Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 108, 2019: 39-44
(Ann. WULS - SGGW, For. and Wood Technol. 108, 2019)

Impact of upholstered furniture seat structures on the long-term use comfort

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Abstract: *Impact of upholstered furniture structures on the comfort of long-term use.* The main objective of the study was to analyze the impact of changes to the structures of upholstered seating furniture to measure the comfort of new furniture and after long use. Tests were conducted with the use of a Force Sensitive Applications sensing mat to record contact pressure, and a profiled cavity pressed into the seat with a force of 760 N. The period of 5 years of long-term use was simulated by the cyclic load of 1000 N x 25,000 repetitions. Based on the analysis of the test results obtained, a decrease in the discomfort factor D by 12.7% for seat I and 11.5% for seat II was observed. This means an increase in the feeling of comfort in using these seats during the period of use. This is associated with a decrease in seat stiffness. Seats with less rigidity ("softer") cause less pressure on the human body due to the larger usable area.

Keywords: seat, upholstered furniture, comfort, contact pressure, foam.

INTRODUCTION

The furniture industry is among the largest industries using foamed materials. In lounge furniture, polyurethane foams are still the main structural material. This material affects the comfort of use. Foam structures on lounge furniture are widely used mostly due to the technological and economic factors. However, a cheap and simple production does not always go hand in hand with quality. In the literature, a lot of attention is paid to issues related to the analysis of the selection and modeling of rigidity of seats made of traditional foams (Linder-Ganz et al. 2005; Schrodt et al. 2005; Vlaovic et al. 2008; Grujicic et al. 2009; Lusiak and Smardzewski 2010; Silber et al. 2010; Smardzewski et al. 2010a, 2010b; Wiaderek and Smardzewski 2010a, 2010b; Smardzewski and Matwiej 2013; Wiaderek et al. 2016*)*. The construction material used is an important seat factor. From a user's point of view, the most important is the impact of seat filling on comfort during use.

The purpouse of the research is to determine the impact of long-term use of selected constructions of upholstered furniture seats for rest on the quality of use.

MATERIALS AND METHODS

Polyurethane foams belong to a wide group of polyurethanes (PURs), which are characterized by wide durability, chemical and physical resistance as well as abrasion resistance. The properties of polyurethane foam depend primarily on their:
- structure: cell sizes, their shape and structure,
- density,
- material constant values (Saha et al. 2005).

The most commonly used types of elastic combinations of upholstered furniture were analyzed. The selected three most representative constructions are presented on Figure 1. The seats have fixed dimensions of 600 x 600 x 150 [mm]. All of them are based on a supporting structure in the form of wooden frames made of pine.

Three seats were prepared for each variant. The load was applied to the seat using a numerically controlled Zwick testing machine. A force of 760 N was applied vertically downwards using a profiled indenter in accordance with the PN-EN 1728: 2012 standard. During the study, the displacement of the seat was recorded. Each seat was subjected to an analysis of contact stress distribution (fig. 2). For this purpose, a 630 x 630 mm mFlex mat was used, equipped with 1024 sensors. The contact stress distribution on the seat surface was recorded with an accuracy of 0.01 kPa. The stress value was registered after 60 seconds from obtaining the assumed load force. This allowed to stabilize the foam deflection caused by the indenter.

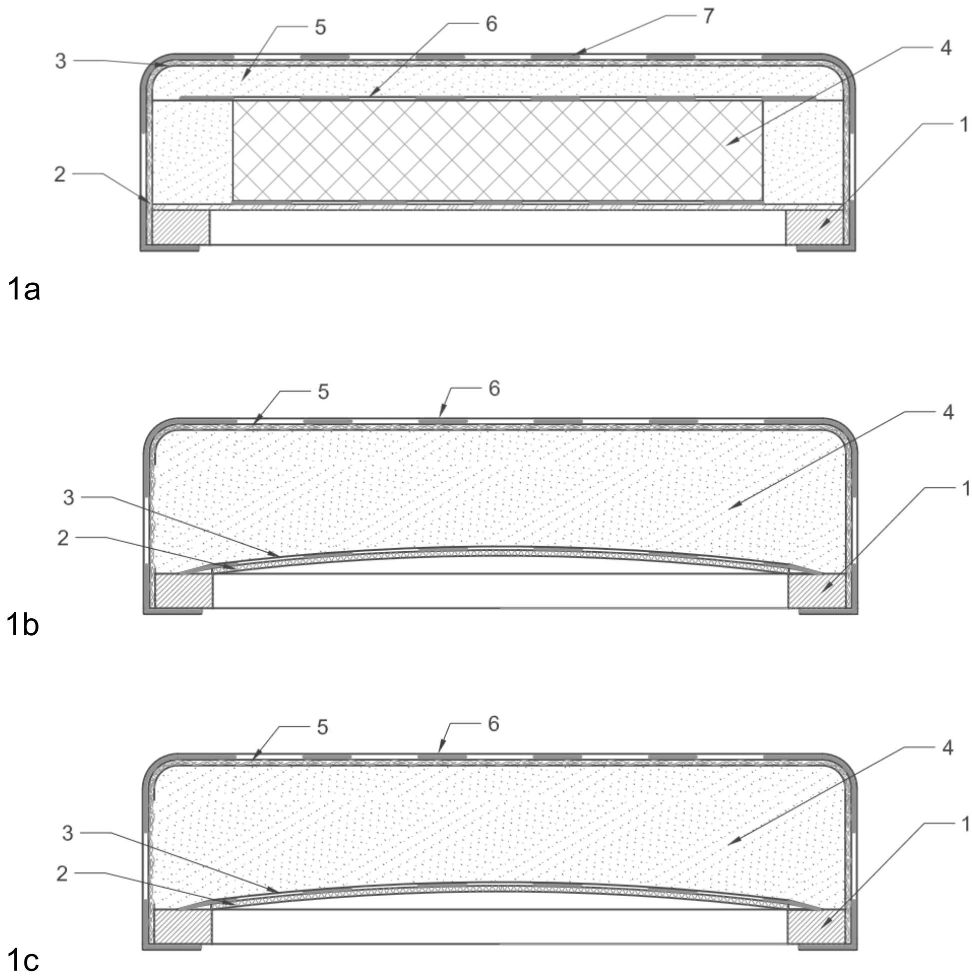


Figure 1. Seat construction: a) 1-frame, 2-fibreboard, 3-wadding, 4- Bonell form, 5- T25180 polyurethane foam, 6-felt, 7-fabric, b) 1-frame, 2-spring, 3-felt, 4- T25180 polyurethane foam, 5-wadding, 6-fabric, c) 1-frame, 2-spring, 3-felt, 4- HDS55 higly elastic polyurethane foam, 5-wadding, 6-fabric

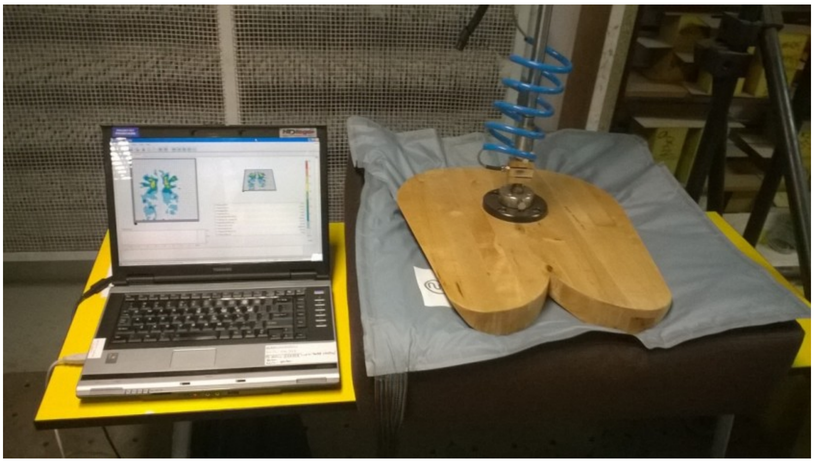


Figure 2. mFlex matting station

Seat comfort tests (Milivojevich et al. 2000) have shown a relationship between an even distribution of stress on the contact surface and a sense of comfort. One way to quantify the even distribution of pressure on the seat surface is to determine the percentage of *SPD* (Seat Pressure Distribution) contact stress distribution coefficient (Ahmadian et al. 2002) defined as:

$$\mathrm{SPD} = \frac{\sum_{i=1}^{n}(p_i - p_m)^2}{4\, n\, {p_m}^2} \times 100 \quad [\%]$$

where:
n - number of sensors in which contact pressure has non-zero values,
p_i - contact pressure in any mat sensor [kPa],
p_m - average contact pressure for n sensors [kPa].

This method is used in conjunction with a system that illustrates the distribution of stress on the seat surface, such as mFlex system. The lower seat pressure distribution coefficient (*SPD*) value indicates a more favorable even distribution of stress on the seat surface. Thus, the seat pressure distribution coefficient (*SPD*), contact stress σ, and contact surface have a direct impact on seating comfort. Unfortunately, this method does not exclude cases where the resulting stresses are too high for sitting comfort. In case of the discomfort factor *D* (Smardzewski et al. 2014), a high index will be obtained at high average contact stress on the p_m sensors and low values of the contact surface *A,* and low values of the *SPD* factor. Low values of the *D* factor will objectively determine a high comfort of seat use. The discomfort factor *D* was determined according to the formula:

$$D = \frac{p_m \times \mathrm{SPD}}{A} \quad \left[\frac{N}{m^4}\right].$$

The next stage was subjecting the seats to long term tests of cyclic load modeled on the PN-EN12520 and PN-EN1728 standards. The tests consisted in a series of 25,000 repetitions of applying a force of 1000 N to the seat (which corresponds to about 5 years of home use). For this purpose, a profile indenter attached to a computer-controlled pneumatic cylinder was used (fig. 2).

RESULTS

Laboratory tests have allowed to observe the load distribution and stress values for the analyzed structural variants of upholstered furniture seats. The results of the research were presented in the form of maps of stress distribution on the usable surface of the seats. A graphic comparison of test results before and after the cyclic loading process is presented in Table 1. To compare the changes in the tested values, Table 2 and a percentage graph were prepared (fig. 3).

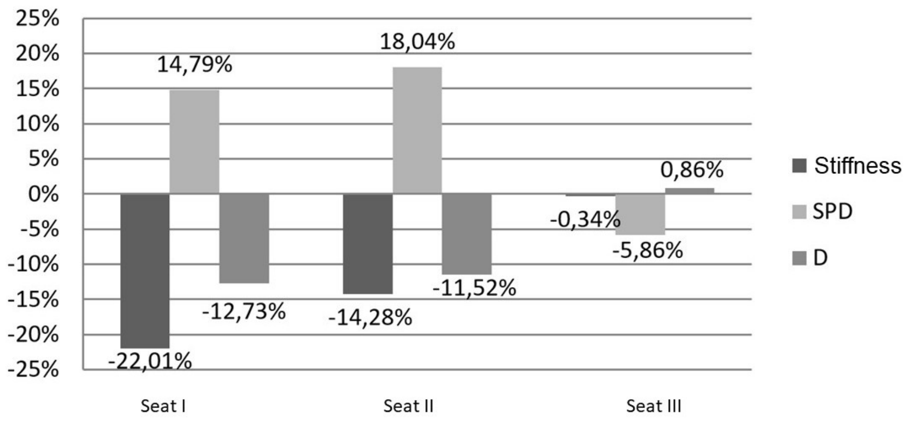


Figure 3. Percentage comparison of the end results of the study

Table 1 Selected seat surface stress distribution maps:

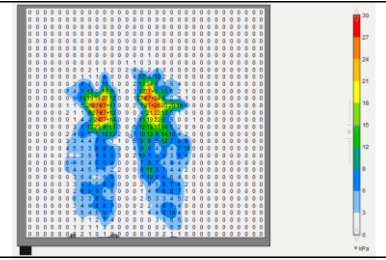
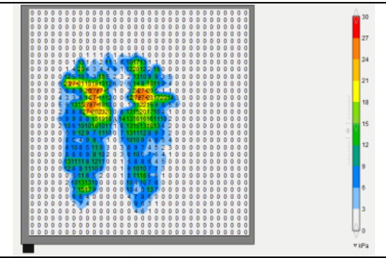
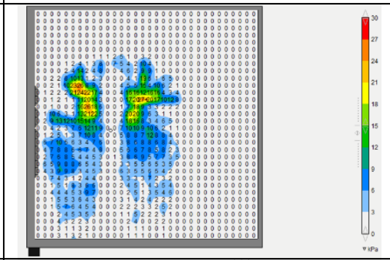
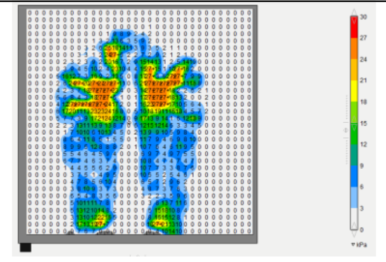
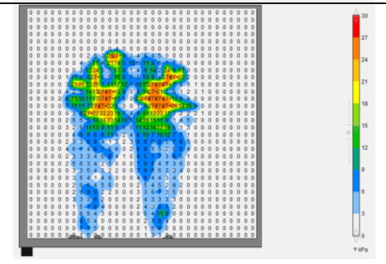
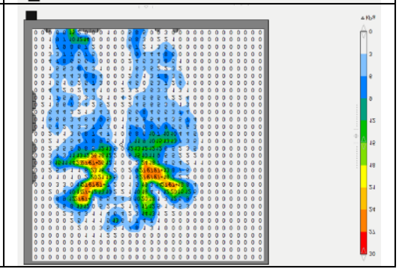
	Seat I	Seat II	Seat III
New			
Long-term use			

Table 2 Comparison of the end results of the study

Indication	Symbol	Unit	Value before cyclic load application			Value after cyclic load application		
			Seat I	Seat II	Seat III	Seat I	Seat II	Seat III
Seat pressure distribution coefficient	SPD	%	17.02	14.38	22.24	19.54	16.97	20.94
Discomfort factor	D	N/m^4	14.13	13.89	9.28	12.33	12.29	9.36
Strain	mm/mm	cm	7.01	6.09	9.74	8.56	6.96	9.77

The analysis of results of the seat deformation test after the cyclic application of 760N, revealed that seat II is characterized with the highest rigidity at the values of deformation (from 6.09 to 6.96 mm/mm) in relation to the seat I (from 7.01 to 8.56 mm/mm) and seat III (from 9.74 to 9.77 mm/mm). However, the smallest decrease in stiffness was recorded for seat III, amounting to only 0.34%. The values of the contact stress distribution coefficient *SPD* indicate that seat III has the highest degree of comfort of use, followed by seat and then seat II. Values of the discomfort factor *D* also show that the most favorable in terms of comfort will be seat III. Although the difference between seat I and II is insignificant, seat I exhibits greater comfort than seat II. A greater discomfort factor indicates that the seat is not very comfortable. The smaller the discomfort factor, the more comfortable is the seat.

DISCUSSION

There is a clear impact of the seat structure on the distribution of usable stress, and thus on the comfort and quality of use. The largest decrease in stiffness was observed in the case of seat I equal to 22 %. It follows that the combination of standard foam T25180 and bonnell springs worsens long-term use. Seat II ranked second, with a decrease in rigidity of 14.2%. In this case, the decrease in seat rigidity results from a decrease in the rigidity of the foam itself. For seats I and II, a clear increase in the *SPD* contact stress distribution coefficient was observed, respectively 14.8% for I and 18% for II. A decrease in the discomfort factor *D* by 12.7% for I and 11.5% for seat II was also observed. This indicates an increase in the feeling of comfort in using these seats. This is associated with a decrease in seat stiffness. Seats with less stiffness, "softer", put less pressure on the human body. In the case of seat III, no decrease was observed, which is due to the use of high quality HDS55 highly elastic foam. This seat does not show significant changes in the SPD coefficient (5.9%) and D factor (0.9%). The foam manufacturer's data are also confirmed, which states that seats made of highly flexible foam retain their properties for up to 10 years of use.

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17. PN-EN 12520 Meble. Wytrzymałość, trwałość i bezpieczeństwo. Wymagania dla siedzisk mieszkaniowych / Furniture. Strength, durability and safety. Requirements for domestic seating.

Streszczenie: *Wpływ konstrukcji mebli tapicerowanych na komfort w okresie długotrwałego użytkowania.* Głównym celem pracy była analiza wpływu zmian konstrukcji siedzisk mebli tapicerowanych na pomiar komfortu mebli nowych oraz po długotrwałym ich użytkowaniu. Badania przeprowadzone były przy użyciu maty sensorowej Force Sensitive Applications z odczytem naprężeń kontaktowych oraz profilowanego wgłębia wciskanego w siedzisko siłą 760 N. Okres 5 letniego, długotrwałego użytkowania zasymulowano działaniem cyklicznego obciążenia 1000N x 25000 powtórzeń. Na podstawie przeprowadzonych analiz uzyskanych wyników badań zaobserwowano niekorzystny wzrost współczynnika dyskomfortu D o około 0,8% przy zaobserwowanym spadku o 12,7 % dla siedziska I i 11,5% dla siedziska II. Oznacza to wzrost odczucia komfortu użytkowania siedzisk I i II w okresie użytkowania. Wiąże się to ze spadkiem sztywności siedzisk. Siedziska o niższej sztywności („bardziej miękkie") wywołują mniejszy nacisk na ludzkie ciało z uwagi na większą powierzchnię użytkową.

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