Determining the Optimal Sitting Position and Analyze Loads in Body

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***Abstract*--** **Analyze loads in body at 5 different positions of backrest and analyze influence of legs rest at loads in body. Provide char models which satisfy results of analyze and main ergonomic criteria's**

***Index Term*--** **Loads in body, L4/L5, L5-Sacrum, maximum muscle activity, char design**.

1. INTRODUCTION

Aim of this analyze is to determine loads in body in sitting posture and according to analyses results we will recommend special chair design which will be based on minimum body fatigue.

The basis of which we engage in the development of paper is loads analysis in body due to changes in angle backrest and legs with focus on L4-L5 and L5-sacrum area. The main factors that will be considered are maximum muscle activity, loads in L4-L5 and loads in L5-sacrum areas. Based on the conducted analysis we will provide models for backrest, seat and legs holder, and offer model of chair design according to main chairs criteria. Software packages with which we conduct the analysis are:

- CATIA V5 R19 – select human body model and perform chair design
- AnyBodyModeling System – find loads in muscle are according to body posture

The reason for choosing this theme is the observation that when we spend only a short time "on some chair" in our perspective short time become like infinity, and after this body needs to rest, although the time spent sitting. Also in the dental ordination the best of all is chair, it relaxes human body and although the dental treatment is a bit stressful but it is easier to pass with comfortable chairs.

What is main aim of this paper is close comfortable chair in everyday life, so that work activities and stress due to working assignments have less influence on body at least from perspective of comfortable at work place.

This software analysis and software model offers a conceptual design of chairs, and it is starting point for further research and development of chair product.

2. STARTING POINT

Chair should be "neutral". It should provide comfort for all body shapes and should avoid creation of peak pressure on body. People with different weights have different pressure distribution on the body or the chair. Loads distribution depends on the height, weight or sitting posture. The aim of this review is to provide preliminary solution of chair which should be built on ergonomic criteria.

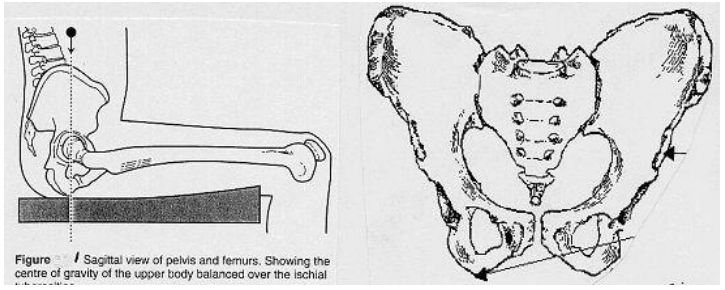


Fig. 1.

Surface pressure affects the feeling of discomfort during the sitting. Distribution of pressures while sitting was such that the maximum is at pelvic bone area when the body in an upright position (Figure 1, show pelvic area in sitting position).

At the back load is concentrate at the lumbar and thoracic areas of the spine while sitting (Figure 2).

Map of pressures is essential for comfort during the sitting. High level of pressure can narrow the blood vessels within the tissue and reduce blood flow that makes sitting uncomfortable.

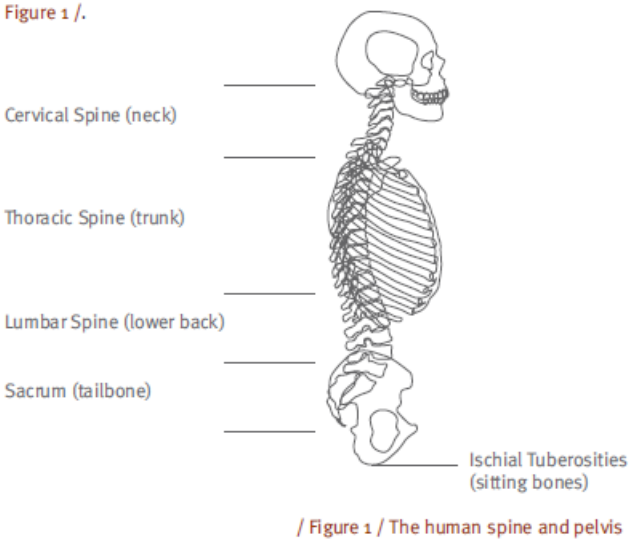
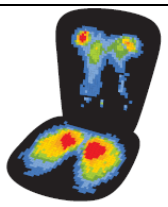
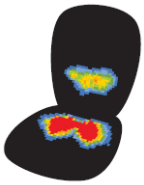
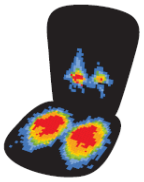
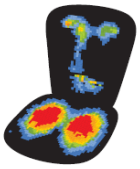
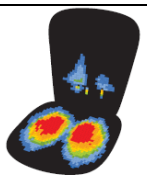


Fig. 2. (Herman Miller, The Art and Science of Pressure Distribution, 2009)

Due to the differences of each body, like size or weight and sitting posture peak pressures are different on the body in different points. It is well known that skin and fatty tissue below the pelvic area less sensitive to pressure then the muscle tissue surrounding the pelvic bones, and thus better *endures forces of sitting at the gluteus area*.

Shown maps present us pressure distribution on the body in a sitting position. The red color indicates the maximum level of pressure, while orange, yellow, green and blue means lower pressure respectively.

Table I
(Herman Miller, The Art of Pressure Distribution, 2003)

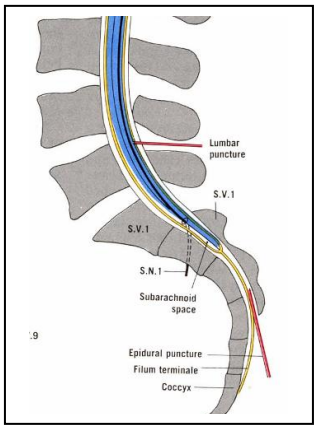
Position 1: Sitting in a reclined position in a chair with topographically neutral support distributes pressure across the thoracic area and away from the spine	
Position 2: Sitting in a sling-type chair puts pressure on the gluteus maximus muscles at the sides of the buttocks as well as on the heads of the femur bones and sciatic nerves.	
Position 3: Sitting in an upright position in a chair with lumbar support shows bands of pressure where the lower back comes in contact with the lumbar support.	
Position 4: Sitting in an upright position in a chair with postural support distributes pressure across the sacral-pelvic, lumbar, and thoracic areas.	
Position 5: Sitting in an upright position in a chair without postural support limits the distribution of pressure across the sacral pelvic, lumbar, and thoracic areas.	

3. Analysis of Force and Determine the Appropriate Seating Position

For the analysis we used software package Anybody Modeling Systems

From the above map pressure scheme we can see that the optimal seating position where are the minimum pressures or where are the smallest maximum surface are, so that we for further analyze will use seating position which is listed as 1st position in table 1. Position 1 represents the position of sitting where back is recline on the backrest follows the shape of the back, *gluteus* area is entirely reclined on seat with *appropriate* form that follows the contours

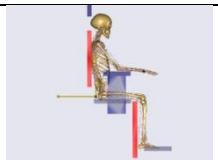
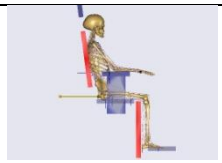
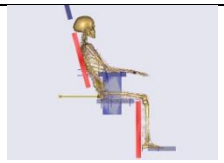
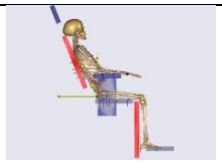
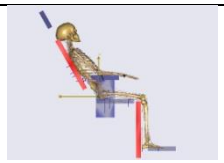
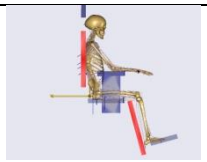
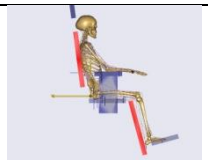
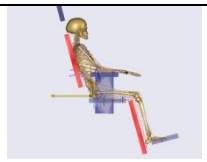
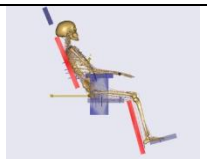
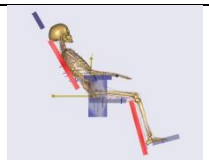
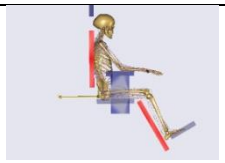
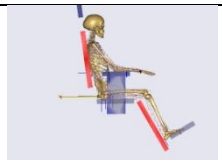
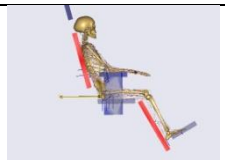
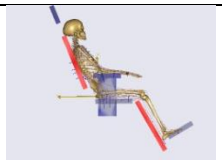
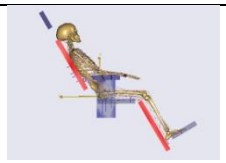
of the body. Legs and feet are reclining on its holders. Also arm rest can be included, and it should be parallel to the femur bone during the sitting. Optimal height of arm holder is on the 1 / 3 of the height of the upper body in sitting position (from femur up to the head).



Maximum value of angle for backrest and legs rest, which we consider is 30 degrees, because the angles larger than 30 degrees would have place body in lying position.

Main factors that affect on seating comfort are minimal muscle activity, load of spinal segments L4/L5 and minimum load of the L5-sacrum area (Figure 3), which represents the lower spine. Muscle activity is expressed as a power through force (the ability of muscle contraction). Muscle activity in the diagrams which follows is expressed in percentages. Thus the obtained results can be applied to larger number of different subjects.

At the bottom figures is shown schematically approach searches optimal sitting position, by changing the angle backrest and angle of legs rest holder (Scheme 1). Shown case (Scheme 1) is when the legs rest is from 0 up to 30 degrees measured from vertical plane and angle of backrest changes in interval of 0 to 30 degrees.

0 degrees					
15 degrees					
30 degrees					
legs rest angle	Zero position	Position 1	Position 2	Position 3	Position 4

Shema 1

Chair for resting, for working or for reading a book it should satisfy the basic principle and it is to be comfortable and not makes unnecessary pressure peaks on the body. These 5 positions represent five different positions of body depending of body activity. Zero position is the position in which the subject sitting, position 1 and 2 are suitable for working activities while position 3 and 4 are suitable for recreation.

Definition of position:

- Position 0:
    - Moment of sitting in chair, zero time. Also represent the position of the working activities for complex and precise tasks where it is necessary that working object be in front of the subject near the eyes. These are jobs like working with small objects

- Position 1:
    - Working at the table, the type of work is paperwork or similar activities that require a work at the table
- Position 2:
    - Represent working at the computer
- Position 3:
    - Represent position suitable for reading books
- Position 4:
    - Represent position suitable for watching TV or similar activities

Note: *Upper activities are grouped in 5 areas, and each position was associated with appropriate activities, according to the position that the body takes on that occasion.*

As in position 0 is maximum value of pressure on the body in the gluteus region and in the thoracic area, it is necessary to reduce these loads to the minimum because of possibility of low blood flow in those region. Influence of holder for legs is important to decrease the loads on the body. Variance of legs holder angle has direct influence in loads at the body and on maximum muscle activities. These data will describe respectively in Tables 2 and 3. At table 2 are given values of loads in body at the L5-sacrum region depending on the angle value for legs rest holder for all 5 examine sitting positions. Examined angles were 0, 15, 30 value of angle was measured of the vertical plane in the opposite direction from clockwise.

Table II

Angle \ Position	Load at L5-Sacrum are				
	0	1	2	3	4
0	323,37	309,36	280,62	248,42	212,06
15	321,23	308,49	279,85	248,04	211,69
30	318,89	307,32	297,32	247,53	211,19

The results of the maximum muscle activity for the defined positions (from 0 up to 4) and already provided angles are in the table (Table 3).

Table III

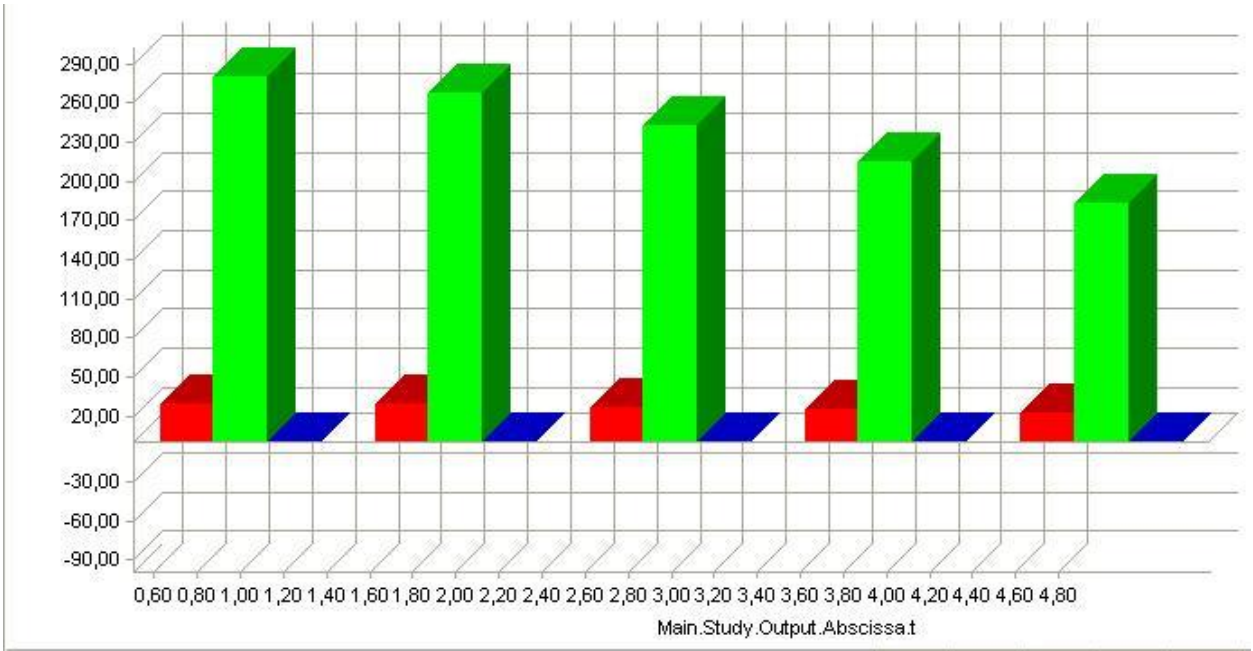
Angle \ Position	Maximal muscle activity (%)				
	0	1	2	3	4
0	6,97	6,45	5,46	4,35	4,21
15	6,79	6,35	5,38	4,28	4,21
30	6,57	6,23	5,28	4,20	4,20

Body passes thru 5 different seating positions and duration time for this period is 5 minutes, or 60 seconds for each single position.

Coefficients of friction are not the same for whole body in sitting position and these coefficients depends of many factors like chair material, clothing materials in which the subject sits, body weight, etc., but generally these coefficients we can represent approximately like in table 4. Vector of force which is acting on the lumbar L4/L5 region is graphically represented at chart 3. These values represent the total value of force at the end of activities after the analysis is completed, also with condition that angle of legs holder rest is set at 0 degree measured from vertical plain.

Table IV

Gluteus area / seat	0.5
Back / backrest	0.5
Legs / legs rest	0.5
Arms / arms rest	0.2



	1	2	3	4	5
Main.Study.Output.Model.HumanModel.Trunk.JointsLumbar.L4L5Jnt.Constraints.Reaction.Fout[0	29,96	28,73	26,91	25,13	23,03
Main.Study.Output.Model.HumanModel.Trunk.JointsLumbar.L4L5Jnt.Constraints.Reaction.Fout[1	279,27	267,44	242,53	214,71	183,13
Main.Study.Output.Model.HumanModel.Trunk.JointsLumbar.L4L5Jnt.Constraints.Reaction.Fout[2	0,00	0,00	0,00	0,00	0,00

Chart 1

As force is vector and it is represent space, we can observe force component on x,y,z axis. "Z" component has blue color on chart and its value is 0, or there are no loads in the Z-axis direction of Z-axis (Figure 4). Force component in X-axis direction is represents at red color and the force component at Y-axis is represent with green color. Chart shows loads in the L4/L5 area for all 5 sitting positions of the body.

Values of vectors at L4/L5 segments for all 5 different body positions and for all 3 angles of legs rest are in table:

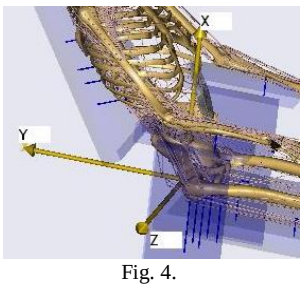


Fig. 4.

Legs rest angle		0	1	2	3	4
0 degree	X-axis	29.96	28.73	26.91	25.13	23.03
	Y-axis	279.27	267.44	242.53	214.71	183.13
	Z-axis	0.00	0.00	0.00	0.00	0.00
15 degree	X-axis	30.40	28.98	27.11	25.34	23.17
	Y-axis	277.64	266.85	242.01	214.52	182.92
	Z-axis	0.00	0.00	0.00	0.00	0.00
30 degree	X-axis	30.96	29.27	27.47	25.61	23.36
	Y-axis	275.88	266.02	241.77	214.28	182.65
	Z-axis	0.00	0.00	0.00	0.00	0.00

CONCLUSION

On the basis of the analysis it is clear that position 4 in Table 6 is the most efficient from the standpoint of minimum load of L5-sacrum and maximum muscle activity and this leads us to the conclusion that the construction of the chair should have:

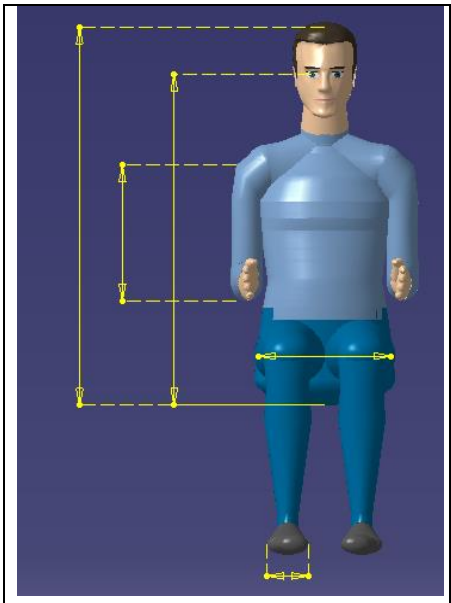
a) Backrest that follows topography of the back and to support head-neck area
b) Seats fully support topography of gluteus area
c) Legs rest follow legs areas and it has adjustable angle up to 30 degrees

4. SOLUTION OF CHAIR DESIGN

For preliminary chair design on the basis of the analysis we will use software package CATIAV5R19

For preliminary design solution of ergonomic chair, basis on the analysis, we suggest that chair has specially designed parts of the backrest and seat to reduce the value of maximum pressure. Precisely in order to increase the surface contact between the body and the chair and thus reduce the loads which strain the body, because if bigger contact between chair and body loads which strain body are smaller (according to formula $esure = \frac{\text{Force}}{\text{Area}}$).

As a reference model is chosen man, European with standard anthropometry and to whom we will realize design chairs.



	Mean [mm]	inf Range [mm]	Sup. Range [mm]
Sitting height	932	790	1074
Eye height, sitting	819	670	968
Hip breadth, sitting	344	252	437
Shoulder-elbow, sitting	365	294	436
Weight	70 [kg]	31 [kg]	109 [kg]

The design is based on a human body, so first of all is to define characteristic contours on the three characteristic area of body. First contour is in the vertical plane and it is parallel to spinal, also it can be represented as contour line at the back and it has form of letters "S". It stretches from the middle of the head to the bottom of the spine where the ends of the sacrum. In the horizontal plane there are two characteristic contours at the area of thoracic and lumbar. These contours are in the form of the number "3", from the sides these contours *comprise* body and at the middle there are up to spine and on this way we provide better contact between back and backrest and increase tangential area. Appendix is small pillow at the bottom of backrest at area of the L5-sacrum and allows the lower back is always achieved contact with the backrest. This convex part is necessary because gluteus region never can fully reached backrest, so the goal of this segment is to provide contacts with the lower back and relieves part of the L5-sacrum and L4-L5 segments (Figure 5).

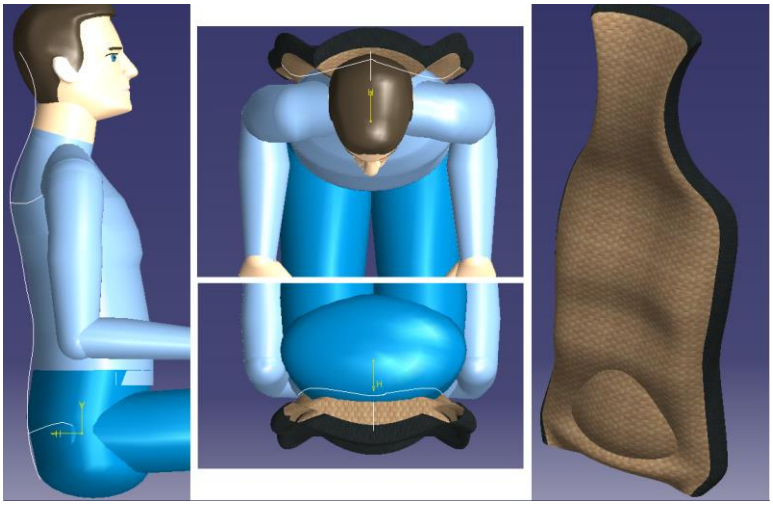


Fig. 5.

Backrest should be adjustable by angle and should follows the shape of the spine, has a topography of the body adapted. **Analysis of surface curvature** on the backrest shows characteristic segments which can be divided into three parts (figure 6):

- neck and head
- thoracic part
- lumbar and sacrum

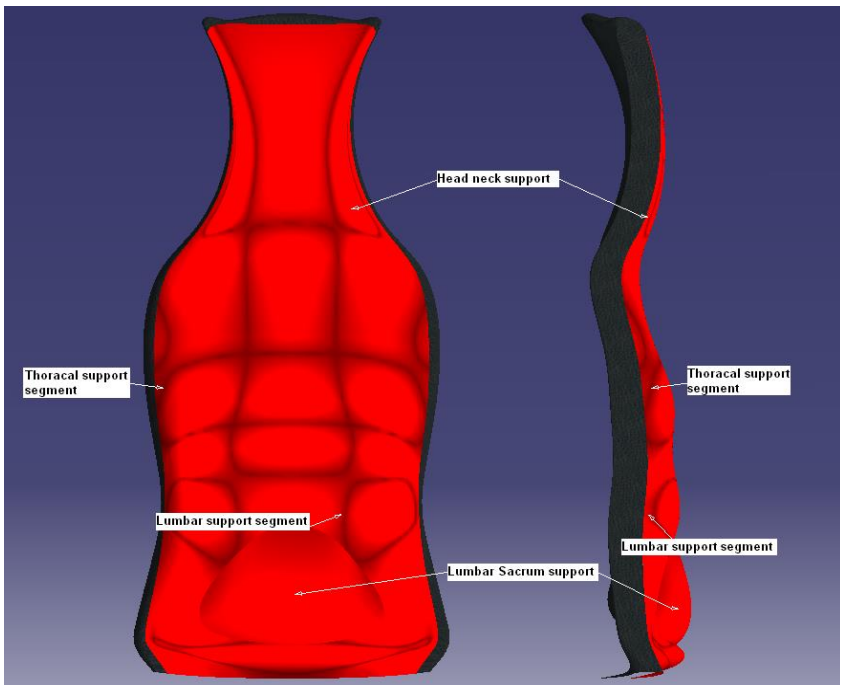


Fig. 6.

For proper design of seat we draft two characteristic curves which following position of legs and gluteus region at sitting. First curve is from back up to knee following figure of legs, and second curve is the perpendicular to the first one and it is in a horizontal plane. It describes the form of muscle below femurs. Analysis of the curvature of the seat area shows that the seat can be divided into two parts, a segment under the gluteus region and the segments under the legs. In the area of gluteus region seat has concave shape throughout its entire length and at the sides seat has special designed which support sides of thighs area. Part of the seat that cover legs is at angle so this angle ensure that thigh bones stay in horizontal position, also this area has form of the number "3" which is necessary to increase contact between human body - chair surface and thus reduce the pressure (Figure 7). Seat should be adjustable by height, the base material is hard plastic which should provide contour and material that is in contact with the body is the same as for backrest.

Footrest is adjustable by angle from 0 to 30 degrees relative to vertical plain, and it has topography that follows the shape of legs. Arm rest has special design and it has form of letter "U" and this makes that arms be fully tangent with arm rest.

Table 7 and figure 10 shows the basic positions of chair and it consists of 11 main parts.

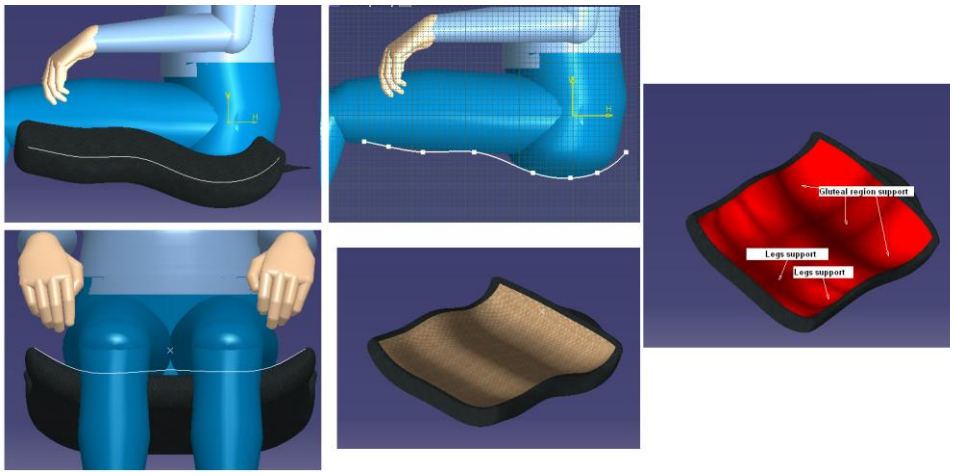
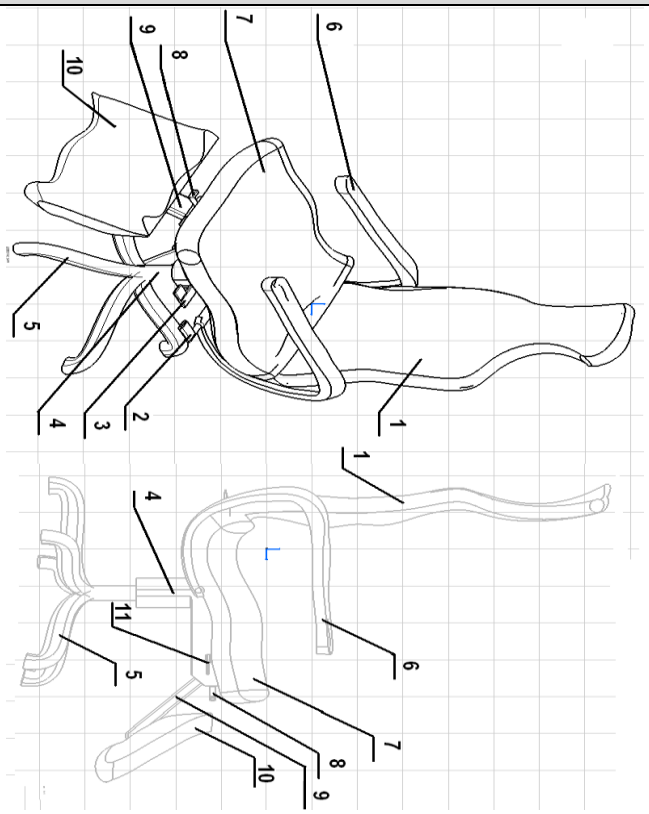


Fig. 7.

Table VII

No	Position	Chair scheme
1	Backrest	
2	Arms rest adjuster	
3	Seat height adjuster	
4	Seat holder	
5	Chairs legs	
6	Arms rest	
7	Seat	
8	seat angle adjuster	
9	Legs rest holder	
10	Legs rest	
11	Backrest angle adjuster	

5. CONCLUSION

The conclusion that imposes itself and on the basis of the analysis of the work is that is necessary make some innovations in the chairs design to maximize comfort. Average worker place whose job is related to the work at the desk in a chair spend about 2 / 3 of day in a sitting position and in the modern world there are majority of working places like this. What is obvious from the current situation for almost all chairs is that legs support or legs rest is missing and according to analysis it Is clearly that there is close relationship between the loads of the body and angle position of the legs. In this paper we do not consider some external support for legs because of large number of various chairs types, and different chair type would required special adjustment of legs rest support. According to this reason we accept approach for design of new ergonomic chair that fulfill ergonomic criteria and has simple designed legs rest integrated in chair. This legs rest increase comfort and can be simple used by subject.

REFERENCES

[1] The Art and Science of Pressure Distribution (ERGONOMIC CRITERIA FOR THE DESIGN OF WORK CHAIRS), *2009 Herman Miller, Inc. Zeeland, Michigan*

[2] The Art of Pressure Distribution (Ergonomic criteria for the design of adaptive suspension work chairs), *2003 Herman Miller, Inc., Zeeland, Michigan*

[3] Importance of Chair Designs That Support the Lower Back, Continuing education unit

[4] Promoting Healthy Movement and Natural Alignment, 2009 Herman Miller, Inc. Zeeland, Michigan Printed in U.S.A.

[5] Healthful Patient Seating: Perspectives from Caregivers and Researchers, 2009 Herman Miller, Inc., Zeeland, Michigan

[6] The AnyBody Modeling System, 2007 AnyBody

[7] 7 Tips for Good Ergonomic Chair Design, Healthy Ergo

[8] *Selecting a Comfortable Chair, (1987) Dr. Leona Hawk*

[9] Check list chair according to ANSI/HFES 100-2007 checklist, Prof. A. Hedge, Cornell university, Dept. Design & Environmental Analysis, Ithaca NY 14850, USA

[10] http://www.sturdy.com.au/ergonomics.php