

THE INFLUENCE OF SUPPORT ELASTICITY ON SITTING COMFORT

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Abstract

The comfortable sitting plays an important role in reducing the risk of musculoskeletal disorders and linked with the continuous increase of the computer aided office work duration justify the intensification of researches focusing on healthy chair development. Majority of the body's weight is placed upon the supporting area of the seat pan therefore a special attention should be paid on the seat cushions. The main objective of this research is to evaluate the influence of support geometry and elasticity on the sitting comfort. For data acquisition, the Tekscan's CONFORMAT body pressure distribution measuring system was used. The effect of geometry and flexibility was evaluated by the peak pressure and contact surface values. Research data and analysis revealed that seat cushion structure and cushion support's characteristics significantly influence the body pressure distribution, an important factor in seat comfort determination.

Keywords: sitting comfort, body pressure distribution, seat pan elasticity, seat geometry, ergonomics

1. INTRODUCTION

Surveys and studies show that more than 50% of employees in the EU perform high- or low-skilled white collar work, predominantly in offices [1]. The prolonged sitting combined with reclining and sleeping results in a persistent contact of the body with a cushion having various flexibility. Statistics reveal the importance of ergonomic sitting since the proper ergonomic seating furniture with proper use can help to reduce injuries and the so-called cumulative trauma disorders (CTDs), which often results from repetitive movements for prolonged periods of time. From ergonomics point of view, the high comfort is related to the well-being, safety feeling and healthy sensation of the users. The comfort of a seating furniture is the combination of the embedded materials, construction and other design factors like dimensions, tilt angles, etc., which may either, add to or detract from the comfort of the finished product. Construction of upholstery, shape and hardness of the sitting surface are included also into features, which determine the sitting

comfort [2]. One of the basic factors of contemporary comfort is the specific pressure to the body, which is smaller when the contact surface of the human body is larger [3], [4]. Other scientific articles focused also on revealing the relationship between sitting comfort and design specifications with the aim of reducing the discomfort of chair users. For example, Manfield *at al.* analyzed the discomfort in vehicle seats and concluded that foam composition can have significant implications on people undertaking journeys of long duration (more than 40 min. in the conditions tested) [5]. They compared different foam types and determined the difference in overall seat discomfort. Small changes to foam composition were shown to affect the overall discomfort in the seat. An experiment conducted by Vlaović *at al.* determined the comfort index (support factor) of chairs obtained from elastic characteristics of materials in the seat of chair [6]. In another study analyzing different types of seats, they concluded that the chair with molded PUR foam is significantly more comfortable than the chair with springs, but statistically it does not differ significantly from the chair with polyurethane foam cushion. According to Vink and Lips the form of the area contacting the body and the softness of this area influence the contact area between the body and the product. The pressure sensitivity of the skin and underlying tissue also plays an important role in the comfortability. In order to create a comfortable seat it is important to define the foam characteristics of the seat pan or the flexibility of the material underlying the foam [7].

The main objective of this research was to evaluate the influence of different supports on body pressure distribution placed under a three layered foam cushion and using a standard loading pad. A second objective of this research was to determine the optimal arrangement of a cushion system consisting of the layered foams and elastic supports.

2. MATERIALS AND METHODS

Polyurethane foams are frequently used components of the upholstery furniture of nowadays. Combined with other flexible materials like springs, felts, belts, latex or using layered foam structures of various firmness assure the comfort of seating and sleeping. Flexible polyurethane foams are soft, durable yet provide good support and maintain their shape therefore are preferred as filling materials for seating cushions and mattresses and can be produced to the density required by the manufacturer. In this research open cell polyurethane foams with different densities (Soft N3530 – 35 kg/m³ (grey); Normal N2538 – 25 kg/m³ (violet); Comfort R4342 – 43 kg/m³ (green) produced by Eurofoam Hungary Ltd were used.

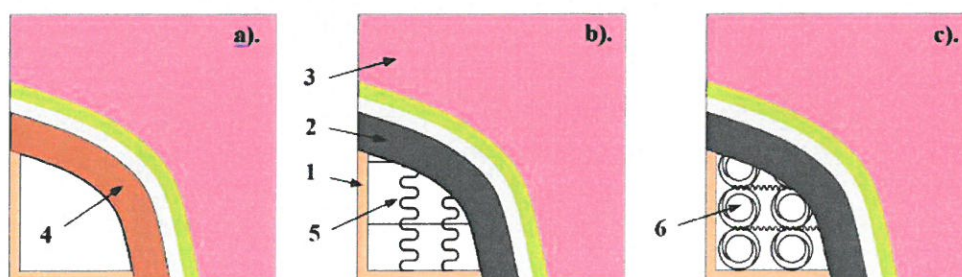


Figure 1: The foam support system, a – plywood (4); b – sinusoidal spring (5); c – bonell spring (6) (1 –wood frame; 2- protective felt; 3 – foam layers)

The selected foam types are commonly used by upholstery manufacturers in Hungary and belong to the Eurofoam Classic foam family, class N and R with the characteristics presented in a previous article [8]. Three types of support with different elasticities fixed on a wooden frame were placed under the foams: bonell spring, sinusoidal spring and plywood respectively (Figure 1). Between springs and foam sheets a protective textile was engaged. 600mm x 600mm sheets with a thickness of 20 mm were prepared from the selected foam types and a 3-layered structures arranged in different combinations of the foam and support types, resulting in 42 experimental setups, totally. The layered structures were loaded with an anatomical seat loading pad according to standard EN 1728:2012 [8]. On each cushion structure loads of 250 N, 500 N, 750 N, and 1000 N was exerted using the standard loading pad for chair tests, the maximum set load values were attained in 3 seconds. 42 measurements were made totally using the Tekscan's Body Pressure Measurement System (Conformat) with pressure sensitive foils size of 488 × 427 mm containing 2016 pressure points with pressure range of 0-350 mm Hg, and accuracy of + / - 3.5 mmHg. The computerized data recorder provides a real-time picture of the pressure distribution. Figure 2. shows the schematic principle of measurements:

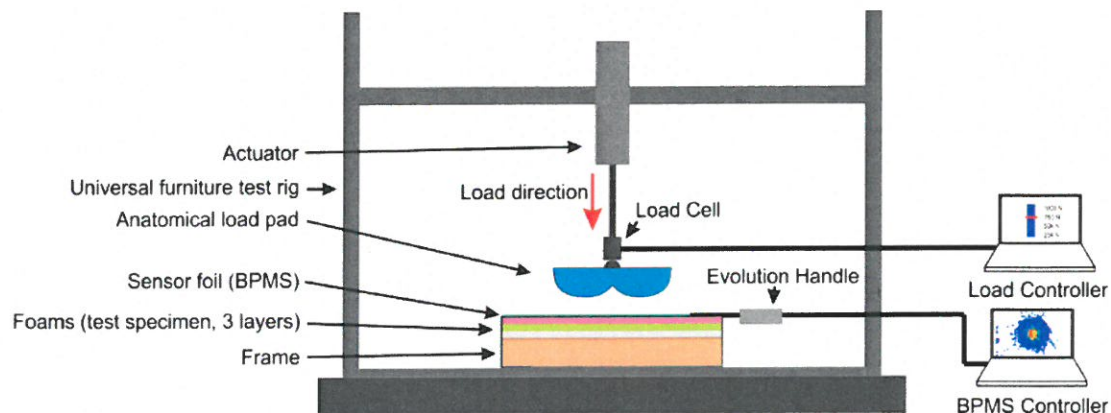


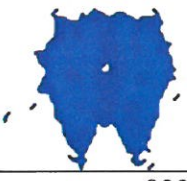





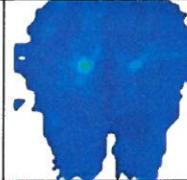
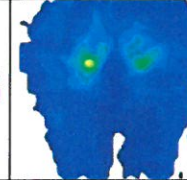
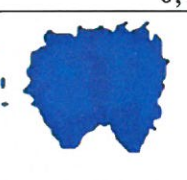

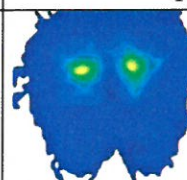
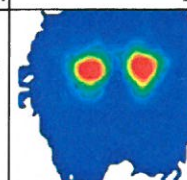
Figure 2: Pressure measurement system

Before using the BPMS measuring system the pressure sensor foils were calibrated with the help of a vacuum pump. After calibration the pressure maps of layered foam structures loaded with four compression force values were collected and analyzed with the software delivered with the system (BPMS Research 7.20) in the form of image (.fsx or .jpg) or short (0-200 s long) video files. On the recorded pressure maps, the contact surface area and peak pressure values were determined.

3. RESULTS

The pressure distribution maps were recorded for all cushion' variations at the set force values and analyzed based on the contact area, pressure dispersion, pressure intensity of different zones, etc. In Table 1. the results for the structure composed of three soft foam layers are presented.

Table 1: Pressure distribution maps of the soft foam

Soft foam	250 N	500 N	750 N	1000 N
Bonell spring				
contact area, cm ²	823,7	1383,2	1563,9	1700,1
peak pressure, N/cm ²	0,41	0,83	1,20	1,58
Sinusoidal spring				
contact area, cm ²	624,5	1160,3	1407,0	1536,0
peak pressure, N/cm ²	0,76	0,94	1,34	1,95
Plywood				
contact area, cm ²	773,2	1226,3	1369,8	1464,8
peak pressure, N/cm ²	0,50	0,97	1,99	3,10

At lower loads the differences between supports are more moderate, the sinusoidal spring shows the lowest contact area and similar peak pressure as the plywood support. When using higher loads there the differences between the two contact areas are less than 5%, however the peak pressures are 30% higher. The bonell spring support assures the highest contact areas in all cases and the lowest peak pressures near the ischial tuberosity.

In Table 2. we find the pressure maps and data related to the use of comfort foam layers. At loads of 250N and 500N there are comparable values with soft foam usage. The load increase resulted in lower peak pressures when plywood support was used, the firmness of foam attenuated the load effect. The bonell spring support decreased the peak pressures even though the contact areas were lower than in previous case. The peak pressures decreased with approximately 20% compared with soft foam layers. Least differences were observed when sinusoidal springs were used.

Based on a prior research which analyzed the effect of density and elasticity of a layered polyurethane foam cushions [9], an optimum system comprising a soft-comfort-comfort foam layers was determined. Table 3 contains the pressure maps and contact area and peak pressure values measured in the case of optimum system. The softness of the top layer and firmness of the bottom layers combined with a bonell spring support offered the best comfort of the system with the lowest peak pressures and uniform pressure distributions. The foam layers could dampen the effect of the hard plywood support. Even though no differences between contact areas were observed at increased loads using the sinusoidal support, the peak pressures decreased with 13% at 750N and 21% at 1000 N.

Table 2: Pressure distribution maps of the comfort foam




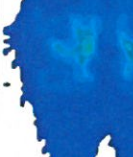


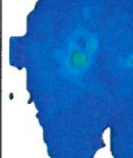
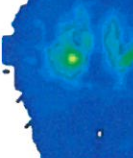


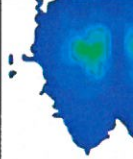
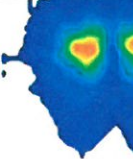







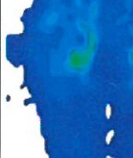



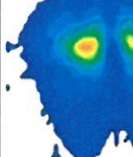
Comfort foam	250 N	500 N	750 N	1000 N
Bonell spring				
contact area, cm ²	631,7	1107,6	1398,7	1570,1
peak pressure, N/cm ²	0,42	0,66	0,99	1,28
Sinusoidal spring				
contact area, cm ²	607,0	1052,9	1365,7	1489,6
peak pressure, N/cm ²	0,66	0,98	1,40	1,91
Plywood				
contact area, cm ²	571,9	970,3	1157,2	1254,2
peak pressure, N/cm ²	0,64	1,01	1,55	2,46

Table 3: Pressure distribution maps of the layered structure

3 layered structure	250 N	500 N	750 N	1000 N
Bonell spring				
contact area, cm ²	717,4	1180,0	1462,7	1613,4
peak pressure, N/cm ²	0,47	0,64	0,93	1,18
Sinusoidal spring				
contact area, cm ²	693,7	1140,6	1384,3	1491,6
peak pressure, N/cm ²	0,71	0,96	1,22	1,51
Plywood				
contact area, cm ²	632,8	1033,3	1266,6	1378,1
peak pressure, N/cm ²	0,53	0,80	1,20	2,30

4. CONCLUSIONS

In this paper the comfort related pressure distribution on layered foam system combined with a flexible support was measured using a body pressure measuring device and standard loading pad. Based on results the effect of support on the contact area and peak pressure was confirmed. The peak pressure attenuation depends on the applied load too, at higher pressure forces (500 N, 1000 N) the damping effect is more accentuated. The bonell spring support with its highest elasticity demonstrated to be the best combination of the analyzed variables from comfort point of view.

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