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Antropotechnical aspects of furniture design

Antropotehnička gledišta oblikovanja namještaja

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ABSTRACT • *A person having direct contact with a piece of furniture becomes part of an arrangement known as anthropotechnical system made up of an animate part (human body) and an inanimate part (technical facility – a piece of furniture). The aim of the research project was to present anthropotechnical aspects of furniture design for sitting and meal consumption. In particular, the author discussed the methodology of the assessment of ergonomics of a chair, a table and a chair + table set, where the assessment criteria were: anthropometric dimensions of the user, stiffness of seats and the value of contact strains on the seat surface.*

Keywords: *furniture, dimensions, ergonomy, anthropometry, mechanical properties*

SAŽETAK • *Osoba koja je u izravnom doticaju s namještajem postaje dio sustava poznatoga pod nazivom antropotehnički sustav. Njega čine pokretni dio (ljudsko tijelo) i nepokretni dio (tehnički objekt – određena vrsta namještaja). Cilj istraživanja bio je prikazati antropotehničko gledište projektiranja namještaja za sjedenje i objedovanje. U radu je posebna pozornost pridana metodologiji vrednovanja ergonomije stolice, sustava stola i stolice te grupe stolova, pri čemu su kriteriji vrednovanja bili antropometrijske dimenzije korisnika, krutost sjedala i vrijednost deformacije na površini sjedala.*

Ključne riječi*: namještaj, dimenzioniranje, ergonomija, antropometrija, mehanička svojstva*

1 INTRODUCTION
1. UVOD

Using furniture a person becomes part of a structure often referred to as an anthropotechnical system. The elements making up this system include: the animate part, i.e. the human body and the inanimate part, i.e. a technical facility. An anthropotechnical system is always developed as a result of a purposeful action of a man on a technical facility, in this particular case – a piece of furniture. The superior objective initiating such systems is the aesthetic improvement of interiors of human dwellings as well as upgrading their functionality, safety and users' comfort. Using technical facilities, we usually try to harmonise them with the character of our work as well as with our own psycho-physical possibilities. This approach aims at humanising work by appropriate organisation of the system: human being-machine – environment conditions in such a way that the performed work is carried out at an as low as possible biological cost and, at the same time, highly effectively (Smardzewski *et al,* 2008).

The procedure of engineer-technical design provides the structural basis for ergonomic designing. The mutual interrelationships of technical and ergonomic design originates from the principle characteristic for anthropocentric ergonomy and recognises the priority of human traits and requirements in shaping technical structure. The technical structure is, obviously, furniture and its most demanding representative is the group of furniture used directly, i.e. the furniture that comes into direct contact with the human body during use (furniture for sitting, lying and resting). A person remaining in direct contact with a piece of furniture becomes part of

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a structure known as 'an anthropotechnical system' made up of an animate part (human body) and an inanimate part (technical facility – a piece of furniture) (Winkler, 2005).

Therefore, during the designing process, the priorities are as follows: increased safety of the product performance taking into consideration all interactions occurring between the object and the user concerning visual, acoustic and tactile stimuli. That is why, when starting to design a new piece of furniture, it is necessary to evaluate criticlally its form, construction, execution technology, functionality and ergonomy of similar products because the human being – object system is the focus of ergonomic design.

The aim of this study was to present the aspects of anthropotechnical designing of furniture for sitting and meal consumption. In particular, the author discussed the methodology of the ergonomic assessment of a chair, a table and a chair + table set assuming the following furniture assessment criteria: anthropometric dimensions of the user, stiffness of seats and the value of contact strains on the seat surface.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The investigations were carried out on a selected chair and table (with a foldable tabletop) manufactured by a Polish producer of household furniture, Figure 1.

In order to perform an anthropotechnical evaluation of a chair, a table and a chair + table set in the CAD environment, the author developed natural size virtual models of a chair, a table and a human phantom making up elements of the human-seat and human-table systems, Figures 2 and 3.

Then a catalog of anthropometric dimensions appropriate for a Polish user of the 50th centile was developed for the human phantom in a sitting position (Juergens *et al,* 2005, Kroemer *et al,* 1994), Figure 4.

Two models of the assessed furniture were elaborated on the basis of the listed anthropometric dimensions: a chair model employed to assess the correctness of linear and angle dimensions as well as geometric proportions of the manufactured chair and a table model used for the ergonomic evaluation of the tabletop surface. The chair representation included two models: the first of them represented a user sitting on the chair with legs bent in the knee joint at the straight angle, Figure 5a, while the second model showed a user sitting on the chair with legs bent in the knee joint at the angle of 45 degrees, Figure 5b.

Figure 1 A table and chair selected for anthropotechnical experiments
Slika 1. Stol i stolica korišteni u antropotehničkom eksperimentu

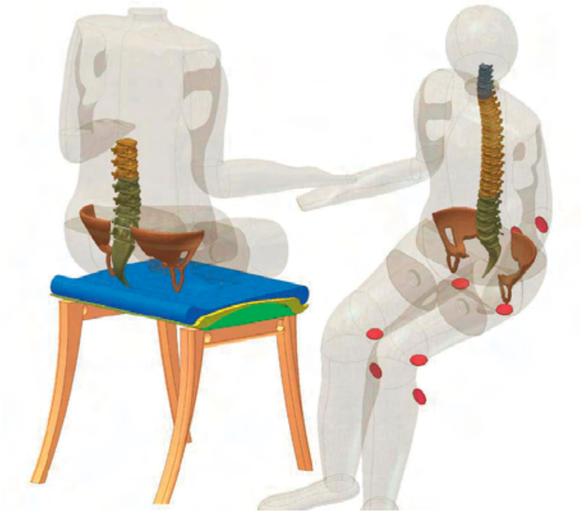
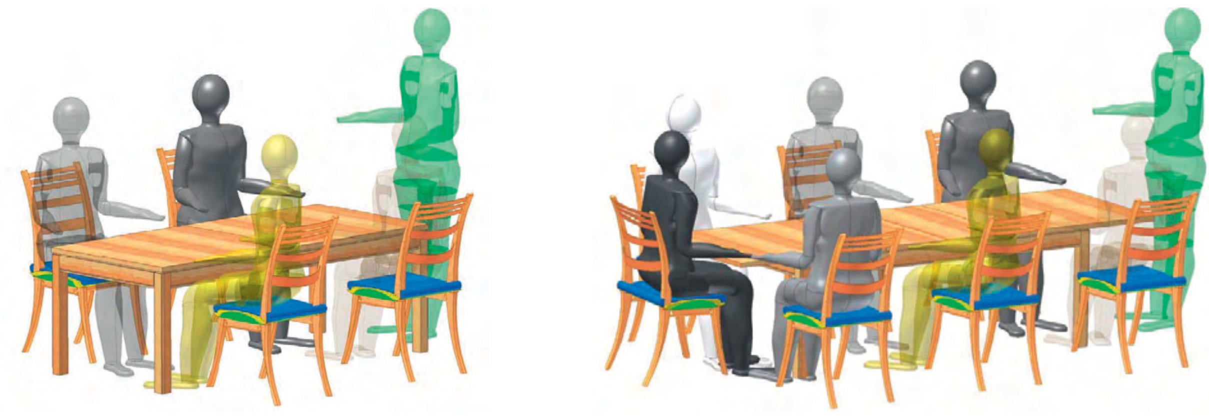


Figure 2 Virtual human phantom in CAD environment
Slika 2. Virtualni CAD model čovjeka



a) b)
Figure 3 Virtual models of human-technical object systems: a) at a folded table, b) at an unfolded table
Slika 3. Virtualni CAD model sustava čovjek-tehnički objekt: a) osnovnih dimenzija, b) s izvlačnim pločama

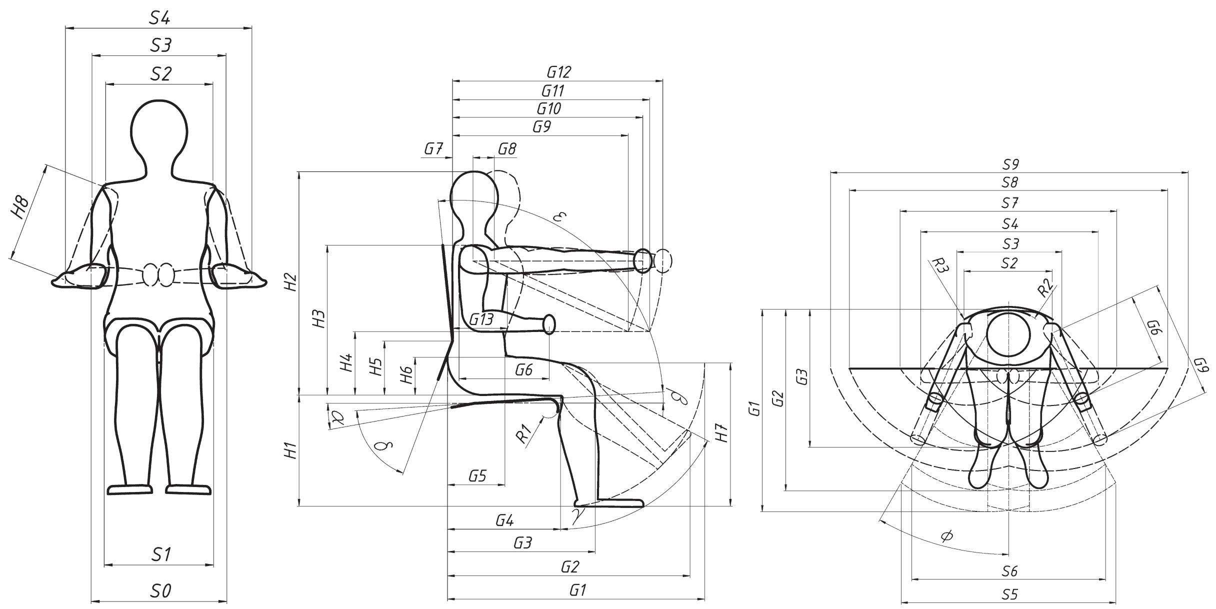
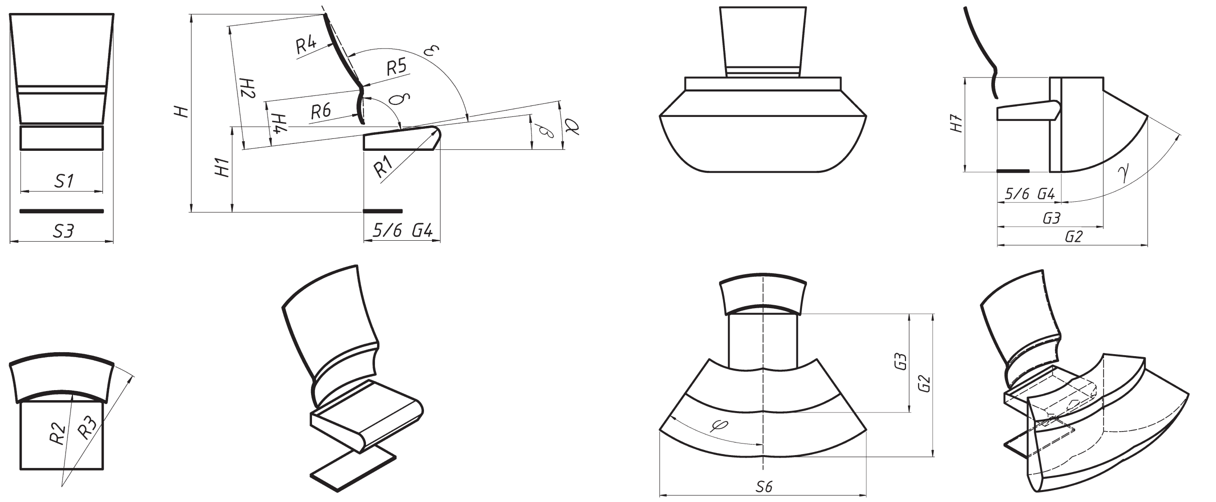


Figure 4 Anthropomentric traits of a Polish user representing the population of the 50th centile
Slika 4. 50-postotni reprezentant antropometrijskih značajki Poljaka



a) b)

Figure 5 Chair model: a) for a user sitting on the chair with legs bent in the knee joint at the straight angle, b) for a user sitting on the chair with legs bent in the knee joint at the angle of 45°
Slika 5. Model stolice: a) pri sjedenju na njoj koljena savijenih pod pravim kutem, b) pri sjedenju na njoj koljena savijenih pod kutem od 45°

The table model specified the minimum working surface per one user taking into account the elbow space between successive persons, Figure 6a, as well as the reach of the upper limbs allowing a free access to objects found on the table surface, Figure 6b.

Putting together the two models made it possible to perform a complete anthropometric assessment of the table–chair system from the point of view of freedom of movement of lower limbs, their collision with table legs and considering other persons sitting at the table as well as the required clearance between the thighs and tabletop, Figure 7.

Another quality assessment criteria of the analysed system was the rigidity of the chair seat expressed by the measure of the local rigidity coefficient LWS = P/ΔL in which P = value of the external load, ΔL – value of the displacement corresponding to load P. The experiments were conducted on a Zwick 1445 testing machine for three different seat designs: A – polyurethane foam on a hard plywood base, B - polyurethane foam on elastic upholterer's straps and C - polyurethane foam on a spring panel base, Figure 8.

The last assessment criterion of the table-chair system ergonomics was the stress level determined on the basis of numerical analysis of the contact phenomenon between the human body and the seat manufactured in accordance with the design of type a, c. For this purpose, the author developed two flat netlike models of polyurethane foam T4060 (of 40 kg/m^3 density) and T2838 (of 28 kg/m^3 density) according to these designs. Human buttocks were modelled as an analytical curve of 160 mm diameter. Similar studies have already been investigated erlier and published in different journals (Gefen *et al,* 1999, 2005; Honma and Takahashi, 2001; Hu and Desai, 2005; Linder–Ganz and Gefen, 2004;

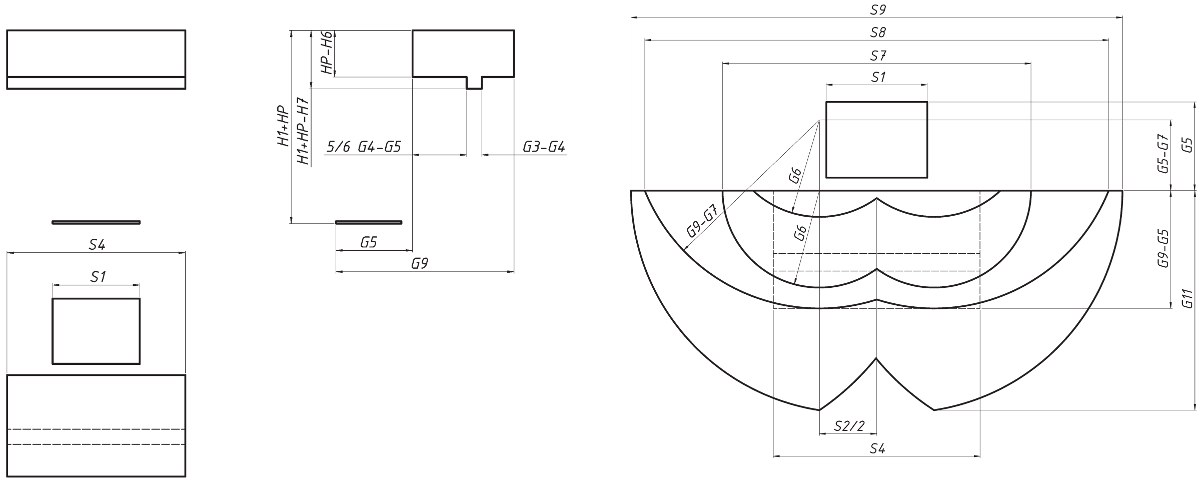


Figure 6 Table model: a) minimum working surface, b) reach of upper limbs
Slika 6. Model stola: a) minimalni radni prostor, b) dohvatni prostor ruku

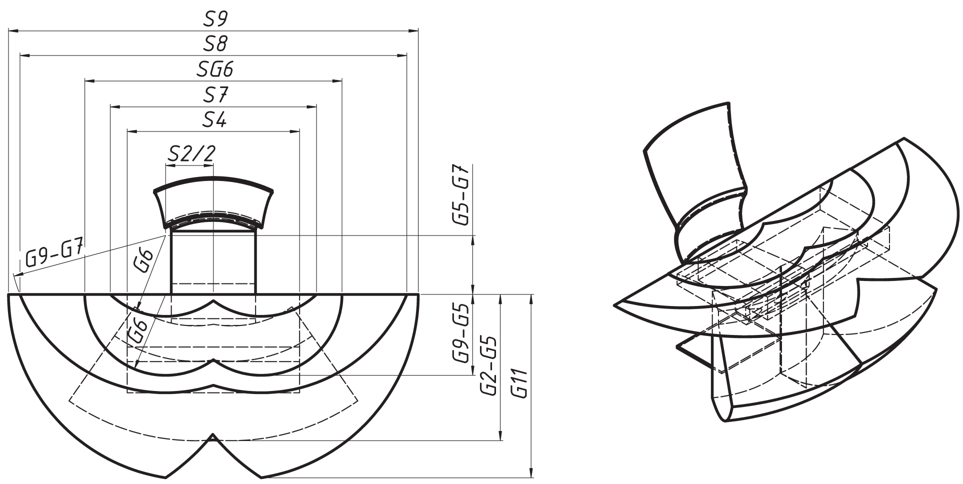
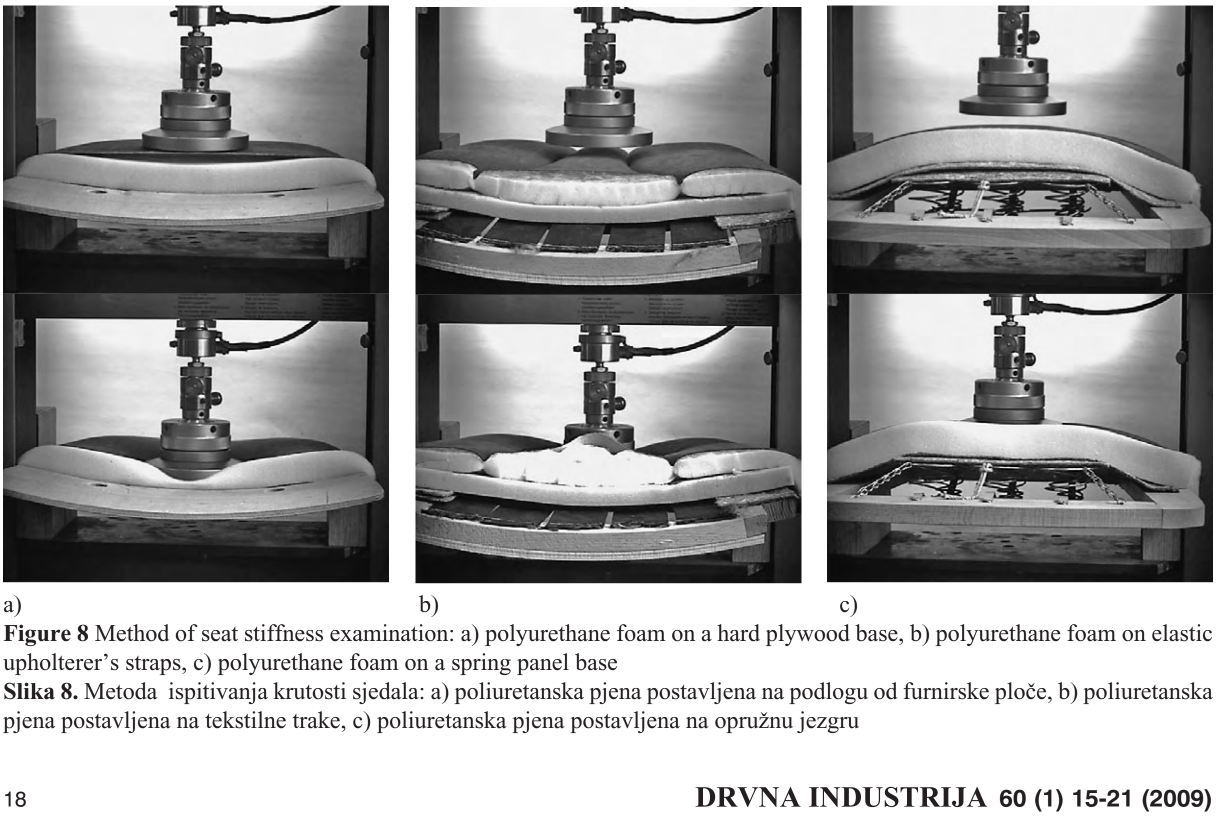


Figure 7 Assembling of table and chair models
Slika 7. Grupa modela stola i stolice



a) b) c)

Figure 8 Method of seat stiffness examination: a) polyurethane foam on a hard plywood base, b) polyurethane foam on elastic upholterer's straps, c) polyurethane foam on a spring panel base
Slika 8. Metoda ispitivanja krutosti sjedala: a) poliuretanska pjena postavljena na podlogu od furnirske ploče, b) poliuretanska pjena postavljena na tekstilne trake, c) poliuretanska pjena postavljena na opružnu jezgru

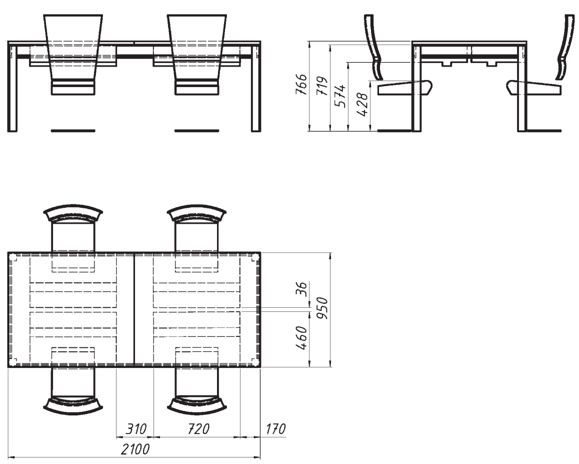


Figure 9 Virtual juxtaposition of the chair model and table model (a man S4) with the assessed table model

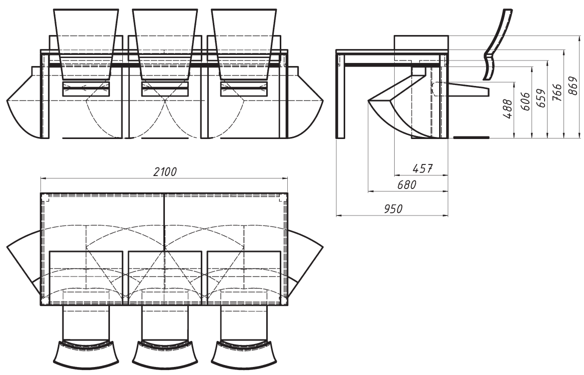


Figure 10 Virtual juxtaposition of the chair model and table model (a man S1) with the assessed table model

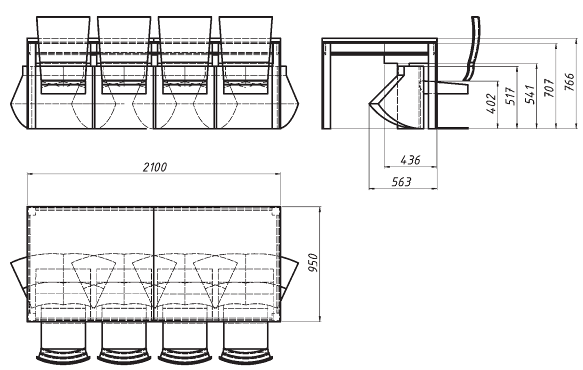


Figure 11 Virtual juxtaposition of the chair model and table model (a woman S1) with the assessed table model
Slika 11. Virtualni postav modela stolica i stola (za ženu S1)

Linder-Ganz *et al,* 2005; Okamoto *et al,* 1998; Qunli, 2005; Smardzewski *et al,* 2007; Smardzewski and Grbac, 1998; Smardzewski *et al,* 2008).

4 RESULTS
4. REZULTATI

On the basis of juxtaposition of the chair and table patterns with the actual model of the examined table, Figure 9, it is quite evident that at the elbow width (S4), four adult persons representing the 50 centile population can sit comfortably at it. When the width of the working surface is reduced to the hip width (S1), the freedom of upper limbs reach is somewhat limited but the advantage is in the fact that six adult men, Figure 10, or eight women, Figure 11, can now sit at the table with lower limbs allowing sufficient mobility. From this point of view, this design is fully ergonomic.

Runs of displacements shown in Figure 12 indicate that seat systems with B and C designs exhibited the most favourable stiffness because the relatively largest displacement increments corresponded to the consecutive increments of small forces. On the other hand, LWS values presented in Figure 13 prove that these coefficients were characterised by linear nature, i.e. one that can easily be subjected to simple analytic modelling.

Assessing the value of acceptable stresses in the contact between the human body and the elastic type A and C seat, the author (Grbac and Dalbelo-Bašić, 1996; Grbac and Domljan, 2007; Grbac and Ljuljka, 1995; Grbac, 2006; Smardzewski *et al,* 2008; Winkler, 2005) assumed that the comfort threshold is defined as the stress level at which the user can sit comfortably on a chair for a period of more than 4 hours, Figure 14. In addition, a comfortable seat should ensure a uniform distribution of stresses spread over the entire surface of support instead of stresses concentrated at points or on a small surface.

It was established, on the basis of numerical calculations, that polyurethane foams T4060 in the type A seat generated parabolic distribution of stresses of 36 kPa, Figure 15a, whereas T2838 foams in the C type seat generated uniform stress distribution of 4.6 kPa, Figure 15b.

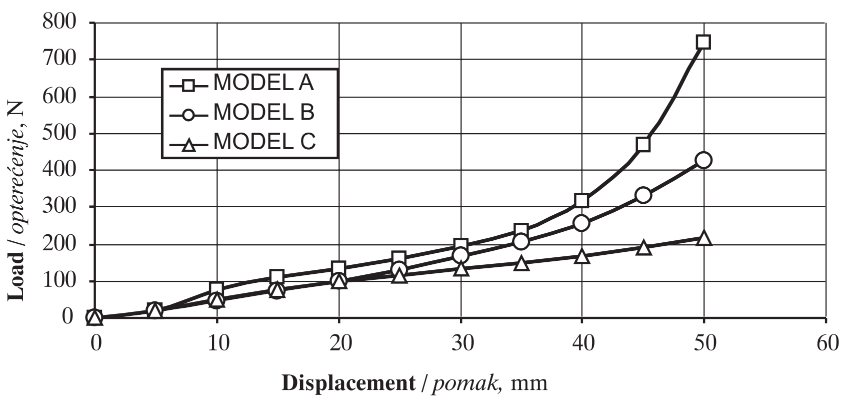


Figure 12 Stiffness of seats with A, B and C designs
Slika 12. Naprezanja sjedala A, B i C konstrukcije

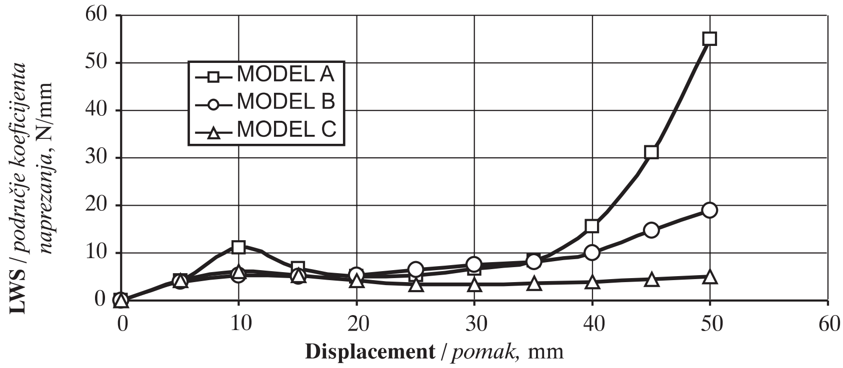


Figure 13 Local stiffness coefficient (LWS) for seats with A, B and C designs
Slika 13. Područje koeficijenta naprezanja (LWS) za sjedalo A, B i C konstrukcije

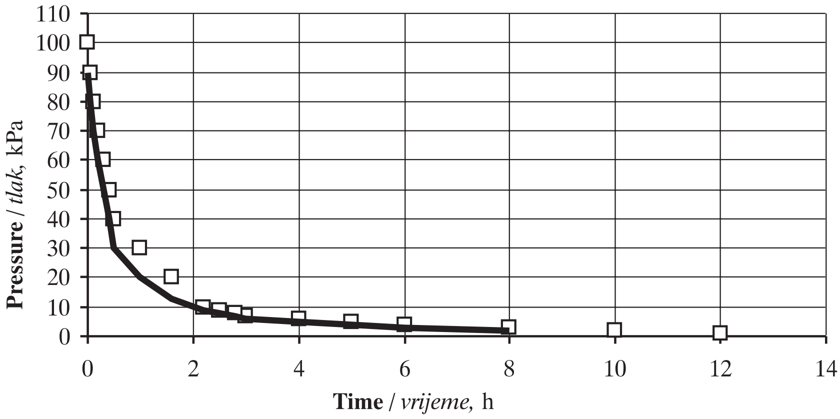
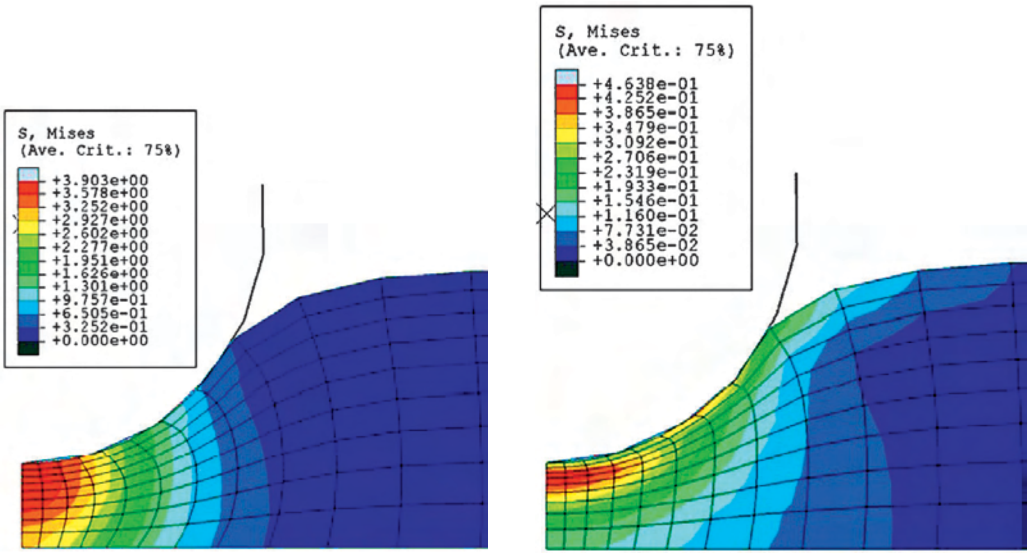


Figure 14 Impact of stresses on the period of seat exploitation
Slika 14. Utjecaj naprezanja na trajanje sjedenja



a) b)
Figure 15 Stress distribution in the seat with foam of type: a) T4060, b) T2838
Slika 15. Raspodjela naprezanja sjedala s poliuretanskom pjenom tipa: a) T4060, b) T2838

Therefore, the latter foams are a better padding material affecting more distinctly the comfort of the user.

5 CONCLUSION
5. ZAKLJUČAK

When designing furniture for sitting at tables, it is necessary not only to take care of correct chair dimensions but also to select appropriate dimension relationships between these two pieces of furniture. In addition, it is also important to pay attention to the proper height of the tabletop, height of the underframe (restricting leg movement), width of the tabletop ensuring freedom of operation on the working surface as well as the depth of the tabletop allowing comfortable reach in relaxed sitting position. By making virtual chair and table models that allow the adjustment of their dimensions to individual types of human phantoms, it is possible – as early as the design phase - to validate the product developed and identify weaknesses of the adopted functional or construction solutions. By comparing the virtual model of an actual dining-room table with a chair model for the user, for example of 50 centile traits, it is possible to eliminate the basic ergonomic and functional mistakes of this system. This kind of design bears the hallmarks of anthropotechnical designing.

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