The Impact of Dovetail Angle in Single Dovetail Joints on Diagonal Compression Strength of Corner Joints for Box-Type Furniture

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Abstract

This study aims to determine the impacts of dovetail angle for dovetail joints on the diagonal compression strength of box-type furniture corner joints prepared in different woods, with different dovetail angles, and with different adhesives. For this reason, after drilling joints of 75°, 78°, 81°, 84°, and 87° on Oriental beech, European oak, Scotch pine, and medium-density fiberboard (MDF) samples, a diagonal compression test was applied on corners glued with polyvinyl acetate (PVAc) and polyurethane (Desmodur-vinyl trieketonol acetate [D-VTKA]) according to the ASTM D1037 standard. The highest result for dovetail diagonal compression strength was observed in the samples of Oriental beech (0.321 N mm^{-2}), while the lowest was found in the samples of MDF (0.154 N mm^{-2}) for wood types. With respect to adhesives, D-VTKA yielded the best results (0.268 N mm^{-2}), while PVAc gave the worst results (0.252 N mm^{-2}). Regarding angle types, the best result was obtained from the samples at 84° (0.302 N mm^{-2}) and the worst from the samples at 75° (0.207 N mm^{-2}) for dovetail joints. For the interaction of wood type, adhesive, and dovetail angle, the highest diagonal compression strength was found in the samples of Oriental beech + 81° + D-VTKA (0.445 N mm^{-2}), while the lowest value was observed in MDF + 78° + D-VTKA (0.128 N mm^{-2}). In conclusion, the angles and adhesives have significant effects on the corner joints of box-type furniture.

Box-type furniture is one of the most important furniture categories manufactured and used today. It is widely used for storage in homes, in office furniture, and in the framed construction of kitchen cabinets, doors, windows, and partitions. The construction style of box-type furniture varies according to the type, value, quality of the furniture, occupational perception of the creator, packaging, and transportation. According to Wagner and Kicklighter (1996), each type of construction has its own function and reason for being preferred. Among these, post and rail elements in picture frames and frames for kitchen cabinet doors (e.g., frame-and-panel doors and glass doors) can be made from solid wood, medium-density fiberboard (MDF), particleboard, and plywood panels. These elements are connected by various joining techniques, such as mortise and tenon and miter and butt joining. The joining techniques are accompanied by reinforcing items, namely, spline, dowel, butterfly, and H-shaped keys and biscuit. Variations of joint geometry and use of reinforcing items as well as auxiliary materials can affect the strength of a joint. Types of loads applied to joints in service and the resulting stresses and variation in joint materials are additional factors that cause joint performance to vary, as reported by Moseyeb et al. (2013).

On the other hand, furniture and composites are opposed to various forces directly or indirectly according to their uses. Compression and withdrawal forces are imposed on the joints of furniture. Accordingly, with the impacts of these forces, deformations, such as gaps paring, bending, cracks, torsion, and rupture, can be observed. To overcome these disadvantages, improving the function of furniture and composites is vitally important for economy and use in the industrialized world.

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Several studies have been done on the construction techniques of corner joints that yielded valuable design information for box-type furniture. Kilic et al. (2009) focused on mitered corner joints containing dovetail fittings in frames of solid poplar for diagonal tension and compression by using polyvinyl acetate (PVAc) and polyurethane adhesives. Altun et al. (2010) studied the effects of adhesives on bending resistance of mitered corner joints containing dovetails under diagonal tensile and compressive loads. Tankut and Tankut (2009) investigated the effects of fastener, glue, and composite material types on the strength of corner joints in case-type furniture construction.

Ozkaya et al. (2010) studied the effects of the number of dovetails and types of adhesives used in frame construction using oriented strand board (OSB). They concluded that the number of dovetails and the type of adhesive affected diagonal tension strength. Altinok (1998) researched the compression strength in center-legged tables of Oriental beech and Scotch pine for dowel and dovetail joints. He found the highest compression strength in dovetail joints of beech (1.82 N mm^{-2}) and the lowest in Scotch pine dowel (0.90 N mm^{-2}).

Joints for box-type furniture are the most critical parts of furniture construction. Thus, in discussing wood and wood-based panel furniture, proper design of the joints is the most important stage of the manufacturing process. To increase the stiffness and service life of furniture, it is necessary for producers to know what factors play major roles in strengthening furniture joints. To date, various studies have been carried out in conjunction with strengthening furniture joints, and some useful information has been compiled. The early studies are numerous, but many subjects have yet to be considered related to new furniture construction materials and techniques.

This study was carried out to determine the impacts of dovetail angle for dovetail joints on the diagonal compression strength of box-type furniture corner joints, prepared in different woods, with different dovetail angles, and with different adhesives.

Materials and Methods

Materials

Wood materials.—Oriental beech (*Fagus orientalis* Lipsky), European oak (*Quercus petreae* Liebl.), Scotch pine (*Pinus sylvestris* Lipsky), and MDF were chosen randomly from timber merchants in Ankara, Turkey. Accordingly, proper, knotless, normally grown, and homogeneous wood materials were selected according to TS 2470 (Turkish Standards Institution [TSI] 1976a). MDF samples were obtained from 183 by 366 by 1.8-cm panels according to TS EN 326-1 (TSI 1999).

Adhesives.—PVAc and polyurethane (Desmodur-vinyl trieketonol acetate [D-VTKA]) adhesives, which are commonly used in the Turkish wood and box-type furniture industry, are preferred in this study. The characteristics of PVAc and D-VTKA adhesives are given in Table 1.

Preparation of test samples

Using four different types of wood and MDF, two different types of adhesives (PVAc and D-VTKA), and five joining angles (75°, 78°, 81°, 84°, and 87°), 200 samples (4 by 2 by 5 by 5) were prepared for diagonal compression test.

Table 1.—Characteristics of adhesives.

Adhesives[a]	pH	Density (g cm^{-3})	Amount of adhesive application (g m^{-2})	Viscosity (mPas)
PVAc	5	1.1	150–200	16.000 ± 3.000
D-VTKA	7	1.11	150–200	5,500–7,500

[a] PVAc = polyvinyl acetate; D-VTKA = Desmodur-vinyl trieketonol acetate.

The samples were cut to 150 by 101.5 by 18 mm and conditioned until reaching permanent weight in a conditioning refrigerator at 20°C ± 2°C and 65 ± 5 percent relative humidity to obtain a moisture value on internal environmental conditions according to TS 2471 (TSI 1976b). Mean humidity of the samples was determined as 9 ± 5 percent on 10 randomly selected samples. The dimensions of samples used in the test were 150 by 101.5 by 18 mm, as shown in Figure 1.

Samples for dovetail joints with five different angles (75°, 78°, 81°, 84°, and 87°) were prepared in accordance with the provisions of the TS 4951 (TSI 1986) standard. The diameters of dove joints in the front 16 mm and at the rear were 28 mm for 75°, 25 mm for 78°, 22 mm for 81°, 20 mm for 84°, and 18 mm for 87°. An illustration of the experimental configuration of dovetail joints is given in Figure 2.

Dovetail joint cutter.—Properties of cutter produced in angles of 75°, 78°, 81°, 84°, and 87° and used in dovetail joints are given in Figure 3.

Surface areas to be glued in dovetail joints according to cutter angles (A = joint and B = conjugate) are given in Table 2.

According to this, the largest joint area was 3,684.10 mm^2 for 75°, and the smallest was 3,275.93 mm^2 for 87°.

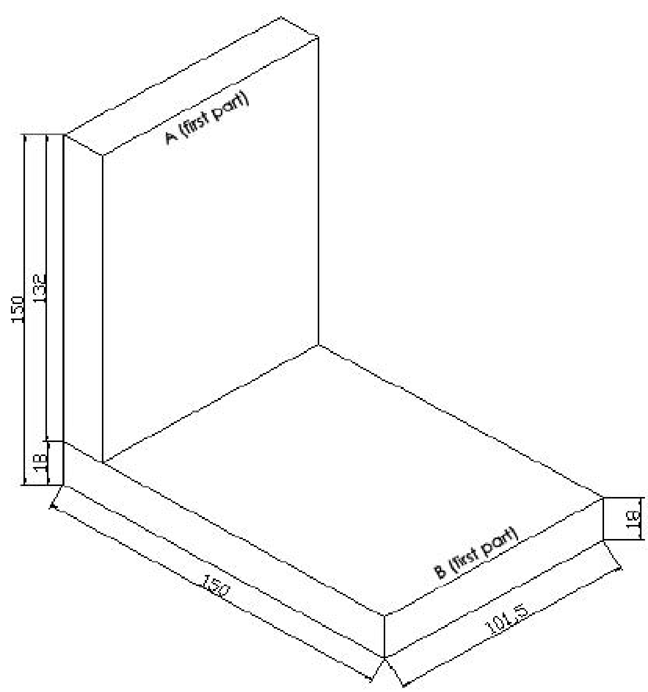

Figure 1.—Test samples dimensions.

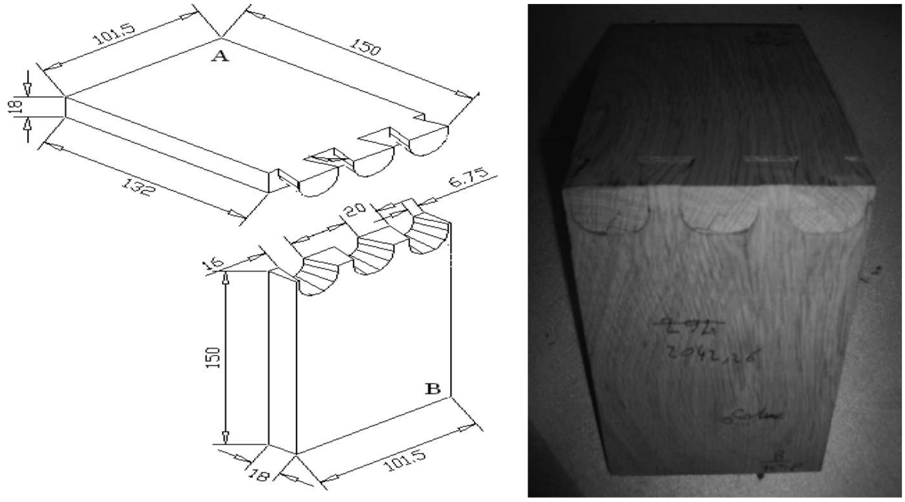

Figure 2.—Dovetail joint dimensions and illustration.

Experimental design.—Application of adhesives was carried in accordance with the provisions of TS 3891 (TSI 1983). D-VTKA and PVAc adhesives were supplied by Polisan, a producer firm in Izmit, Turkey. For the amount and application methods of the adhesives to be applied on the surfaces of the samples, manufacturer's prospectuses were followed (Polisan 1997). They were utilized because of their useful properties, such as cold application, easy spreading, rapid drying, being scentless and fireproof, and being preferred in the production of the furniture products. Before applying adhesives, dust on the surfaces was cleaned by a brush and vacuum method with the aim of gluing on the sample surfaces. Dry surfaces were moistened so as to increase the hardening speed of the glue.

Both of the adhesives were applied to only one surface with an amount of 150 to 200 g m^{-2} at 20°C ± 2°C and 65 ± 5 percent relative humidity conditions. The density of PVAc was 1.1 g cm^{-3}, the viscosity was 16 ± 3 mPas, and the pH value was 5. The density of D-VTKA was 1.1 g cm^{-3}, the pH was about 7, and viscosity was 5,500 to 7,500 mPas. Pressing time for the bonding process was 75 minutes for PVAc and 24 hours for D-VTKA. After applying adhesive on joint surfaces of the A and B types, samples were mounted by pressure with a clamp for a pressing time of 75 minutes. The pressure was applied equally to approximately 2 to 3 N mm^{-2} for diagonal compression strength measurements.

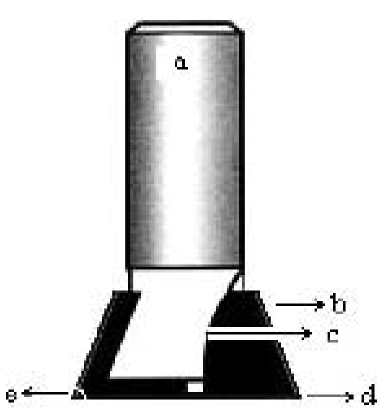

Figure 3.—Dovetail joint cutter.

Testing methods

Diagonal compression strength measurement.—A ZWICK Z010 test machine of kN ×∼1,000 kg was used in the experiments. The test was carried out in accordance with ASTM D1037 (American Society for Testing and Materials 1998). A diagonal compression strength test was carried out with a 0.15- to 0.25-mm/min loading speed. The forces of test samples in the event of deformation were measured in N (newtons). The test mechanism is shown in Figure 4.

The load resistance capacity for the diagonal compression strength was calculated with the following equation:

$$\text{Load Value (LV)} = \mathrm{F}max/\mathrm{A}\ (\mathrm{N\ mm}^{-2})$$

where LV is the load value carrying capacity of the glued joints under diagonal compression loading (N mm^{-2}), F*max* is the force at the moment of separation or breaking (N), and A is the bonding area. According to this, the largest joint area (A) was 3,684.10 mm^2 for 75°, and smallest area was 3,275.93 mm^2 for 87°. The failure mode was accepted at the moment of separation or breaking of the samples.

Statistical analyses

In this study, analysis of variance was used to determine the effects of adhesives on diagonal compression capacity. In case the difference between the groups was significant, a comparison was made with the Duncan multiple range test

Table 2.—Joint areas of A (joint) and B (conjugate) composites in dovetail joint.

Angle type	Area measured (mm^2)
75°	3,684.10
78°	3,567.72
81°	3,462.03
84°	3,364.64
87°	3,275.93

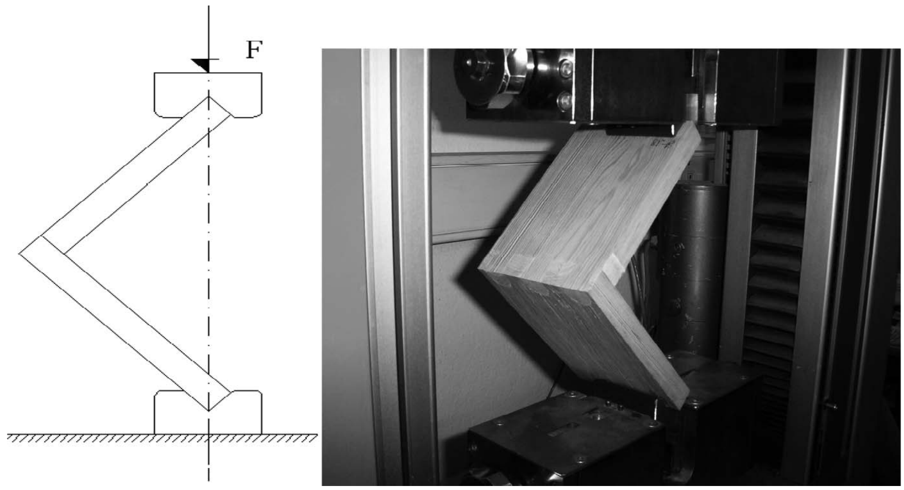

Figure 4.—Test stand for diagonal compression.

at a 0.05 level of probability. SPSS 11.5 software was used in the statistical analysis.

Results

The results of multiple variance analysis for the impacts of material type, dovetail angle, and glue type on diagonal compression strength are given in Table 3.

The interactions of wood, angle, and adhesive type were found to be statistically significant ($\alpha = 0.05$) for diagonal compression strength. A single comparison analysis of wood, adhesive, and dovetail angle types on diagonal compression strength is given in Table 4.

With respect to the means in Table 4, during the single comparison of the factor types, the effect of wood type on the diagonal compression strength values was found to be significant. The highest result was observed in the samples of Oriental beech (0.321 N mm^{-2}), while the lowest was found in the samples of MDF (0.154 N mm^{-2}) for wood types. Another way of stating the diagonal strength of Oriental beech is that it is 1.25 percent higher than European oak, 24 percent higher than Scotch pine, and 61 percent higher than the MDF samples, respectively. A double comparison of dovetail angles and woods on diagonal compression strength is given in Table 5.

According to Table 5, Oriental beech + 87° gave the highest result (0.389 N mm^{-2}) for compression strength, while MDF + 78° yielded the lowest result (0.131 N mm^{-2}) for wood material type and dovetail angle interaction. A double comparison of woods and adhesives on diagonal compression strength is given in Table 6.

For the interaction of wood material and adhesive type, the highest result was observed in European oak + PVAc (0.342 N mm^{-2}), while the lowest result was obtained in MDF + PVAc (0.145 N mm^{-2}). A double comparison of dovetail angles and adhesives on diagonal compression strength is given in Table 7.

With respect to the double comparison of dovetail angle and adhesive types, the highest value was obtained in 84° + D-VTKA (0.324 N mm^{-2}) and the lowest in 78° + D-VTKA (0.202 N mm^{-2}) for diagonal compression strength. Results of the Duncan test for a triple comparison of the wood, adhesive, and dovetail angle types on the compression strength are shown in Table 8.

According to Table 8, for the triple comparison of the wood, adhesive, and dovetail angle types, the highest value (0.445 N mm^{-2}) was yielded in the samples of Oriental beech + 81° + D-VTKA, while the lowest value (0.128 N mm^{-2}) was observed in MDF + 87° + PVAc for diagonal compression strength. The impacts of wood, angle, and adhesive types of diagonal compression strength of dovetail joints are reported in Table 9.

According to Table 9, with respect to coefficient variations, the highest result was observed in the samples of Scotch pine with an angle of 75° (0.187 N mm^{-2}) for

Table 3.—Multiple variance analysis results.[a]

Source of variance	Degrees of freedom	Sum of squares	Mean square	*F* value	Probability (0.05) (significance)
Wood type (A)	3	11,242,905.506	3,747,635.169	847.2426	0.0000
Angle type (B)	4	2,504,181.076	626,045.269	141.5325	0.0000
Interaction (AB)	12	1,233,292.594	102,774.383	23.2346	0.0000
Adhesive type (C)	1	163,557.947	163,557.947	36.9762	0.0000
Interaction (AC)	3	942,884.598	314,294.866	71.0539	0.0000
Interaction (BC)	4	307,442.725	76,860.681	17.3762	0.0000
Interaction (ABC)	12	758,643.008	63,220.251	14.2925	0.0000
Error	160	707,733.094	4,423.332		
Total	199	17,860,640.547			

[a] Factor A: material type (Oriental beech, European oak, Scotch pine, medium-density fiberboard); factor B: dovetail angle (75°, 78°, 81°, 84°, 87°); factor C: adhesive type (polyvinyl acetate, Desmodur-vinyl trieketonol acetate).

Table 4.—Single comparison: wood, adhesive, and dovetail angle types (N mm^{-2}).

Factors	Types	X (N mm^{-2})[a]	HG[b]
Wood material[c]	Oriental beech (Ob)	0.321	A
	European oak (O)	0.312	A
	Scotch pine (S)	0.246	C
	Medium-density fiberboard (MDF)	0.154	D
Adhesive type[d]	D-VTKA (D)	0.268	A
	PVAc (P)	0.252	B
Dovetail angle[e]	75° (I)	0.216	C
	78° (II)	0.207	D
	81° (III)	0.286	AB
	84° (IV)	0.302	A
	87° (V)	0.294	B

[a] X = average.
[b] HG = homogeneous group.
[c] LSD = 0.092.
[d] D-VTKA = Desmodur-vinyl trieketonol acetate; PVAc = polyvinyl acetate; LSD = 0.016.
[e] LSD = 0.008.

PVAc, while the lowest result was also found in the samples of European oak with an angle of 81° (0.010 N mm^{-2}) for D-VTKA. Another way of stating the compression strength is that Oriental beech and Scotch pine gave the highest result (15.07%) for 78°, and the lowest result (0.89%) was obtained in the samples of European oak for 81° dovetail angle. Failure modes for compression strength are given in Table 10.

Table 11 summarizes the highest and lowest performances of failure modes for compression strength.

For diagonal compression tests, the lowest five average values of failure loads in order from smallest to largest were obtained as 0.128 (78° + MDF + D-VTKA), 0.130 (75° + MDF + P), 0.132 (87° + MDF + P), 0.136 (78° + MDF + P), and 0.151 (84° + MDF + PVAc) N mm^{-2}, respectively. On the other hand, the highest five average values of failure loads ranging from highest to lowest were 0.445 N mm^{-2} for 81° + Oriental beech + D-VTKA, 0.412 N mm^{-2} for 87° + European oak + PVAc, 0.406 N mm^{-2} for 84° + Oriental beech + D-VTKA, 0.393 N mm^{-2} for 87° + Oriental beech + D-VTKA, and 0.385 N mm^{-2} for 87° + Oriental beech + PVAc and 84° + European oak + PVAc.

Loading illustrations in Figures 5 through 8 and ultimate failure modes of test corner joints in Figures 9 through 12 are given in decreasing order as the highest values for Oriental beech (0.445 N mm^{-2}) (Figs. 5 and 9), European oak (0.412 N mm^{-2}) (Figs. 6 and 10), Scotch pine (0.341 N mm^{-2}) (Figs. 7 and 11), and MDF (0.175 N mm^{-2}) (Figs. 8 and 12).

Table 5.—Double comparison: dovetail angles and woods (N mm^{-2}).

Dovetail angles	European oak X[b]	European oak HG[c]	Oriental beech X	Oriental beech HG	Scotch pine X	Scotch pine HG	MDF[a] X	MDF[a] HG
75°	0.265	C	0.239	D	0.206	E	0.159	F
78°	0.238	D	0.244	D	0.216	E	0.131	G
81°	0.336	B	0.362	A	0.275	C	0.173	F
84°	0.380	A	0.383	A	0.280	C	0.163	F
87°	0.384	A	0.389	A	0.255	D	0.149	G

(Wood types)

[a] MDF = medium-density fiberboard.
[b] X = average.
[c] HG = homogeneous group; LSD = 0.027.

Table 6.—Double comparison: woods and adhesives (N mm^{-2}).

Woods	PVAc X[b]	PVAc HG[c]	D-VTKA X	D-VTKA HG
Beech	0.245	B	0.338	A
Oak	0.342	A	0.296	B
Pine	0.215	D	0.276	C
MDF[d]	0.145	F	0.163	E

(Adhesives[a])

[a] PVAc = polyvinyl acetate; D-VTKA = Desmodur-vinyl trieketonol acetate.
[b] X = average.
[c] HG = homogeneous group; LSD = 0.097.
[d] MDF = medium-density fiberboard.

Discussion

The impacts of angles for dovetail corner joints were determined by several factors, including the types of woods, adhesives, and dovetail angles on the compression strength of corner joints for box-type furniture. In light of the main results, the following insights can be discussed.

Regarding the adhesive types, the diagonal compression strength was found to be highest in the adhesive of D-VTKA (0.268 N mm^{-2}) for European oak and Oriental beech and the lowest in PVAc samples (0.252 N mm^{-2}) for MDF. This is contrary to the results of Ozkaya et al. (2010) and Altun et al. (2010). According to their studies, PVAc gives better results for single dovetail joints for OSB. However, this study shows that the diagonal compression strength of polyurethane (D-VTKA) is 6 percent higher than PVAc. This may result from the higher adhesion power of polyurethane. This result may be due to the homogeneous structure and smooth texture of wood materials and the high cohesive strength of the D-VTKA glue. However, in general, joint combinations based on the maximum compression loading capacities in corners of the joints showed that all joints of any type with adhesive were closely clustered together. This indicated the significant effect of adhesive in the final loading capacity of the joints. It can

Table 7.—Double comparison; dovetail angles and adhesives (N mm^{-2}).

Dovetail angles	PVAc X[b]	PVAc HG[c]	D-VTKA X	D-VTKA HG
75°	0.214	D	0.217	D
78°	0.212	DE	0.202	E
81°	0.265	C	0.308	A
84°	0.279	BC	0.324	A
87°	0.293	BC	0.296	B

(Adhesives[a])

[a] PVAc = polyvinyl acetate; D-VTKA = Desmodur-vinyl trieketonol acetate.
[b] X = average.
[c] HG = homogeneous group; LSD = 0.028.

Table 8.—Triple comparison analysis of wood, adhesive, and angle types (N mm^{-2}).

Factors		Dovetail angles									
		75°		78°		81°		84°		87°	
Material type	Adhesives[a]	X[b]	HG[c]	X	HG	X	HG	X	HG	X	HG
Oriental beech	PVAc	0.263	IJK	2.690	IJKLM	0.279	HI	0.355	EF	0.376	CD
	D-VTKA	0.250	JKLM	0.220	OPQ	0.445	A	0.412	BC	0.386	CD
European oak	PVAc	0.317	FG	0.266	HIJ	0.361	DE	0.393	BCD	0.406	B
	D-VTKA	0.230	KLM	0.216	MNO	0.303	FG	0.386	CD	0.354	DE
Scotch pine	PVAc	0.186	QR	0.182	PQR	0.242	LMNO	0.212	NOP	0.228	LMN
	D-VTKA	0.237	IJKLM	0.241	IJKL	0.299	GH	0.341	EF	0.246	IJKLM
Medium-density fiberboard	PVAc	0.132	V	0.136	UV	0.155	STU	0.151	TUV	0.128	UV
	D-VTKA	0.175	RST	0.130	UV	0.174	R	0.171	RS	0.166	RST

[a] PVAc = polyvinyl acetate; D-VTKA = Desmodur-vinyl trieketonol acetate.
[b] X = average.
[c] HG = homogeneous group; LSD = 0.019.

Table 9.—Impact values for dovetail angle and glue type on compression strength (N mm^{-2}).[a]

Angle type	Statistical values	O + P	O + D	Ob + P	Ob + D	S + P	S + D	MDF + P	MDF + D
75°	Max.	0.319	0.241	0.266	0.265	0.189	0.240	0.142	0.198
	Min.	0.281	0.213	0.218	0.213	0.173	0.219	0.123	0.154
	SD	0.014	0.010	0.024	0.025	0.034	0.008	0.007	0.018
	CV	0.046	0.044	0.099	0.105	0.187	0.035	0.054	0.104
	X	0.303	0.227	0.241	0.237	0.182	0.230	0.130	0.174
78°	Max.	0.275	0.267	0.330	0.227	0.196	0.268	0.149	0.153
	Min.	0.241	0.173	0.236	0.204	0.173	0.238	0.114	0.117
	SD	0.014	0.037	0.038	0.009	0.010	0.018	0.014	0.015
	CV	0.053	0.175	0.143	0.042	0.054	0.073	0.103	0.117
	X	0.263	0.212	0.266	0.216	0.186	0.246	0.136	0.128
81°	Max.	0.360	0.319	0.286	0.465	0.263	0.336	0.173	0.181
	Min.	0.351	0.312	0.267	0.405	0.237	0.265	0.140	0.153
	SD	0.004	0.003	0.007	0.023	0.010	0.026	0.013	0.011
	CV	0.011	0.010	0.025	0.052	0.040	0.087	0.084	0.065
	XD	0.354	0.317	0.278	0.445	0.250	0.299	0.155	0.170
84°	Max.	0.404	0.385	0.394	0.449	0.231	0.369	0.163	0.199
	Min.	0.367	0.363	0.329	0.360	0.206	0.306	0.139	0.155
	SD	0.020	0.009	0.024	0.032	0.009	0.023	0.009	0.016
	CV	0.052	0.024	0.067	0.079	0.041	0.068	0.060	0.091
	X	0.385	0.375	0.361	0.406	0.220	0.341	0.151	0.175
87°	Max.	0.446	0.392	0.392	0.433	0.263	0.271	0.137	0.198
	Min.	0.385	0.332	0.380	0.352	0.219	0.262	0.124	0.138
	SD	0.023	0.023	0.006	0.029	0.016	0.004	0.005	0.025
	CV	0.056	0.065	0.016	0.074	0.066	0.015	0.039	0.150
	X	0.412	0.355	0.385	0.393	0.242	0.269	0.132	0.166

[a] SD = standard deviation; CV = coefficient variance; X = average; O = European oak; Ob = Oriental beech; S = Scotch pine; MDF = medium-density fiberboard; P = polyvinyl acetate glue; D = Desmodur-vinyl trieketonol acetate glue.

Table 10.—Average values of failure modes for diagonal compression strength (N mm^{-2}).[a]

Angle type	O + P	O + D	Ob + P	Ob + D	S + P	S + D	MDF + P	MDF + D
75°	0.303	0.227	0.241	0.237	0.182	0.230	0.130	0.174
78°	0.263	0.212	0.266	0.216	0.186	0.246	0.136	0.128
81°	0.354	0.317	0.278	0.445	0.250	0.299	0.155	0.170
84°	0.385	0.375	0.361	0.406	0.220	0.341	0.151	0.175
87°	0.412	0.355	0.385	0.393	0.242	0.269	0.132	0.166

[a] O = European oak; Ob = Oriental beech; S = Scotch pine; MDF = medium-density fiberboard; P = polyvinyl acetate glue; D = Desmodur-vinyl trieketonol acetate glue.

Table 11.—Performances of failure modes for diagonal compression strength.

Samples	Highest performance			Lowest performance		
	Load ($N\ mm^{-2}$)	Angle	Adhesive[a]	Load ($N\ mm^{-2}$)	Angle	Adhesive
European oak	0.412	87	PVAc	0.212	78	D-VTKA
Oriental beech	0.445	81	D-VTKA	0.216	78	D-VTKA
Scotch pine	0.341	84	D-VTKA	0.182	75	PVAc
Medium-density fiberboard	0.175	84	D-VTKA	0.128	78	D-VTKA

[a] PVAc = polyvinyl acetate; D-VTKA = Desmodur-vinyl trieketonol acetate.

Figure 5.—Oriental beech + 81° angle + Desmodur-vinyl trieketonol acetate.

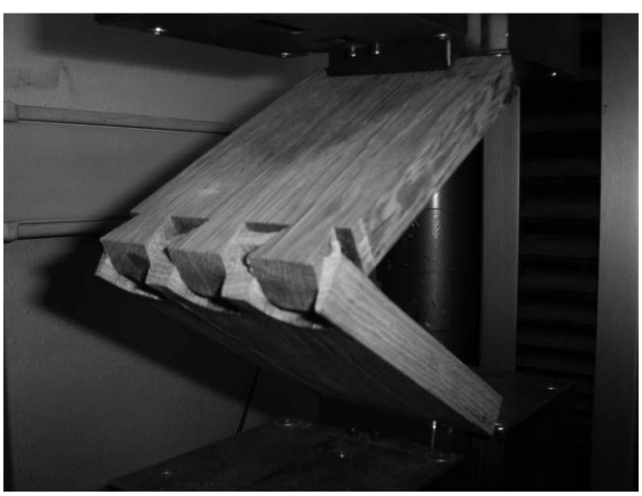

Figure 6.—European oak + 87° angle + polyvinyl acetate.

therefore be said that application of a common adhesive such as D-VTKA or PVAc can significantly improve the load-carrying capacity of dovetail joints. Moreover, permeability in MDF was reported to be significantly lower than in woods; the lower permeability in MDF indicates that the fibers are more compactly stuck together in MDF. The lower permeability makes more parts of the applied adhesive be

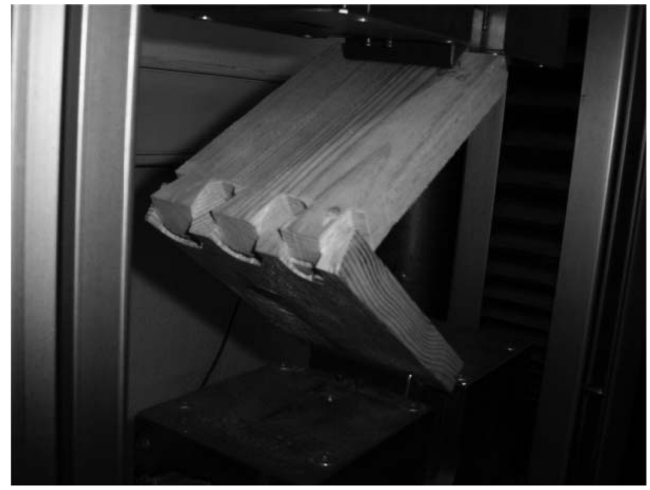

Figure 7.—Scotch pine + 84° angle + Desmodur-vinyl trieketonol acetate.

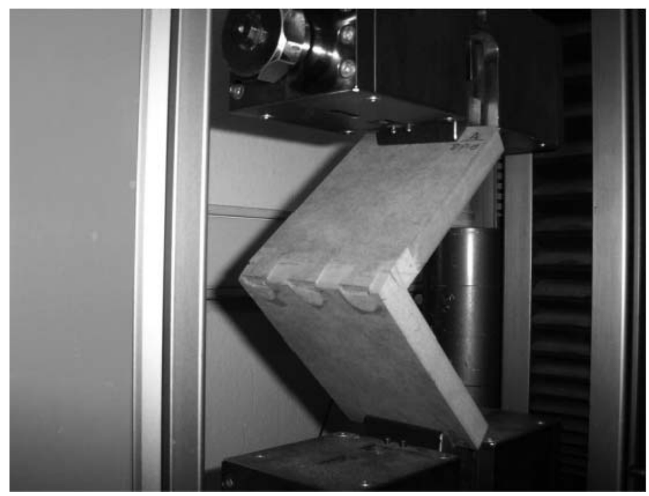

Figure 8.—Medium-density fiberboard + 84° angle + Desmodur-vinyl trieketonol acetate.

present in the joint line, and eventually the overall load-carrying capacity increased. When loaded to higher stress levels, failure occurs (Figs. 5 through 12). The reason could be that the buckling of the fibers seriously affects the compression strength of woods and composites. Similar insights for bonding surfaces were also reported in corner joints made from white fir (Dalvand et al. 2013) and MDF and particle panels (Taghiyari et al. 2017).

According to the angle types, the best result was obtained from the samples at 84° (0.302 $N\ mm^{-2}$) and the worst from the samples at 75° (0.207 $N\ mm^{-2}$) for dovetail joints. The angle of 84° gives the best performance, approximately 2 percent more than 81°, 5 percent more than 87°, 23 percent more than 85°, and 30 percent more than 78°. This may occur from the parallelism between fiber and the fiber cut angle of the cutter prepared at an 84° angle because of the ductility of fiber when force is applied. The results of the study are in agreement with those reported by Özçifçi (1996) and Kilic et al. (2009).

According to the wood types, it is possible to indicate that in all types and combinations of corner joints, those made

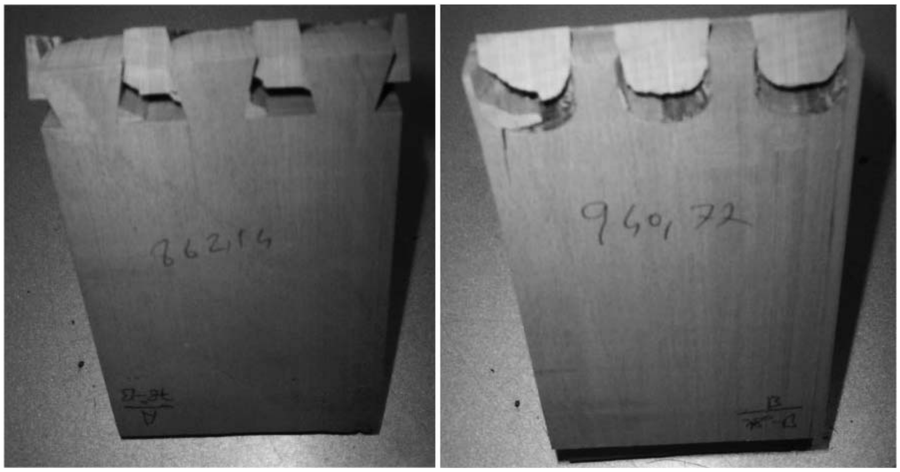

Figure 9.—Failure modes for Oriental beech + 81° angle + Desmodur-vinyl trieketonol acetate.

Figure 10.—Failure modes for European oak + 87° angle + polyvinyl acetate.

Figure 11.—Failure modes for Scotch pine + 84° angle + Desmodur-vinyl trieketonol acetate.

Figure 12.—Failure mode for medium-density fiberboard + 84° angle + Desmodur-vinyl trieketonol acetate.

from Oriental beech, European oak, and Scotch pine (Figs. 5 through 7) had greater load-carrying capacities than MDF (Fig. 8). The highest result was observed in the samples of Oriental beech (0.321 N mm^{-2}), while the lowest was found in the samples of MDF (0.154 N mm^{-2}) for wood types. The compression strength of Oriental beech is 1.25 percent higher than European oak, 24 percent higher than Scotch pine, and 61 percent higher than the MDF samples, respectively. The first reason could be that Oriental beech and European oak have greater density than Scotch pine and MDF; therefore, they have less void space but more mass to resist compressive forces. The second reason is that the void spaces of Oriental beech and European oak are smaller than those of Scotch pine and MDF, limiting adhesive penetration. This may be due to the homogeneous structure and smooth texture of Oriental beech, which is limited to fibers breaking at an 84° angle of D-VTKA adhesive, which fills gaps in the field of combination. Another point could be the higher integrity of woods in comparison to MDF. The results of low values measured in Scotch pine and MDF support this argument. Also, the findings of the studies are compatible with those reported by Altinok (1998) and Altinok et al. (2009), who concluded that the diagonal compressions were lower in all spline-jointed wooden board structures that used PVAc glue and higher in those structures that used D-VTKA.

Conclusions

In light of the findings and discussion, the following conclusions can be made:

- The samples of Oriental beech yielded the best performance (0.321 N mm^{-2}), while the samples of MDF gave the lowest performance (0.154 N mm^{-2}) for wood types.
- D-VTKA yielded the highest results (0.268 N mm^{-2}), while PVAc gave the lowest results (0.252 N mm^{-2}) for adhesive types.
- The angle of 84° (0.302 N mm^{-2}) gave the best performance, approximately 2 percent more than 81°, 5 percent more than 87°, 23 percent more than 85°, and 30 percent more than 78°, while 75° (0.207 N mm^{-2}) yielded the worst result for angle types.
- The lowest failure loads in order from smallest to largest were 0.128 (78° + MDF + D-VTKA), 0.130 (75° + MDF + P), 0.132 (87° + MDF + P), 0.136 (78° + MDF + P), and 0.151 (84° + MDF + PVAc) N mm^{-2}, respectively.
- The highest failure loads were 0.385 (87° + Oriental beech + PVAc), 0.385 (84° + European oak + PVAc), 0.393 (87° + Oriental beech + D-VTKA), 0.406 (84° + Oriental beech + D-VTKA), 0.412 (87° + European oak + PVAc), and 0.445 (81° + Oriental beech + D-VTKA) N mm^{-2}.

The main results of this study indicate that, considering the number of techniques and elements that go into today's industries, the effects of woods, adhesives, and dovetail angles on diagonal compression strength were significant for the corner joints of box-type furniture. In conclusion, maximum compression strength of the corner joints was a function of the angle, wood, and adhesive types.

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