Comparison of test methods for furniture corner connections

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Abstract: Mechanical loading of furniture is dependent depending highly on material as well as on the properties of corner connections.

One of the quality criteria of corner connections is the mechanical flexibility, the inverse of mechanical elasticity. This parameter can be derived by means of different test methods. These test methods are presented and compared in this paper.

New is among other usage of classical static methods the usage of a nondestructive method, called laservibrometry. It is suitable both for explanation of short and for long term characteristics of mechanical systems. The aim is to classify this test method for furniture product tests in the future.

Advantages of the laservibrometry are the independence of new materials or new corner connection methods in furniture construction. The presented results should give first guidelines for furniture construction compared with results of simulation tools.

Keywords: furniture corner connection; mechanical stress; standard test method; laservibrometry

1 Introduction

Mechanical stresses and deformation of furniture corner connections are depending highly on material as well as on the other properties of corner connections. Therefore it is necessary to test furniture corner connections under different mechanical loadings. Actually there exist different standards and methods as well. In this paper we will show and compare different methods to determine the suspension rate of corner connections.

2 Examples

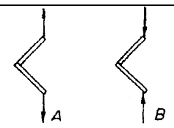
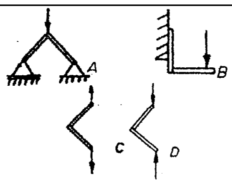
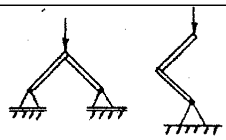
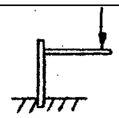
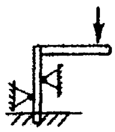
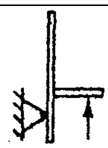
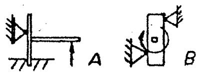
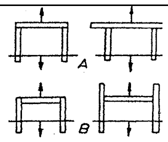
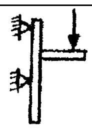
For the purpose of easily assembling or disassembling a piece of furniture, the corner con-nection hardware should be easily accessible and must provide a reliable connection between particular joints. In this paper, we focus on carcass, case and seating furniture, built from different materials and different furniture corner connections.
Regardless of the special corner connection and the joint material the constructions are designed with widespread functionality in mind:

- ensuring maximal stability, even with heavy weights,
- assembly child's play,
- demands on water resistance,
- long term reliability,
- design aspects etc.

3 Standard test methods and new procedure

As mentioned above, the mechanical properties of corner connections need to be tested and confirmed. Table 1 shows different test methods with their mechanical objectives.

Table 1. Most frequently used test methods in furniture construction

No.	Test method according to	Load scheme	Load characteristics	Objectives
1	Lesnikowski et Drouet		A tension B pressure	break resistance
2	Albin et Müller		A, B bending C tension D pressure	break resistance ultimate moment fracture angle
3	Kjučukov		bending	break resistance ultimate moment
4	Mazurkiewicz		bending	Deflection Inclination
5	Rinkefeil et Wienert		bending	deflection break resistance inclination stiffness
6	Lechner		bending	deflection suspension rate
7	Albin et Hünker		A bending B torsion	break resistance ultimate moment
8	Kjučukov		A tension B shear	break resistance shear strength
9	TU Dresden		bending	suspension rate

It can be seen, that different loads lead to different evaluation criteria such as deflections or inclinations due to bending or torsion. The suspension rate remains a combined parameter. To summarize, the table contains static, more or less destructive, partially long term tests. However, our focus is to establish a new standard regarding short-term characteristics.

All these deliberations led to our decision to use a typical system dynamics black box model. The input (excitation) consists of harmonic vibration and the output (response) function of vibration velocities. The ratio between the response and excitation, the transfer or response function is a measure for the dynamic flexibility, the inverse of the suspension rate. The dynamic suspension rate may be compared to the results of classical procedures. Our considerations resulted in using laservibrometry to determine the suspension rate dynamic.

4 Material and methods

The objective of the investigations was to determine the suspension rate (mechanical flexi-bility) of different corner connections in dependency of material and the comparison between standard tests according to table 1 and laservibrometry (LV). For this this paper, we used two materials (larch, Larix decidua and oak, Quercus robur) and two corner connection types (dowel and box joint). Figure 1 shows the scheme of the entire investigation.

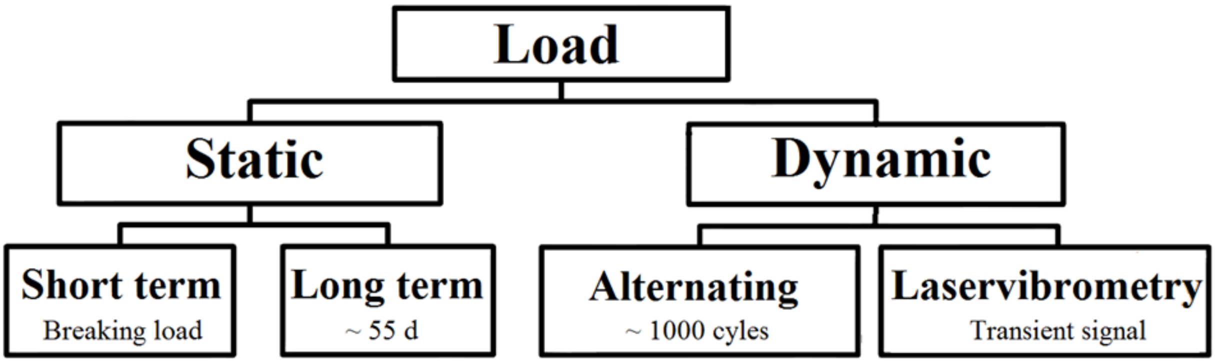


Figure 1. Scheme of compared test methods

To establish laservibrometry as a possible non-destructive standard in furniture construction, we used it as mentioned above in comparison with classic test procedures such as static short and long tests and alternating tests (~ 1000 cyles). Main advantage of a non-destructive test is saving costs because the specimen can be used for additionally other tests too. The main advantage of using laservibrometry is saving time due to rapid instrumentation.

The test bed is to be seen in figure 2. A shaker was used for the excitation of the specimen, a Polytec laser vibrometer PSV 300 for measuring the vibration velocities.

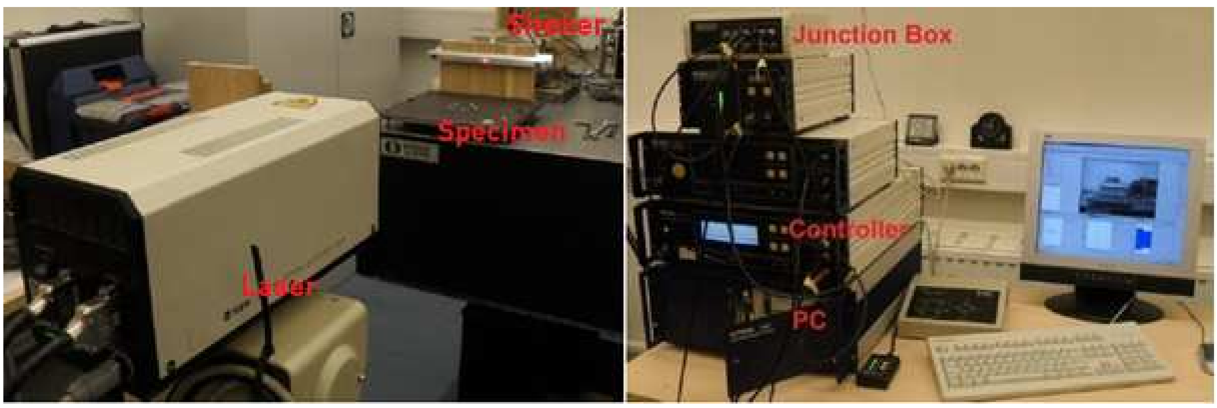


Figure2. Laservibrometry test bed

The suspension rate was calculated by modulus of the transfer function (figure 3). This function, the ration between output function (vibration deflection y) and excitation (shaker force x) we get as follows: we consider the differential equation for a single-degree-of-freedom SDOF) model with the mass m, damping k, stiffnes c; excitation x and response y

$$m\ddot{y} + k\dot{y} + cy = x(t) \quad . \tag{1}$$

LAPLACE transform with initial conditions at zero with $s = \delta + j\,\omega$ leads to

$$Y(s)\left[-s^2 m + jsk + c\right] = X(s) \quad . \tag{2}$$

Limit of $\lim_{\delta \to 0} s = \lim_{\delta \to 0}(\delta + j\,\omega) = j\,\omega$ leads to FOURIER transform of (2), after rearranging weg get the transfer function $H(j\omega)$

$$H(j\omega) = \frac{Y(s)}{X(s)} = \frac{1}{-m\omega^2 + jk\omega + c} \quad . \tag{3}$$

Laservibrometry is based on the DOPPLER effect, it ist possible to measure vibrations out of the plane. Ther frequencies can be variied from 0 Hz to 30 MHz and it is possible to measure amplitudes between a few nanometers and 10 meters. In mechanical engineering it is widely used for non-contact measuring of vibrations as well as for hot or soft structures. The only condition is a good surface quality. This can be reached by spray or reflector stripes.

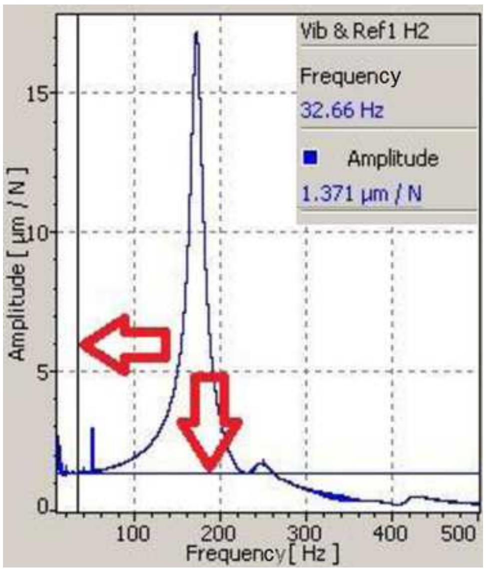


Figure 3. Transfer function, red arrows show reference lines for deriving abszissa and ordinate values for computing dynamic stiffnes

For purposes of testing the linearity of the system we superimposed the dynamic load with different static loads. The results of vibration tests were later compared to those obtained from short and long term static tests and short time alternating tests. Figure 4 shows the geometry of the specimen and a typical force-displacement curve leading to break resistance.

Results of long term static tests are to be seen in figure 5. From the curves the suspension rate c can be derived by force F and displacement d according to

$$c = \frac{F}{d} \quad . \tag{4}$$

and for the special geometry according to figure 4 (Lechner 1982)

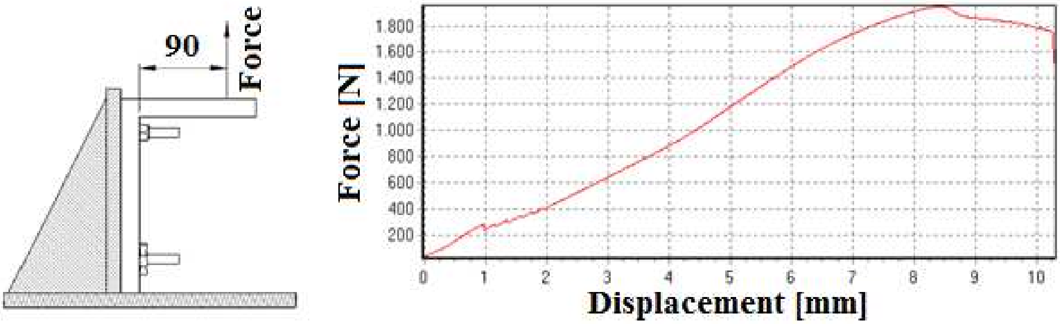


Figure 4. Short time static test bed for determining break resistance (left) and force-displacement curve for (right)

$$c_L = \frac{1}{\frac{d}{F \cdot \ell_S^2} - \frac{\ell_S^2}{3EI}} \quad . \tag{5}$$

In equation (5) we see the modulus of elasticity E, area moment of inertia I, distance of the point load (ℓ_S= 90 mm), force F and deflection d.

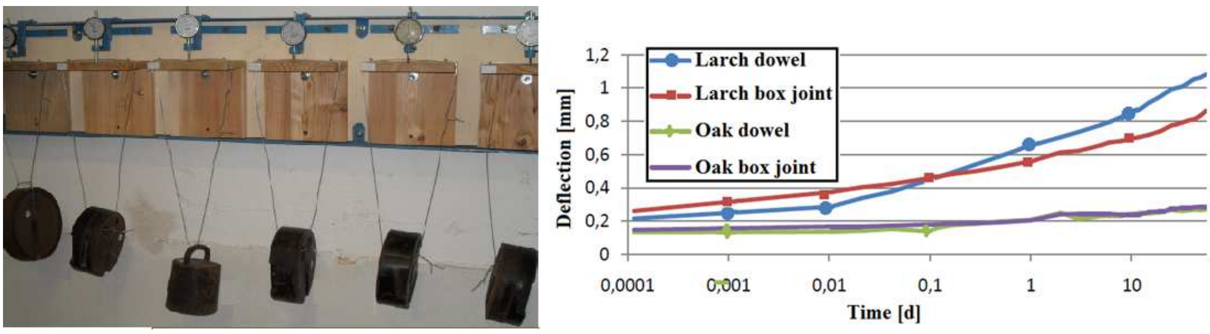


Figure 5. Long time static test bed (left) and and force-displacement curve (right)

5 Results

Figure 6 shows the comparison of selected results. It can be seen that the results of laservibrometry are approximately in the same range of results determined by classic tests.

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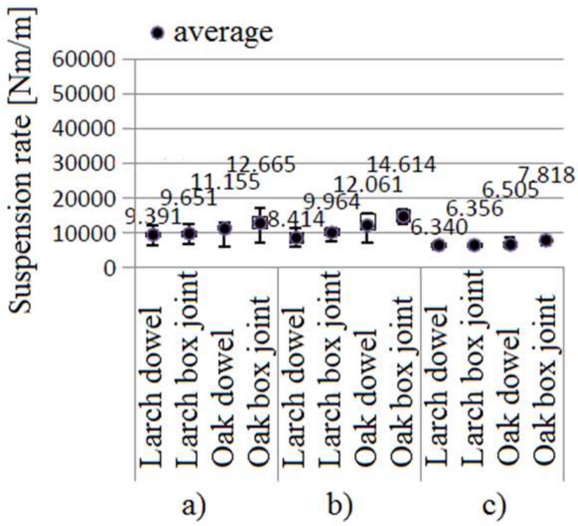

Figure 6. Comparison of suspension rate determined by a) laservibrometry, b) static test, c) alternating test

It can be seen that the results of laservibrometry are approximately in the same range of results determined by classic test methods.

6 Conclusions

Advantages of the laservibrometry are the independence of new materials or new corner connection methods in furniture construction. It is possible to perform a non-destructive rapid test. Furthermore, the presented results should give first guidelines for furniture construction compared with results of simulation tools. Laservibrometry is suitable both for explanation of short and for long term characteristics of mechanical systems. The aim is to classify this test method for furniture product tests in the future. The results of laservibrometry investigations are comparable to that of classical tests according to table 1. This shows that this measurement procedure is suitable for determining the suspension rate of corner connections. Variation of dynamic loads from 1 N to 7 N during laservibrometry measurement does not result in a variation of suspension rate. That means that the set-up is linear, stable and time-independent. The change of static preload, however, leads to a slightly higher suspension rate.

This allows assumption on solidification of corner connection because of the static preload.

In the future we want to establish the laservibrometry a standard test procedure for furniture industry. This should go in several steps:

- application to more different types of wood,
- application to more different types of corner connections
- a mobile laservibrometry system including a quick-clamp mechanism for reception of specimen and
- guidelines for using the test.

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