



## Detachable connecting fittings failure loads on plywood furniture

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**Abstract.** The main objective of this study is to find the most suitable detachable joint for plywood details. Connecting fittings of different type were tested under failure loads. Both tensile and shear tests were used. The test specimens are made from 21 mm thick birch plywood. Lamello AG products Clamex P10, Clamex P15, and Invis Mx and Minifix connectors with dowel as joint type have been used. The test results showed that the Invis Mx has the highest average strength value in tensile test and Minifix with beech dowel in shear test. Based on the test results, the best fitting for connecting plywood boards was determined.

**Key words:** detachable furniture fittings, mechanical properties, plywood, case-type furniture.

### 1. INTRODUCTION

Carcass furniture constructional durability mostly depends on the right furniture fitting. Mechanical strength of the joint is decisive, because the failure usually is related to the furniture fitting [1]. To export the product, the assembly must be done by the client. The assembly has to be simple and handy. But the joint must withstand severe loads.

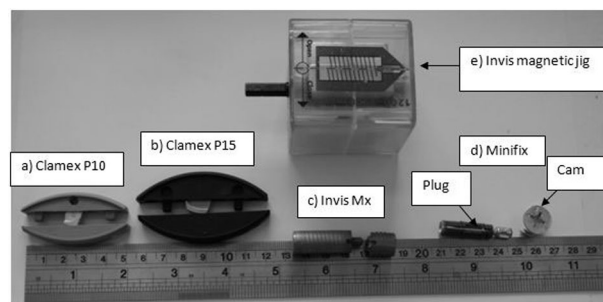
The trend in the furniture industry is to use different Minifixes (Fig. 1d) and dowels made for connecting wood-based panels like particleboard (PB), medium density fibreboard (MDF), or solid wood panels at the point of assembly and disassembly [2].

One factor is the strength of the joint, but another is the aesthetical appearance of the connection. When using traditional Minifix fittings, the cam part leaves a big opening that can be covered with a cap. The design of the furniture can leave both sides of the furniture element visible. Therefore the furniture fitting has to be with no or minimal connection opening slots.

For aesthetic reasons and strength of the joint, the tested furniture fittings Lamello AG products Clamex P10 (Fig. 1a), Clamex P15 (Fig. 1b), and Invis Mx

(Fig. 1c) were chosen [3]. An additional factor was the novelty of the furniture fittings and their processing.

Many researchers have tested joints in tension and compression modes [4–6]. Yerlikaya et al. [4,5] studied the biscuit and Minifix fittings in MDF and in PB. Smardzewski et al. [6] researched the elastic modulus of L-type joints with different furniture fittings in PB. But there was a lack of information of furniture fittings in plywood. Based on Nandanwar et al. [7], tensile and shear test were conducted. The shear and tensile test results of the above mentioned fittings are compared with the most commonly used Minifix fitting. In the shear test, the Minifix fitting joint is strengthened with a beech dowel, which is a common approach in furniture



**Fig. 1.** Tested furniture fittings.

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industry. The connector fitting confirms and closes the joint. The dowel diameter was chosen according to [8–10]. Based on other research, conducted by Dalvand et al. [9], it was suggested to use 8 mm diameter beech dowels. This article provides more knowledge about novel furniture fittings and their strength capacity in the joint.

## 2. MATERIALS AND METHODS

The specimens are made of 21 mm thick birch plywood. The tensile test specimen includes two plywood details that form a T-joint (Fig. 2).

The shear tests specimens consisted of two plywood boards, connected with the fitting to form an L-type joint (Fig. 3). No glue was added to Minifix with the dowel in joint.



Fig. 2. Tensile test setup.

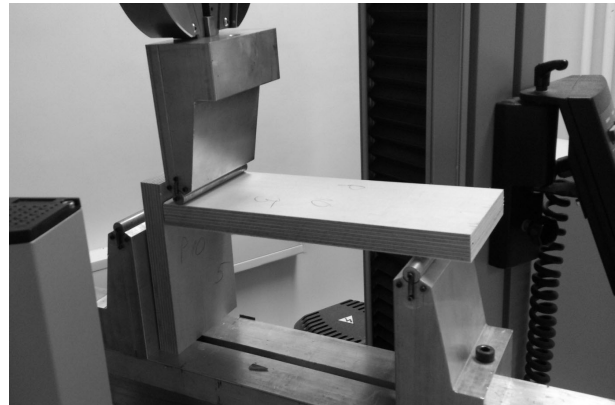


Fig. 3. Shear test setup.

### 2.1. Fittings

Lamello AG products Clamex P10, Clamex P15, and Invis Mx and Minifix fittings were used (Fig. 1).

Clamex P10 (Fig. 1a) and Clamex P15 (Fig. 1b) are oval biscuits shape connectors with a lateral ridge. The shell is made from fibreglass reinforced plastic and zinc die cast lever. Compared to Clamex P15, Clamex P10 is 1/3 smaller; the mounting depth is 10 mm. Then it is used for a thinner material. For Clamex P15 the mounting depth is 15 mm. For Clamex P10 the minimum material thickness is 13 mm for corner joints and 16 mm for mitre joints. For Clamex P15 the minimum material thickness is 13 mm for corner joints and 19 mm for mitre joints. The insertion of the fitting to the groove is quick and tool-free. The Clamex fasteners can be removed by hand and the removal creates minimal wear to the pit. The side ridges provide the steadiness of the fitting in the pit. Because the fittings are not glued or screwed to the pit, they are able to move in the pit, so they match to the opposite fitting. The Clamex P system can connect details from 30 to 180 deg, but the pit has to align at 90 deg to the joint. The Clamex P system has special positioning fingers to avoid twisting. For closing, a standard 4 mm hexagon key is needed to close the joint [2].

Invis Mx (Fig. 1c) is a magnet-driven connection fitting with no visible opening when the joint is connected. It consists of a metal connector with a thread and a stud that is screwed into the prepared 12 mm holes of the joint. A rotating magnetic field is created with a special jig (Fig. 1e). The jig is fixed to the cordless drill and rotated on the surface to close the connection. The metal connectors thread begins to rotate by the magnetic field, so that the thread will screw into the opposite stud. To open the connection, simply change the drill direction. The manufacturer offers multiple connector and stud lengths that can be combined. In this study, 29 mm length connector and 13.5 mm stud is used [2].

Minifix (Fig. 1d) joints consist of a cam and a bolt with a plastic plug. The bolt with a plastic plug was

installed to the hole. The cams were mounted into holes in the opposite member. The joint was fixed by turning the cam with a screwdriver.

## 2.2. Specimen preparation

Both Clamex P10 and Clamex P15 fitting grooves were processed with Zeta P2 profile biscuit jointer [1]. The jointer has an oscillating motion. The cutter makes forward motion oscillating up and down, then backward to the starting position. As mentioned earlier, the difference between the Clamex P10 and Clamex P15 is the cutting depth. The cutting depth of Clamex P10 is 10 mm and of Clamex P15 is 15 mm. On one side of the specimen, a 6 mm diameter hole is drilled for closing the joint.

For Invis Mx one 12 mm diameter hole is drilled on both sides of the specimen. The depth of the connector hole is 30 mm and depth for the stud hole is 15 mm. The holes are drilled with Homag Weeke BHC280 CNC machine to get accurate drilling. The Minifix holes were drilled with Homag Weeke BHC280 CNC. The rational distance of the dowel and eccentric cam was 64 mm. The centre of the holes was 18 mm from the edge.

## 2.3. Testing procedures

The tests were conducted by using electromechanical testing system Instron 5866 equipped with Bluehill software. The load and displacement graphs were plotted by a computer for all tests. The test was stopped when the graph of the test began to decrease after the maximum force. The tests were carried out at room temperature of 20°C with a 10 kN loading capacity on testing machine Instron at a speed of 50 mm/min.

In the tensile test, the specimens were fixed on the testing machine with two metal brackets. The specimens were connected to the machine with a bolt on the upper bracket and with a fixing bracket beneath the specimen (Fig. 2).

The shear test specimen's vertical side leans on the support of the testing machine. The upper support applies compression at 2 mm from the joint (Fig. 3). Both tests contained 10 specimens.

## 3. RESULTS AND DISCUSSION

The results of the tensile test are presented in Table 1. It is seen that Invis Mx had the highest average tensile strength (3345 N), although the standard deviation of the test results was high. Clamex P15 average tensile strength was 1000 N higher than that of Clamex P10. But the standard deviation of Clamex P15 was 9 times higher. Minifix had by far the lowest average tensile strength, only 253 N. The dowel was not included in the Minifix joint.

**Table 1.** Tensile test results with standard deviation

Fitting	Average force, N
Clamex P10	1385.57±50.47
Clamex P15	2204.52±457.08
Invis Mx	3344.69±288.25
Minifix	253.78±70.32

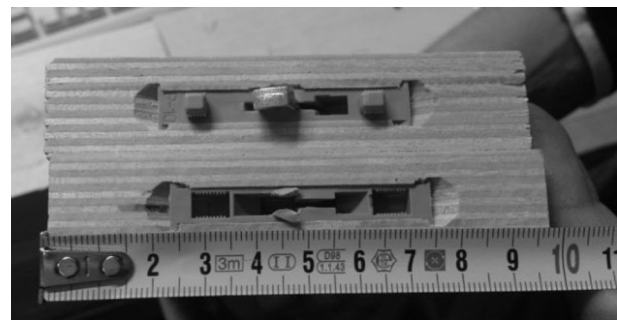
**Table 2.** Shear test results with standard deviation

Fitting	Average force, N
Clamex P10	1616.25±153.04
Clamex P15	2512.18±174.21
Invis	2659.74±337.92
Minifix	1678.59±56.02
Minifix with dowel	3143.66±328.18

The shear test results show how important the beech dowel is in the joint (Table 2). Minifix with a beech dowel had the highest average shear strength. The dowel gave 50% higher shear strength than the Minifix joint itself. This is higher result than in a similar research [11]. Invis Mx and Clamex P15 gave also good results, accordingly 2660 N and 2512 N. When in the tensile test the difference was 1/3 in favour of Invis Mx, then in shear test the results are almost the same. The standard deviation of Minifix with dowel and Invis Mx are high, more than 300 N. It shows that the failure depends of the quality of the plywood. Clamex P15 is 1/3 stronger than Clamex P10.

## 4. FAILURE MODE

Failure in the joint was mainly from the fitting. In the tensile test, the Clamex P fittings lever was pulled out from the plastic anchorage (Fig. 4). The anchorage broke or was distorted. Invis Mx and Minifix were also pulled out from the hole. The fittings had no damage. Invis Mx is like a bolt; when pulled out the thread bruised the plane of the hole. Minifix bolt with plastic



**Fig. 4.** Distorted plastic anchorage on Clamex P10.

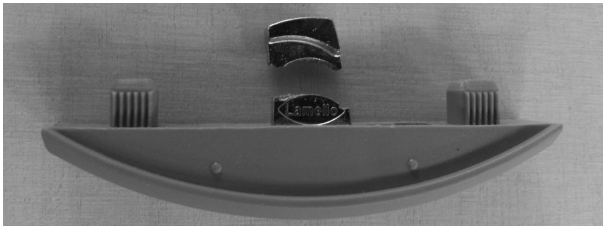


Fig. 5. Broken lever on Clamex P10.

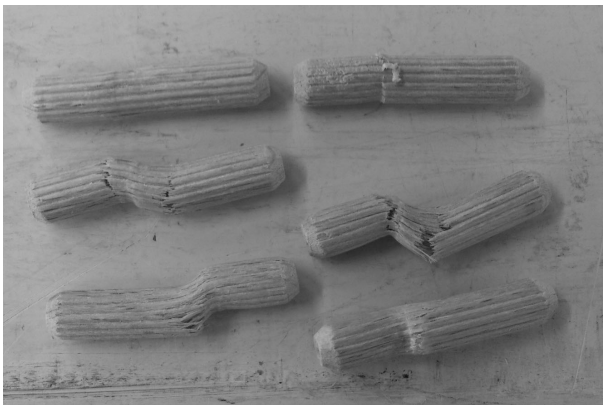


Fig. 6. Broken or deformed beech dowels.

plug was pulled out with no damage to the plane of the hole. Minifix does not work in plywood, because plywood is denser than MDF or PB. The surface of the hole in plywood is smoother. The plastic plug does not have the clasp, so it is pulled out with a slight force. In the shear test, Clamex P fittings broke from the lever (Fig. 5). Invis Mx was broken from the fitting but the plywood was also delaminated. Minifix with the beech dowel was broken from the bolt or because of the plywood delamination. The dowel had shear deformations (Fig. 6).

## 5. CONCLUSIONS

Testing procedure for different fixtures has been worked out. Mechanical tests of different fittings were made in tensile and shear conditions. In tensile test, Invis Mx had the highest maximum load. Clamex P15 has almost half more tensile strength than Clamex P10. Minifix had by far the lowest average tensile strength. Invis Mx and Minifix fittings did not break in the tensile test. Both Clamex P fittings were broken or distorted from the fibre reinforce plastic anchorage in the tensile test. But in the shear test they broke from the lever. The shear

test results show how important the beech dowel is in the joint. Minifix with a beech dowel had the highest average shear strength. The dowel gave 50% more shear strength than the Minifix joint itself. Invis Mx and Clamex P15 gave also good results. When in the tensile test the difference was 1/3 in favour of Invis Mx, then in shear test the results are almost the same. Clamex P15 is 1/3 stronger than Clamex P10.

As a results of this work, furniture constructors have a perception of new furniture fittings. If a joint has to be with no visible connection then Invis Mx is the best fittings. If the appearance of the joint is not an important factor then the traditional Minifix with dowel is recommended.

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## **Lahtivõetavate mööblikinnitusfurnituuride purunemine vineerist mööblis**

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Antud töös katsetati lahtivõetavate seotiste mehaanilist tugevust tõmbe- ja nihkekoormisel. Katsetel rakendati koormust liite purunemiseni kasevineerist katsekehades. Katsetatavateks kinnitusfurnituurideks olid Šveitsi tootja Lamello AG tooted: plastlamellid Clamex P10 ja P15 ning magnetühendus Invis Mx. Neid võrreldi traditsiooniliselt mööbliühendustes kasutatava ühendusega Minifix-i mööblitõmmit koos puittüübliga. Valiti sellised lahtivõetavad seotised, mis oleksid ilma nähtava sulgemisavata või et see avaus oleks minimaalsete mõõtmetega.

Mööbliühenduse purunemine toimus enamasti kinnitusfurnituuris. Tõmbekatsetel andis parima tulemuse seotis Invis Mx, keskmine tulemus 3345 N. Nihkekatsel andis parima keskmise tulemuse puittüübliga tugevdatud tõmmitseotis 3144 N. Puittüübli kasutamine tõmmitseotises tagab 50% suurema nihketugevuse.

Kui aga soovitakse väliste kinnitusavadeta liidet ja mööblieset on vaja korduvalt teisaldada, lahti võtta ning koostada, siis selleks otstarbeks sobib paremini magnetühendus Invis Mx. Kui liite disainis on fikseerimisavad lubatud, siis ei ole lahtivõetavates liidetes vastast traditsioonilisele puittüübliga tõmmitseotistele.

Tulemustel on praktiline väärtus, sest neid saab kasutada mööblitootmisega tegelevate ettevõtete igapäevases konstrueerimistöös.