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″FLUID CUSHION″ - ERGONOMIC SEAT

Fikret Veljović, Hadis Bajrić, Ibrahim Veljović, Mehmed Imamović
Faculty of Mechanical Engineering
Sarajevo, Bosnia and Herzegovina

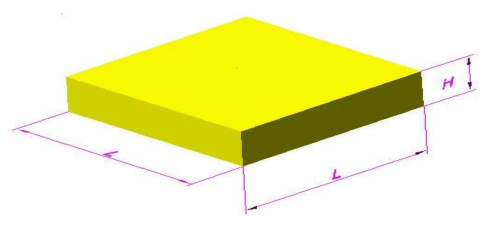
ABSTRACT
Ergonomic seat problems; ″Fluid cushion″ as solution for problem; Functional and construction principals of ″fluid cushion″; ″Fluid cushion″ compared with other solutions.
Key words: ergonomic seat, ″fluid cushion″.

1. INTRODUCTION
Here are described our efforts to find ergonomic solution for seat design with uniform force distribution on sitting surfaces of human body, what will ensure better blood circulation in that area and less fatigue.

2. ERGONOMIC SEAT PROBLEMS
The first problem or task is that touching surface between human and seat must be maximal, or pressure on seat user body must be minimal.
The second problem or task is that mentioned load from the seat on human body must be uniformly distributed, without any extreme values.
The third problem or task is that seat must bi ergonomic for wide range of anthropometric dimensions.

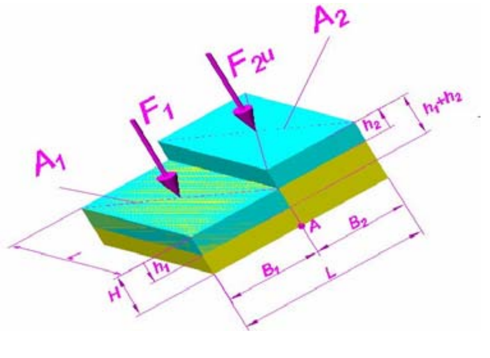
3. ″FLUID CUSHION″ - PROBLEM SOLUTION
Basic idea is that cushion made from waterproof material, with suitable volume, fill with fluid of certain characteristics (fluid volume is smaller than total cushion volume).

4. FUNCTIONING PRINCIPALS OF ″FLUID CUSHION″



H – Cushion height (cushion height filled with fluid), cushion has the possibility to raise its height for h_{2j}.
Let's have following assumptions:
Cushion width and length is not changing under load, L = const
Fluid in cushion is incompressible, density ρ=const.
Let's suppose that we put uniform load (with total sum equal to force F_1) on one part of cushion (surface A_1), figure 2.

Figure 1 ″Fluid cushion″



Static equations for fluid in Descartes coordinate system are:

$$\frac{dp}{\rho} = f_{mx}dx + f_{my}dy + f_{mz}dz \qquad (4.1)$$

Where are:
f_{mx}, f_{my}, f_{mz} - Mass forces.
In the field of gravity, if fluid is motionless, static equations are becoming:

$$dp + \rho g dz = 0 \qquad (4.2)$$

Figure 2

because: $f_{mx} = 0; f_{my} = 0; f_{mz} = -g$.

In case of incompressible fluid ρ=const (fluid in cushion) and from equation (4.2) we get:

$$\int_{p_0}^{p} dp + \rho g \int_{z_0}^{z} dz = 0, \quad \text{and} \quad p + \rho g z = p_0 + \rho g z_0 = c \tag{4.3}$$

We can write equations for pressure in a plane which has the point A, from left side (P_{AL}) and from right side (P_{AD}):

$$\frac{F_1}{A_1} + \rho g (H - h_1) = \frac{F_{2u}}{A_2} + \rho g (H + h_2) \tag{4.4}$$

If we suppose that force $F_{2u} = 0$ and suppose that $h_1 < H$, than from (4.4) we get:

$$\frac{F_1}{A_1} + \rho g (H - h_1) = \rho g (H + h_2) \tag{4.5}$$

$$h_2 = \frac{F_1}{A_1 \rho g} - h_1 \tag{4.6}$$

Values for h_2, are shown on diagrams, for two cases: fluid u cushion is water (ρ=998.2 kg/m^3) and fluid in cushion is air (ρ=1.293 kg/m^3).

m_s – mass of human acting on seat

According to Literature 1 we get:

m_s=0.695m (where m – total human mass) (4.7)

Diagram 4.1.

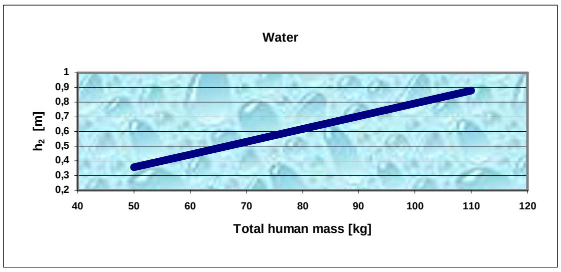
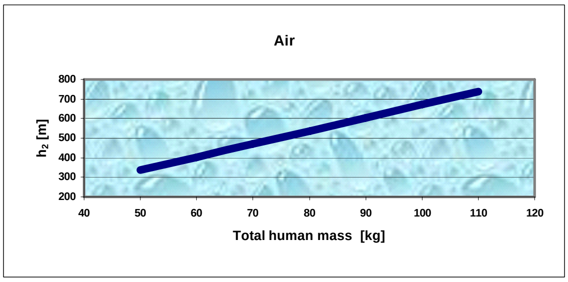


Diagram 4.2.



At asymmetrical sitting (figure 4.3), in the worst case person do not sit with angle more than 10°, so β_{max} < 10º.

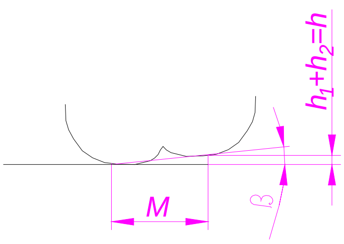


Figure 4.3

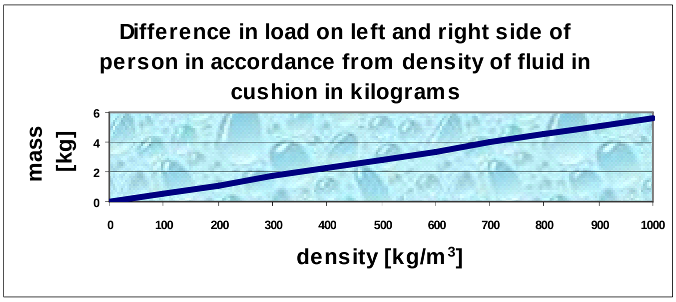


Diagram 4.3.

$$F_{2u} = F_2 + F_j \tag{4.8}$$

Where is:

F_2 – Force acting on cushion from second part of the body, it starts acting when fluid level become so high that cushion come in contact with the second part of the body

F_j – Force which cushion takes on itself, it starts acting when fluid rich maximal height for cushion (H+h_{2j}), (cushion volume is higher than volume of fluid inside cushion)

Based on equation (4.4) and equation (4.8) we get:

$$\frac{F_1}{A_1}+\rho g(H-h_1)=\frac{F_2+F_j}{A_2}+\rho g(H+h_2) \tag{4.9}$$

And because of $h_1+h_2=h$ we have:

$$\frac{F_1}{A_1}=\frac{F_2+F_j}{A_2}+h\rho g \tag{4.10}$$

From diagram 4.3 we can conclude that if we take water for our fluid force F_1 will be higher then force F_2, and if take air for fluid we get that $F_1 \approx F_2$, what is more convenient and because of that we suggest that cushion should be filled with lower density fluid (e.g. air).

5. ″FLUID CUSHION″ DESIGN

Cushion dimensions, width and length, are not changing L=const. To obtain that condition cushion is divided in separated volumes (ribs). As we have two constant dimensions, cushion is also divided on two different levels, and each level is divided in described volumes (ribs). Ribs of both levels are perpendicular on each other (figure 5.1.).

Ribs are not here only to keep width and length constant, but also to prevent escaping of fluid into one part of cushion, what can result in larger contact area between body and cushion.

One unloaded rib and height it can rich is shown on figure 5.2.

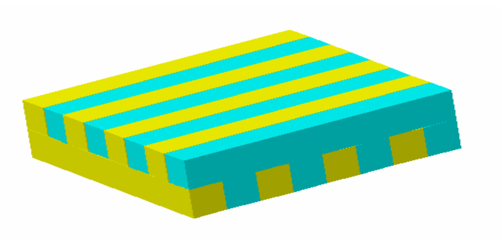


Figure 5.1 Final „fluid cushion“

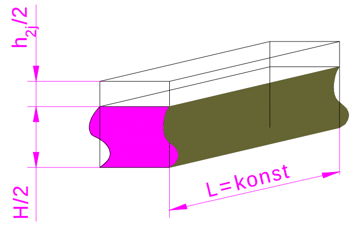


Figure 5.2

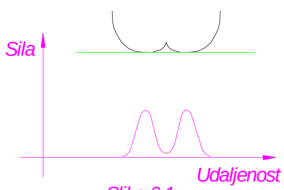
6. ″FLUID CUSHION″ ADVANTAGES OVER OTHER SOLUTIONS

“Fluid cushion” advantages will be shown comparatively to seat made of hard material and to seat made from soft or elastic material, for characteristic sitting positions.

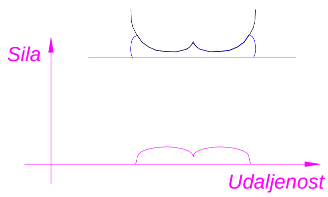
Symmetrical sitting

Load distribution on human body, for different solutions of chair cushion and symmetrical sitting is shown on figures 6.1, 6.2 and 6.3.

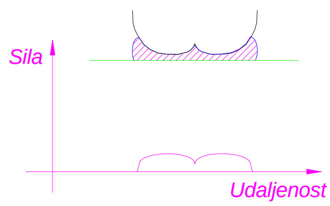
Distribution of tension on human body for sitting on absolutely hard, not ergonomically shaped base is shown on figure 6.1.



Slika 6.1.



Slika 6.2.



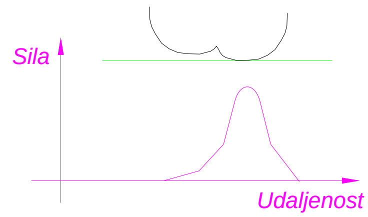
Slika 6.3.

On figure 6.2 we have tension distribution, for case that absolutely rigid base is covered with some soft or elastic material. Contact surface A is enlarged, and that makes decrease of extreme pressure values and its more uniform distribution.

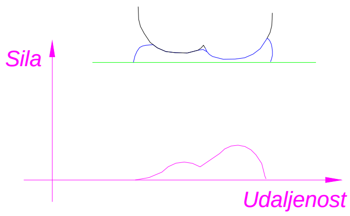
On figure 6.3 we have sitting on “fluid cushion”. We can see that tension distribution is similar to distribution on figure 6.2, so it is necessary to explain why it is justified to make “fluid cushion”.

Asymmetrical sitting

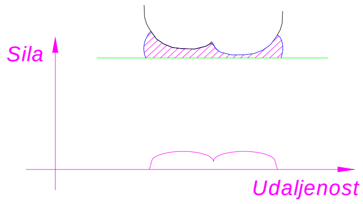
Tension distribution for asymmetrical sitting on absolutely rigid base, soft seat and “fluid cushion” is shown on fures 6.4, 6.5 and 6.6 respectively.



Slika 6.4.



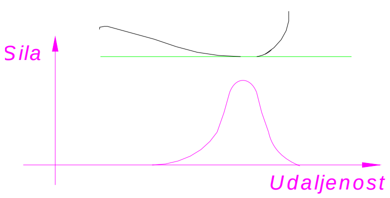
Slika 6.5.



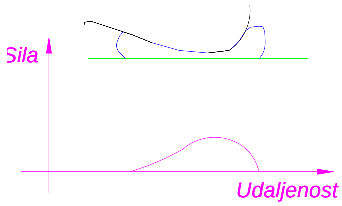
Slika 6.6.

Pressure distribution in sagittal plane

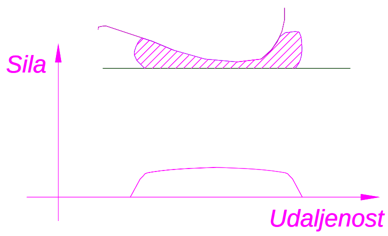
Tension distribution in sagittal plane for sitting on absolutely rigid base, soft seat and “fluid cushion” is shown on fures 6.7, 6.8 and 6.9 respectively.



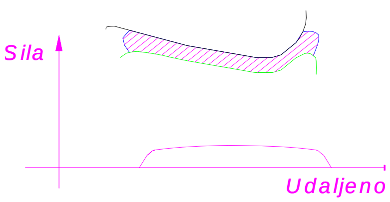
Slika 6.7.



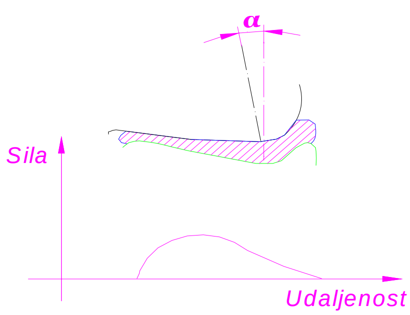
Slika 6.8.



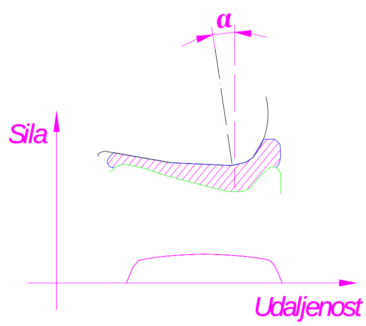
Slika 6.9.



Slika 6.11.



Slika 6.14.



Slika 6.15.

On figure 6.11 and 6.14 we have tension distribution on soft, anatomically shaped seat for vertical seating and leaning for angle α. On figure 6.15 is shown “fluid cushion” with leaning forward, and we can see difference between these two solutions.

7. CONCLUSION

“Fluid cushion” is the best solution compared with competition because of the next reasons:

- It has the biggest contact area between human body and the seat;
- It is the best way to solve problems with pressure concentration;
- It keeps all mentioned qualities even in case of asymmetrical (irregular) sitting and other solutions don’t;
- It has the biggest seat universality, in other words possibility to be used for wide range of anthropometric dimensions without loosing ergonomic characteristics.

8. REFERENCES

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