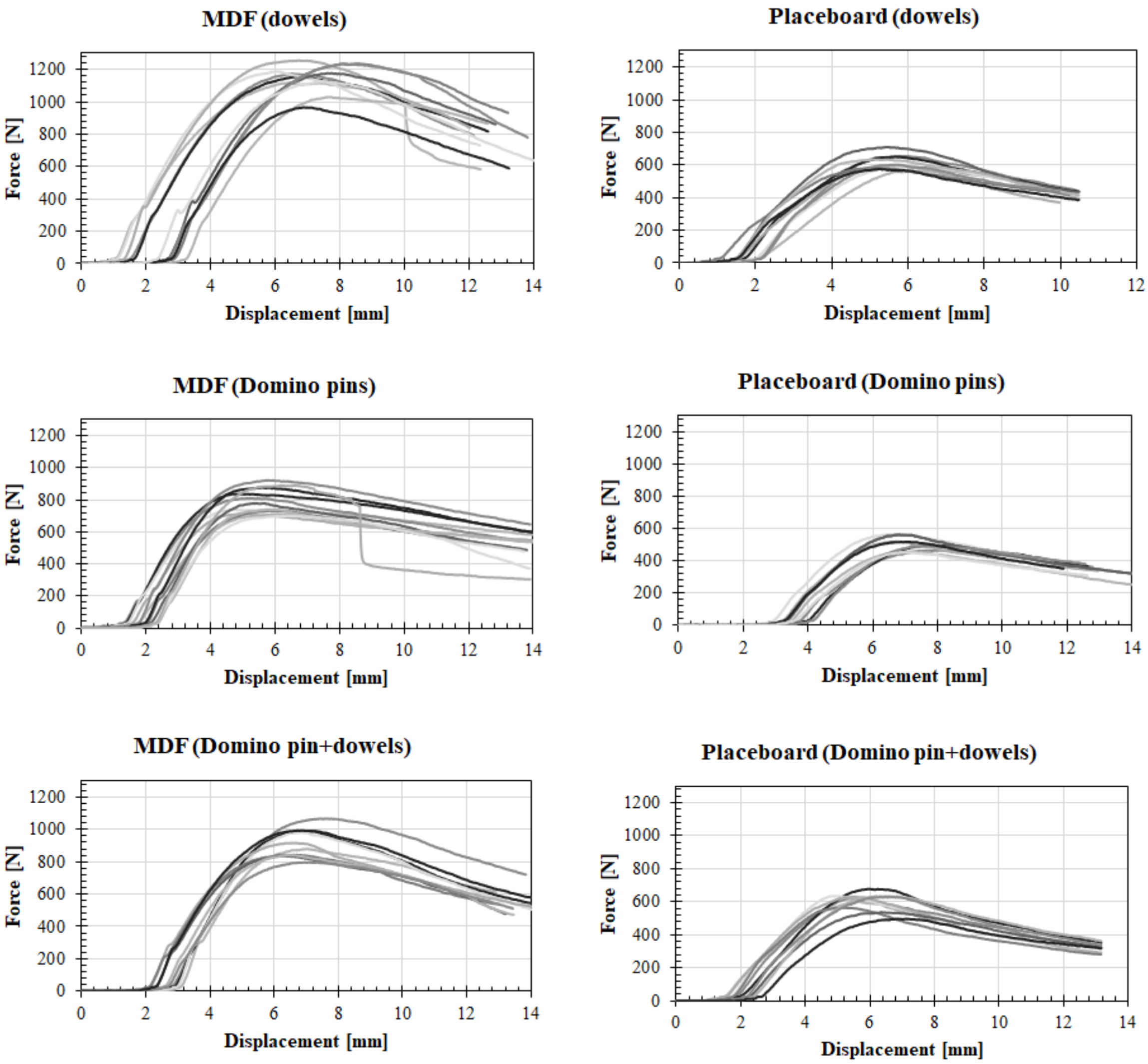

Fig.4. The distribution of forces during the experiment for tested joints and materials

The test results (maximum load) of the corner wall connection with 3 versions of the connectors arrangement (dowels, Domino pins and Domino pin+ dowels) are shown in Figure 5. The averages of the maximum strength and standard deviation were determined.

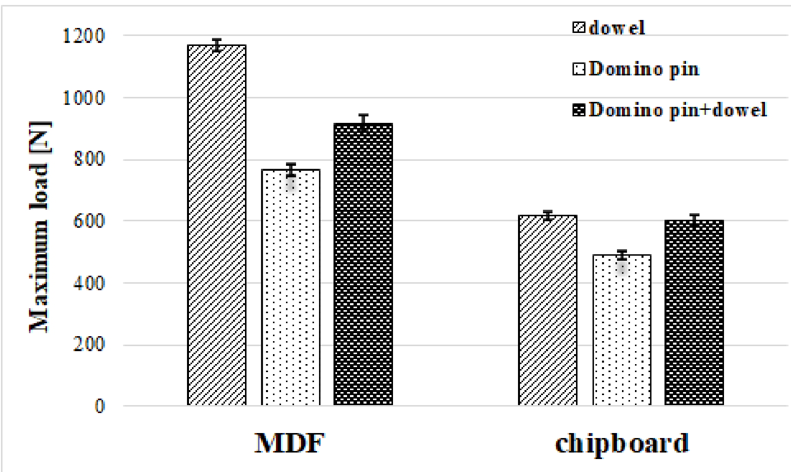

Fig. 5. The average maximum strength of the corner joints for three variants of connectors arrangement

The strong dependence between the load and the variant of the layout of connectors can be recognized. As for the jointing technique the highest values of the maximum force were observed for dowel joints, the lowest obtained in Domino joining. Moreover, it turned out that the highest load was for MDF panels for the dowel joints (F=1169 N), the lowest one – for chipboard panels for joining with Domino pins (F=488 N). It turn out that the average maximum strength value of the tested corner joints constructed with Domino pins was 35% lower than in the case of the use of dowels, for MDF samples. However, in the case of the connection with dowels and Domino pin, this value drops by 22%. In addition, the strength increase in chipboard corner joints with the use of dowels compared to corner joints with the use of Domino pins was clear and amounted to on average 21%. Interestingly , the connection with Domino pin and dowels in this case only reached the values 2% lower.

Statistical significance of the jointing technique factor was verified by a standard analysis of variance (one-way ANOVA). The results of this analysis confirmed that there were significant differences in strength in terms of the type of connectors used (p= 0,001; Fig. 6).

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	715570	2	357785	7.84	0.001
Error	2600017.3	57	45614.3		
Total	3315587.3	59			

Fig. 6. Results of ANOVA analysis for joints type factor

Furthermore, research reported here indicated that all type of the jointing technique resulted in higher strength values when applied in MDF (by 47% the dowels connection, by 36% the Domino pins connection and by 34% the Domino pin and dowels connection), in comparison with their application in chipboard.

Moreover, the effects of the factor like type of wood-based materials on the strength was also confirmed with an analysis of variance (ANOVA). It was found that the influence of the type of the panels was statistically significant ($p=5{,}45841e^{-15}$; Fig. 7)

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	2.16866e+06	1	2168660.8	109.67	5.45841e-15
Error	1.14693e+06	58	19774.6		
Total	3.31559e+06	59			

Fig. 7. Results of ANOVA analysis for material type factor

The results of vertical density profiles of scanned MDF and chipboard samples are presented graphically in Figure 8.

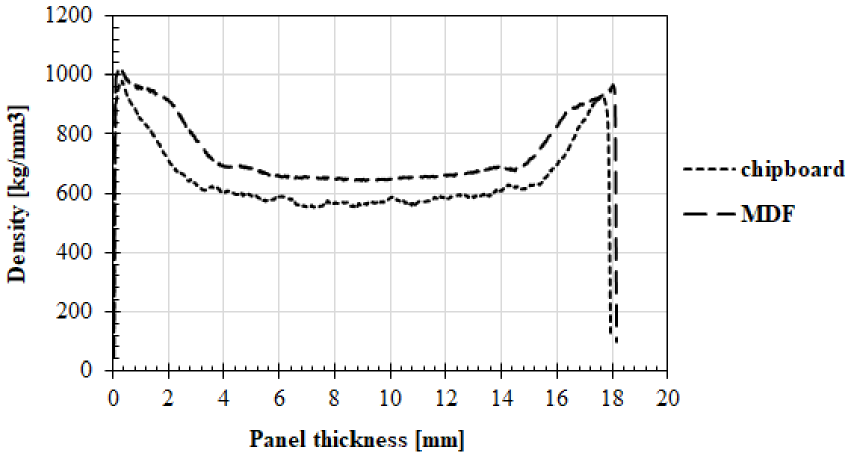

Fig. 8. The density distribution of MDF and chipboard panel – wood-based materials used in strength tests

There is a relationship between the maximum force acting on the joint and the density of the wood-based panels used in the joints was observed. The board with the lowest load, i.e. the chipboard, had the lowest density of face layers. Low density results in lower values of the maximum force that can be applied to the strength of corner furniture connections made of wood-based panels.

CONCLUSIONS

Experimental results indicated that the maximum strength of wooden hidden joints, definitely depends on the type of wood-based board and the type of fastener used. Based on the results obtained it can be concluded that the strongest connection in the case of the box furniture corners is the joining with dowels, regardless of whether MDF or chipboard elements are used. Interestingly, the joint type with the least strength was observed to be the corner joint with Domino pins. It is worth noting that the aforementioned tendency was in effect in all type of wood-based boards.

Moreover, the test results show that all 3 variants glued MDF corner joints were stronger than similar joints made of chipboard. Generally, it turned out that the density and gradation of the materials used on furniture elements significantly affects the strength of corner joints in the case of using dowel and domino fasteners.

On the basis of the obtained results, it was concluded that research on various configurations of wooden connectors should be continued. The factors that should be analyzed may be such as the type of adhesive, spacing of connectors, size of the connector, type of wood-based materials, depth of fastener embedding in the material.

REFERENCES

1. ABDOLZADEH H., EBRAHIMI G., LAYEGHI M., GHASSEMIEH M., 2015: Analytical and experimental studies on stress capacity with modified wood members under combined stresses. Maderas. Ciencia y Tecnologia, 17(2), 263-276.
2. ALTINOK M., TAŞ H.H., ÇIMEN M., 2009: Effects of combined usage of traditional glue joint methods in box construction on strength of furniture. Materials & Design, 30(8), 3313-3317.
3. AMAN R.L., WEST H.A., CORMIER D.R., 2008: An evaluation of loose tenon joint strength. Forest Products Journal, 58(3), 61-64.
4. BARDAK T., TANKUT A.N., TANKUT N., AYDEMIR D., SOZEN E., 2017: The bending and tension strength of furniture joints bonded with polyvinyl acetate nanocomposites. Maderas. Ciencia y Tecnologia, 19(1), 51-62. http://dx.doi.org/10.4067/S0718-221X2017005000005
5. BRANOWSKI B., STARCZEWSKI K., ZABŁOCKI M., SYDOR M., 2020: Design Issues of Innovative Furniture Fasteners for Wood-based Boards. BioResources, 15(5), 8472-8495.
6. CHEN M., LYU J., 2018: Properties of double dowel joints constructed of medium density fiberboard. Ciencia y tecnología 20(3), 369 – 380.
7. CHEN CH., XING Y., XU W., TOR O., QUIN F., ZHANG J., 2019: Ultimate Direct Withdrawal Loads of Low Shear Strength Wooden Dowels in Selected Wood Species for Furniture Applications. BioResources 14(4), 9214-9227.
8. DERIKVAND M., EBRAHIMI G., ECKELMAN C.A., 2014: Bending moment capacity of mortise and loose-tenon joints. Wood and Fiber Science: Journal of the Society of Wood Science and Technology, 46(2), 1-8.
9. EDRIL Y.Z., ECKELMAN C.A., 2001: Withdrawal strength of dowels in plywood and oriented strand board. Forest Products Journal, 25, 319-327.
10. ECKELMAN C.A., HAVIAROVA E., 2011: Rectangular mortise and full-width tenon joints in ready-to-assemble light-frame timber constructions. Wood and Fiber Science, 43(4), 345-352.
11. HAO J., XU L., WU X., LI X., 2020: Analysis and modeling of the dowel connection in wood T type joint for optimal performance. College of Material Science and Engineering, Central South University of Forestry and Technology, Changsha, Hunan, China 2020
12. İMİRZİ H. Ö, EFE H., 2013: Analysis of strength of corner joints in cabinet type furniture by using finite element method. Proceedings of the XXVIth International Conference Research for Furniture Industry. Ankara Turke 2013
13. JOŠČÁK P., KRASULA P., VIMPEĽ P., 2014: Strength properties of corner joints and extending joints on honeycomb boards. Annals of Warsaw University of Life Sciences – SGGW Forestry and Wood Technology, 87, 97-104
14. KASAL A., ERDİL Y.Z., DEMİRCİ S., ECKELMAN C.A., 2012: Shear Force Capacity of Various Doweled Frame Type Furniture Joints. Journal of Forestry Faculty, Kastamonu Üni, Orman Fakültesi Dergisi, 13(1), 60-71.
15. KASAL A., KU¸SKUN T., SMARDZEWSKI J., 2020: Experimental and Numerical Study on Withdrawal Strength of Different Types of Auxetic Dowels for Furniture Joints. Materials,13, 4252.
16. KOWALUK G., FUCZEK D., BEER P., GRZESKIEWICZ G., 2001: Influence of the raw materials and production parameters on chosen standard properties for furniture panels of biocomposites from fibrous chips. BioResources 6(3), 3004-3018.

17. LANGOVÁ N., JOŠČÁK P., GRIČ M., 2013: Strength properties of self-locking furniture joints with shape adapted for the production by CNC technology. Annals of Warsaw University of Life Sciences – SGGW Forestry and Wood Technology, 83, 179-184.
18. LANGOVÁ N., RÉH R.. IGAZ R., KRIŠT'ÁK L., HITKA M., JOŠˇCÁK P., 2019: Construction of Wood-Based Lamella for Increased Load on Seating Furniture. Forests, 10, 525.
19. MAJEWSKI A., KRYSTOFIAK T., SMARDZEWSKI J., 2020: Mechanical Properties of Corner Joints Made of Honeycomb Panels with Double Arrow-Shaped Auxetic Cores. Materials, 13, 4212.
20. NORVYDAS V., JUODEIKIENĖ I., MINELGA D., 2005: The Influence of Glued Dowel Joints Construction on the Bending Moment Resistance. Materials Science (MEDŽIAGOTYRA), 11(1), 36-39.
21. SAAR K., KERS J., LUGA U., REISKA A., 2015: Detachable connecting fittings failure loads on plywood furniture. Proceedings of the Estonian Academy of Sciences, 64, 113–117.
22. ŠIMEK M., HAVIAROVÁ E., ECKELMAN C.A., 2008: The end distance effect of knock-down furniture fasteners on bending moment resistance of corner joints. ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS, SBORNÍK MENDELOV Y ZEMĚDĚLSKÉ A LESNICKÉ UNIV ERZITY V BRNE, 26(2), 203-210.
23. SMARDZEWSKI J., 2019: Projektowanie mebli, Powszechne Wydawnictwo Rolnicze i Leśne, Warszawa.
24. SMARDZEWSKI J., PREKRAD S., 2002: Stress distribution in disconnected furniture joints. Electronic Journal of Polish Agricultural Universities 5(2).
25. SMARDZEWSKI J., RZEPA B., KILIC H., 2016: Mechanical Properties of extennaly invisible furniture joints made of wood-based composites. BioResources, 11(1), 1224-1239.
26. SYDOR M., 2005: Właściwości konstrukcyjne półsztywnych kątowych połączeń płyt drewnopochodnych ze złączami, Politechnika Poznańska, Wydział Maszyn Roboczych i Transportu, Poznań.
27. TANKUT A.N., TANKUT N., 2009: Investigations the effects of fastener, glue, and composite material types on the strength of corner joints in case-type furniture construction. Materials and Design, 30, 4175-4182. doi:10.1016/j.matdes.2009.04.038
28. TAS H.H., 2010: Strength properties of L-profiled furniture joints constructed with laminated wooden panels. Scientific Research and Essays 5(6), 545-550.
29. UYSAL M., HAVIAROVA E., 2018: Estimating Design Values for Two-Pin Moment Resisting Dowel Joints with Lower Tolerance Limit Approach. BioResources 13(3), 5241-5253
30. WANG X., SALENIKOVICH A., MOHAMMAD M., LIN J. HU, 2006: Evaluation of density distribution in wood-based panels using X-ray scanning. 14TH International Symposium in Nondestructive Testing of Wood, May 2005, University of Applied Sciences, Germany, Eberswalde, 11(4).
31. WILCZYŃSKI A., WARMBIER K., 2000: Wpływ sposobu mocowania i obciążania próbki połączenia narożnego o złączu dwukołkowym na sztywność i nośność połączenia. Zeszyty Naukowe Wyższej Szkoły Pedagogicznej w Bydgoszczy, 20, 59-75.
32. ZABORSKY V., BORUVKA V., KASICKOVA V., GAFF M., 2018: The Effect of Selected Factors on Domino Joint Stiffness. BioResources 13(2), 2424-2439.

33. ZWERGER K., 2012: Wood and Wood joints: Building Traditions of Europe, Japan and China”, Basel, Switzerland.
34. Festool, 2016. The Domino System User Manual, Festool, Wendlingen, German
35. Festool, 2011. Połaczenia domino. Podręcznik użytkowania

Streszczenie: *Właściwości wytrzymałościowe narożników meblowych z zastosowaniem różnych łączników drewnianych i materiałów drewnopochodnych*. Celem pracy było określenie wpływu rodzaju niewidocznych łączników drewnianych na wytrzymałość połączeń klejonych narożników konstrukcji mebli skrzyniowych dla płyty wiórowej i MDF, materiałów najczęściej stosowanych przy tego typu meblach. Rozważono trzy warianty rozmieszczenia łączników: wariant I - z wykorzystaniem 4 kołków bukowych ryflowanych, wariant II - z wykorzystaniem 2 kołków bukowych Domino, wariant III - układ mieszany łączników. Wyniki eksperymentu wykazały, że próbki połączone na kołki wykazały najwyższe wartości wytrzymałości ze wszystkich wariantów (F=1169 N dla płyty MDF, F= 617 dla płyty wiórowej). Ponadto zaobserwowano, że połączenia narożne z kołkami Domino wykazywały najniższą wytrzymałość. Warto zauważyć, że powyższą tendencję zaobserwowano dla obu płyt drewnopochodnych. Wpływ materiału okazał się czynnikiem istotnym statystycznie. Zastosowanie płyty MDF zwiększyło wartości wytrzymałościowe (o 47% w przypadku połączenia kołkowego, o 36% przy łącznikach Domino i o 34% przy układzie mieszanym) w porównaniu z ich zastosowaniem w płycie wiórowej.

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