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Holding strength of insert fittings of the eccentric joints in particleboard and MDF

V.Vassiliou and J.Barboutis
Aristotle University, School of Forestry and Natural Environment, Thessaloniki, Greece

Abstract
Eccentric joints are commonly used in ready-to-assemble cabinet furniture to connect particleboard and MDF. Different insert fittings as screws, screws with plastic sockets and metal or plastic eccentric fittings (cams, rafixes, etc) of many manufacturers are offered for this kind of joints in the market. Yet, little information is available concerning their withdrawal capacity in these materials. Research reported here indicates that face withdrawal strength of the screws differ slightly from manufacturer to manufacturer in particleboard and MDF panels, while withdrawal strength of the screws with plastic sockets and the insert fittings differ greatly from one manufacturer to another. Furthermore, the withdrawal capacity is correlated with the density of used panels.

Key words: ready-to-assemble furniture, eccentric joints, insert fitting, holding strength, particleboard, MDF.

Introduction

It is well known that durability of furniture depends primarily on the strength of joints. The way of fastening furniture insert fittings and the withdrawal resistance during removing these fittings determines to a great extent the strength and stability of ready-to-assemble furniture.
Factors affecting joint strength have been studied by many researchers [5,6,10,11]. Also, the resistance to withdrawal of different types of fasteners, mainly metal screws, have been studied by many researchers in different wood species and wood-based panels [1,3,4,7,8,9,10,12].

Although, eccentric joints are relative innovative connectors for use in ready-to-assemble cabinet furniture they have captured a strong share of furniture market in Europe. Research results concerning the resistance to withdrawal of the specific fasteners used in eccentric joints have not been found in the literature. Today, insert fittings for eccentric joints of many manufacturers (patented or not) are sold in the European market and the study of their comparative withdrawal capacity is needed. The knowledge and understanding of factors affecting the insert fittings withdrawal strength of eccentric joints can be used for joint improvements in ready-to-assemble case furniture construction.

A subject of investigation in this paper is the face withdrawal resistance during removing insert fittings of eccentric joints of particleboards and MDF, which are the most often used wood-based panels. Nowadays, as much as 90% (or more) of all furniture made in Europe is based on wood-based panels, especially on particleboards and MDFs [12].

Materials and Methods

The wood-based panels tested include particleboard and medium density fiberboard (MDF), of 16 mm thickness. Specifically, particleboards uncoated (of 4 different mean densities –Pd1, Pd2, Pd3, Pd4), coated with melamine (Pdm) and veneer (Pdv), and MDF uncoated (MDF), coated with melamine (MDFm) and veneer (MDFv) were tested. The specimens measured 5 cm square.
The insert fittings tested include screws, screws with plastic sockets (screws w.p.s.), and the following insert fittings: plastic single (Pl-1), plastic double (Pl-2), metallic single (Met-1) and metallic double (Met-2). The insert fittings of two manufacturers used in the study were commercially available standard items (Fig.1)

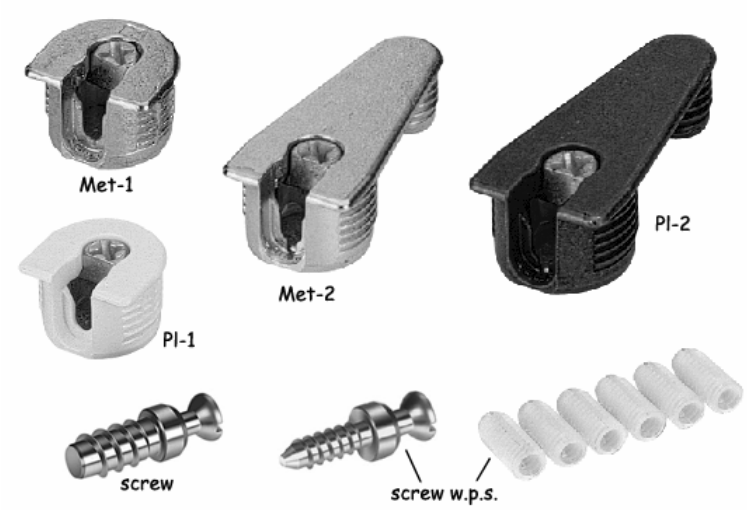

Figure 1. The connecting insert fittings used in the study.

Manufacturers recommendations were followed with respect to pilot hole sizes and the insertion of screws, screw plastic sockets and the insert fittings (Table 1). Pilot holes were drilled through the center of each specimen by means of a drill in a direction perpendicular to the face of a sample. All of the tests were carried out on a Shimatzu testing machine according to the standard EN 13446:2002. The withdrawal capacity is determined in Newtons (N) instead of N/mm^2, in order to have the absolute values of the maximum load applied, in different insert fittings (screws by screwing, metal and plastic fitting items by knocking).

Table 1. Description of the insert fittings of the two manufacturers used in the study.

Fitting item / Characteristic	Screw	Screw w.p.s.	Plastic socket	Fitting item single	Fitting item double
Hole diameter (mm)	5.0	5.0	5.0	20.0	20.0 + 10.0
Hole length (mm)	13.0	13.0	13.0	12.5	12.5 +10.5
Fitting item diameter (mm)	5.0	3.0	3.0	20.0	20.0 + 10.0
Fitting item length (mm)	11.0	11.0	13.0 A/12.0 B	12.5	12.5 +10.5

Results and Discussion

A. Holding strength of the insert fittings in Particleboard

The results of the tests of the two manufacturers' insert fittings in particleboards are given in Table 2.

Table 2. Holding strength results of the insert fittings of two manufacturers in particleboards.

Panel type	Pd1	Pd2	Pd3	Pd4	Pdm	Pdv
Panel density (g/cm³)	0.64	0.66	0.69	0.73	0.65	0.62
Panel IB (N/cm²)	0.35	0.50	0.56	0.75	0.42	0.43
Fitting insert type						
Manufacturer A						
Screw	590 (30)*	687 (61)	872 (43)	962 (37)	681 (35)	793 (33)
Screw with p.s.	687 (43)	734 (47)	918 (35)	1076 (53)	804 (41)	880 (39)
Fitting plastic single	234 (29)	228 (33)	232 (30)	254 (34)	222 (23)	287 (42)
Fitting plastic double	251 (37)	257 (50)	251 (38)	264 (24)	229 (40)	286 (52)
Fitting metal single	252 (42)	260 (46)	314 (40)	457 (61)	303 (32)	333 (49)
Fitting metal double	335 (25)	371 (45)	483 (39)	624 (56)	362 (56)	425 (46)
Manufacturer B						
Screw	622 (54)	724 (29)	897 (21)	1040 (27)	718 (60)	767 (30)
Screw with p.s.	545 (32)	475 (35)	559 (72)	565 (28)	598 (25)	567 (21)
Fitting plastic single	233 (28)	256 (33)	285 (52)	325 (41)	260 (22)	330 (23)
Fitting plastic double	259 (25)	264 (35)	281 (48)	307 (46)	251 (25)	311 (22)
Fitting metal single	271 (29)	279 (61)	396 (44)	462 (49)	343 (50)	508 (57)
Fitting metal double	345 (28)	351 (31)	486 (61)	595 (59)	364 (45)	525 (49)

* Means of 20 samples (N). Values in parenthesis are standard deviations.

In general, the holding strength of the screws without sockets of the two manufacturers is about the same for the same type of particleboard. On the contrary, the holding strength of the screws with plastic sockets varied greatly from manufacturer A to manufacturer B for the same type of board. From the other side, the holding strength of the insert fittings of the two manufacturers is about the same for the same type of particleboard, but from 7.5% to 76.4% lower than the corresponding holding strength of the screws.

Detailed results of the tests for each manufacturer's insert fittings in particleboards are given in Figures 2 through 7.

In the case of manufacturer A the screws without sockets gave holding strength that ranged from 590 N to 962 N, while the screws with plastic sockets gave values from 687 N to 1076 N. The combination of screws with sockets gave better values in relation to screws without sockets increasing the mean strength by 11% (Fig. 2).

From the other hand, the holding strength of the plastic fittings ranged from 228 N to 287 N in single items and from 251 N to 286 N in double items, respectively (Fig. 3). This corresponds to a very small increase of the mean holding strength of the double fittings by 5.9%, compared to the single fitting items. Also, the holding strength of the metal fittings ranged from 252 N to 457 N in single items and from 335 N to 624 N in double items, respectively. This corresponds to an increase of the mean holding strength of the double fittings by 35.5% compared to the single ones. It is obvious that the use of metal fittings gave significantly better values of the mean holding strength by 31.6%, compared to the single plastic items and by 68.9% compared to the double plastic items, respectively.

In the case of manufacturer B the screws without sockets gave a slight increase in mean values of holding strength, by 4.0%, compared with to the manufacturer A results, but the screws with plastic sockets gave a great decrease of the mean strength values, by 34%, in comparison with to the manufacturer A results. This can be attributed mainly to the sorter length of the plastic socket (12 mm) and the low quality of the socket material (Fig. 4).

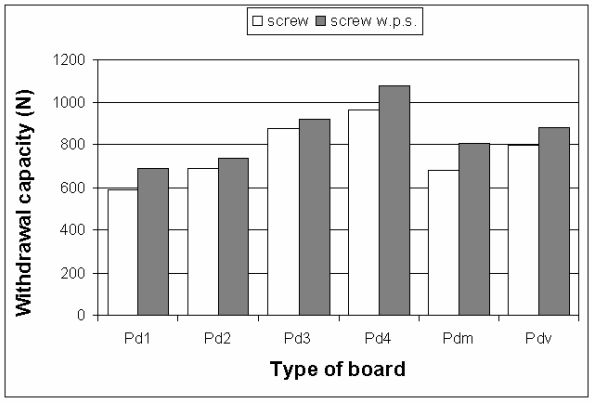

Fig. 2. Withdrawal capacity of manufacturer A screws in particleboards.

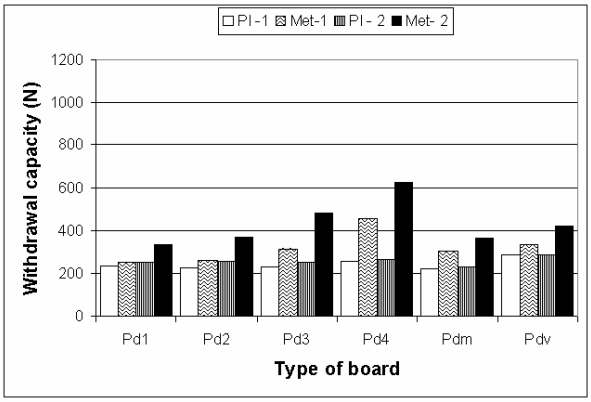

Fig. 3. Withdrawal capacity of manufacturer A fittings in particleboards.

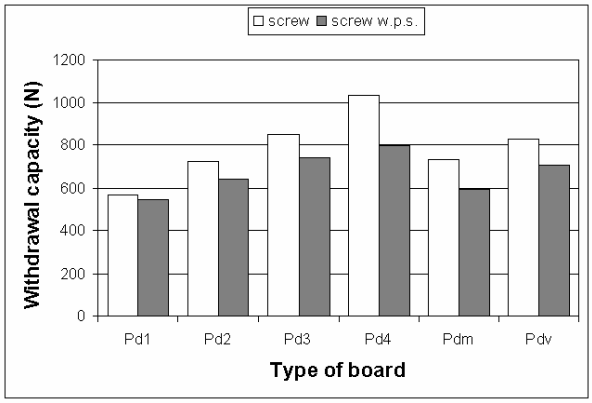

Fig. 4. Withdrawal capacity of manufacturer B screws in particleboards.

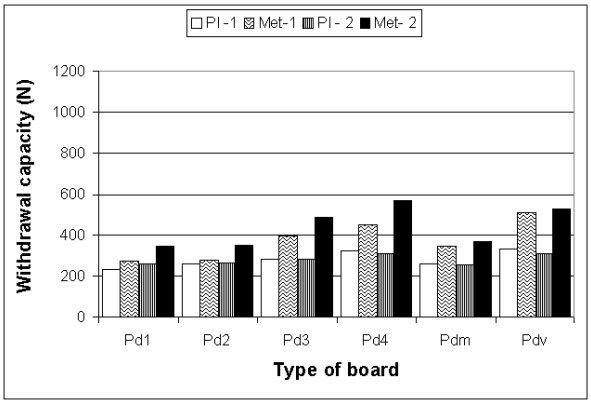

Fig. 5. Withdrawal capacity of manufacturer B fittings in particleboards.

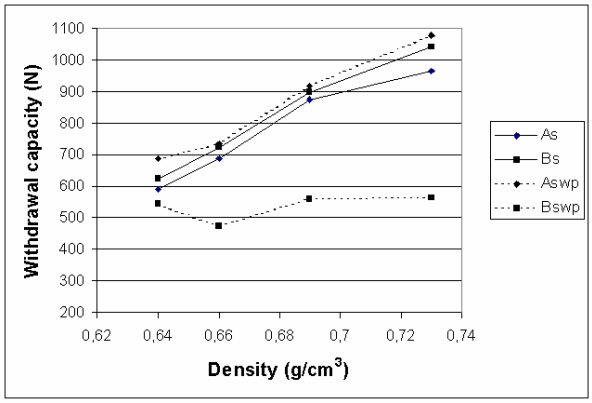

Fig. 6. Effect of particleboards density on the withdrawal capacity of both manufacturers screws.

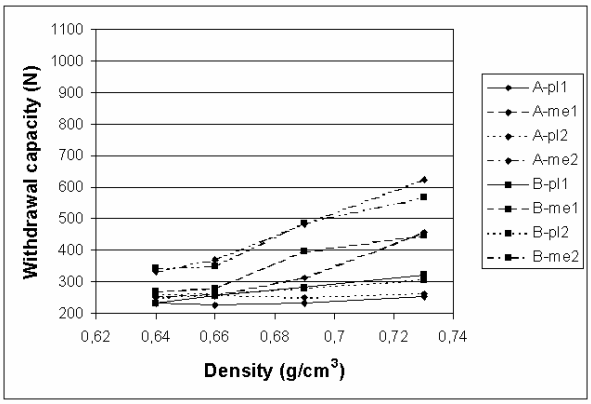

Fig. 7. Effect of particleboards density on the withdrawal capacity of both manufacturers fittings.

From the other hand, the holding strength of the plastic fittings ranged from 233 N to 330 N in single items and from 259 N to 311 N in double items, respectively (Fig. 5). This corresponds to a very small decrease of the mean holding strength of the double fittings by 0.3%, compared to the single fitting items. Also, the holding strength of the metal fittings ranged from 271 N to 508 N in single items and from 345 N to 595 N in double items,

respectively. This corresponds to an increase of the mean holding strength of the double fittings by 19.0% compared to the single ones. It is obvious that the use of metal fittings gave better values of the mean holding strength by 32.2%, compared to the single plastic items and by 57.7% compared to the double plastic items, respectively.

In both cases, the results clearly demonstrate that the mean holding strength of both plastic and metal fittings is quite lower than the corresponding holding strength of the screws and the screws with sockets (by 35.1% to 76.4% in manufacturer A and by 7.2% to 70.5% in manufacturer B). This is due to the way of their application by knocking and screwing, respectively. In practice, this means that in eccentric joints the weak part is the insert fitting item and this is appeared especially when we try to remove such furniture from its position.

Furthermore, in both cases the differences of holding strength results measured in different panel types can easily be explained by the effect of panels' density. The results indicated that there is a strong relationship between the holding strength of the screws of both manufacturers and the panel density. There is a near linear increase in holding strength of screws and screws with sockets as density of the panel is increased, with the exception of manufacturer B screws with sockets which failed to succeed better results. The correlation between the holding strength and the particleboard density can be expressed by the following equation: $F = 4{,}135*D - 2{,}046.0$, with $r^2 = 0.805$ (where: F=Holding strength and D=Panel density) (Fig. 6).

The same relationship was found to exist between the holding strength of insert fittings and the panel density. The relationship was more pronounced in the case of the metal insert fittings, while the plastic fittings failed to confirm this conclusion (Fig. 7).

Also, it is important to comment that the use of melamine and veneer coatings in particleboards seems not to affect the holding strength of the insert fittings in a different way.

B. Holding strength of the insert fittings in MDF

The corresponding results of the tests of the two manufacturers insert fittings in MDF are given in table 3.

Table 3. Holding strength results of the insert fittings of two manufacturers in MDF.

Panel type	**MDF**	**MDFm**	**MDFv**
Panel density (g/cm³)	**0.72**	**0.76**	**0.74**
Panel IB (N/cm²)	**0.42**	**0.57**	**0.52**
Fitting insert type			
Manufacturer A			
Screw	995 (40)*	1000 (50)	962 (58)
Screw with p.s.	987 (41)	1070 (30)	1067 (46)
Fitting plastic single	364 (56)	367 (57)	362 (32)
Fitting plastic double	386 (64)	384 (64)	392 (61)
Fitting metal single	534 (48)	539 (50)	532 (47)
Fitting metal double	631 (63)	669 (59)	690 (72)
Manufacturer B			
Screw	906 (29)	1077 (47)	1025 (59)
Screw with p.s.	780 (55)	680 (68)	597 (74)
Fitting plastic single	507 (64)	488 (68)	498 (32)
Fitting plastic double	461 (58)	501 (68)	462 (39)
Fitting metal single	530 (55)	590 (64)	537 (54)
Fitting metal double	667 (71)	643 (75)	632 (45)

* Means of 20 samples (N). Values in parenthesis are standard deviations.

Generally, the holding strength values of the different insert fittings of both manufacturers in MDF panels are similar to the values in the particleboard panels. The holding strength of the insert fittings is about the same for the same type of MDF panel, but from 5.4% to 66.0% lower than the corresponding strength of the screws.

Detailed results of the tests for each manufacturer's insert fittings in MDF are given in Figures 8 through 11.

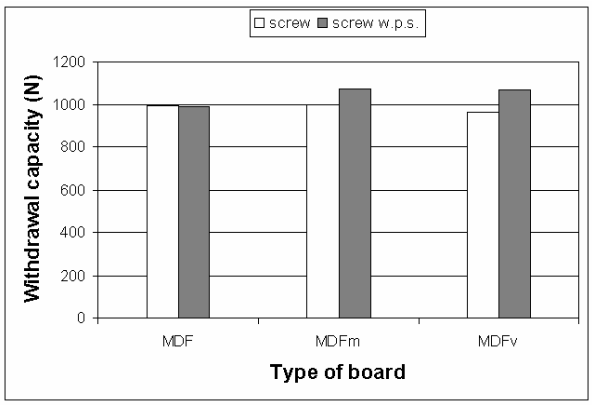

Fig. 8. Withdrawal capacity of manufacturer A screws in MDF.

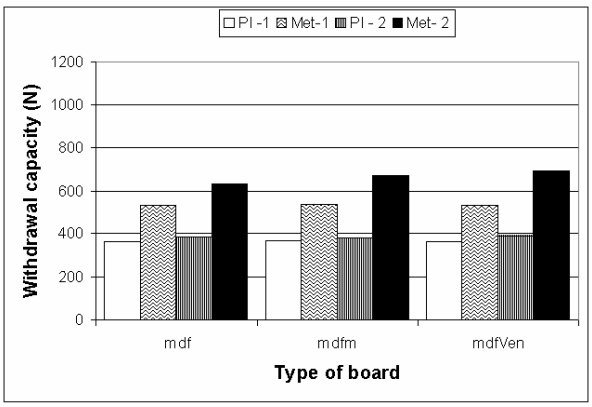

Fig. 9. Withdrawal capacity of manufacturer A fittings in MDF.

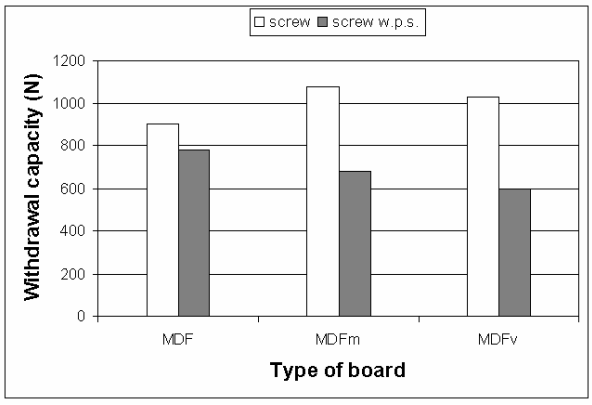

Fig. 10. Withdrawal capacity of manufacturer B screws in MDF.

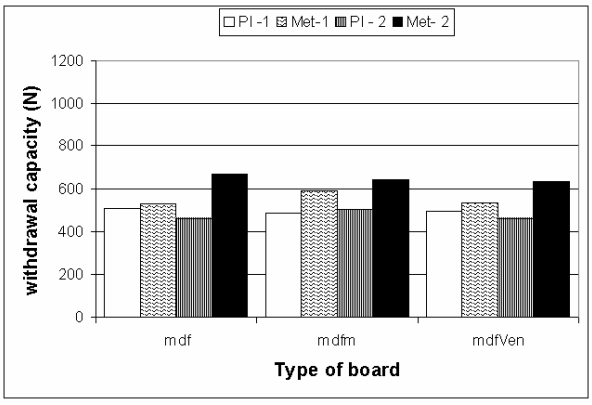

Fig. 11. Withdrawal capacity of manufacturer B fittings in MDF.

In the case of manufacturer A the screws without sockets gave holding strength that ranged from 962 N to 1000 N, while the screws with plastic sockets gave values from 987 N to 1070 N. The combination of screws with sockets gave better values in relation to screws without sockets increasing the mean strength by 5.7 % (Fig. 8).
From the other hand, the holding strength of the plastic fittings ranged from 362 N to 367 N in single items and from 384 N to 392 N in double items, respectively (Fig. 9). This corresponds to a small increase of the mean holding strength of the double fittings by 6.3%, compared to the single fitting items. Also, the holding strength of the metal fittings ranged from 532 N to 539 N in single items and from 631 N to 690 N in double items, respectively. This corresponds to an increase of the mean holding strength of the double fittings by 24.0% compared to the single ones. It is also obvious, that the use of metal fittings gave greater values of the mean holding strength by 46.9% compared to the single plastic items and by 71.2% compared to the double plastic items, respectively.

In the case of manufacturer B the screws without sockets gave a slight increase in mean values of holding strength, by 1.8 %, compared with to the manufacturer A results, but the screws with plastic sockets gave a great decrease of the mean strength values, by 34.1 %, in comparison with to the manufacturer A results (Fig. 10).
From the other hand, the holding strength of the plastic fittings ranged from 488 N to 507 N in single items and from 461 N to 501 N in double items, respectively (Fig. 11). This corresponds to a small decrease of the mean holding strength of the double fittings by 4.5%, compared to the single fitting items. Also, the holding strength of the metal fittings ranged from 530 N to 590 N in single items and from 632 N to 667 N in double items, respectively. This corresponds to an increase of the mean holding strength of the double fittings by 17.5% compared to the single ones. It is obvious that the use of metal fittings gave better values of the mean holding strength by 33.2%, compared to the single plastic items and by 36.6% compared to the double plastic items, respectively.

In both cases, the results clearly demonstrate that the mean holding strength of both plastic and metal fittings is quite lower than the corresponding holding strength of the screws and the screws with sockets (by 28.3% to 66.0% in manufacturer A and by 5.4% to 54.9% in manufacturer B).
Also, it is important to comment that the use of melamine and veneer coatings in MDF panels seems not to affect the holding strength of the insert fittings in a different way.

CONCLUSIONS

1. The holding strength of the screws of the eccentric joints in particleboard and MDF panels differ slightly from manufacturer A to manufacturer B.
2. In contrast, the holding strength of the screws with plastic sockets in particleboard and MDF panels differ greatly from manufacturer A to manufacturer B, depending on the dimensions and the raw material quality of the plastic sockets.
3. The plastic and metal insert fittings give quite lower holding strength in comparison with to the screws and screws with sockets (by 7.2% to 76.4% in particleboard and by 5.4% to 66.0% in MDF panels).
4. The plastic insert fittings give lower holding strength compared with to the metal insert fittings. Actually, the double plastic fittings of both manufacturers don't give better values than the single plastic items, in both particleboard and MDF panels.
5. The double metal insert fittings give higher holding strength compared with to the single metal fittings (by 19.0% to 35.0% in particleboard and by 17.5% to 24.0% in MDF panels, respectively).
6. There is a near linear increase in face holding strength of the screws of both manufacturers as density of the uncoated particleboard panels is increased. The same correlation appears to exist in uncoated MDF and all the coated particleboard and MDF panels.

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