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The Load of the Organism and Calculation of Energy Consumption on the Working Place in the Function of Nutrition

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***Abstract* – During the work, laborers are often in bent, half-bent and crouching position because they need to finish their working activity. These working activities are changed many times during the working day. In this article, the use of software package CATIA for calculating the loads is being described. If the working place is not designed on the right way, exceeded overloads are present and they are not really desirable for the health of the laborer. The laborer will be more fatigue and less efficient on work and its health is being endangered. In this article, the load in L4/L5 vertebra is analyzed in 3 positions of the laborer, during the process of taking, carrying and putting the cement in the truck. After calculations of organism load, another calculation of energy consumption is done for that specific working place in the function of our laborers diet.**

***Keywords* – Biomechanics, CATIA Software Package, Anthropology, Load, Diet**

I. Introduction

Ergonomy is the use of scientific information about a man with the goal of designing tools, system and the environment for people. In this work, the use of software package CATIA is described and how to calculate the loads which are present during some specific activities. Using this software it is possible to get ideal parameters for saving workers health. It is possible to get the information about the loads in the L4 and L5 vertebrae spine. Workers are often in 3 positions during the work activities such as bending, squatting and kneeling. From the previous experience, it has come to the conclusion that there are many problems present if it doesn't take care for the construction of working place. The purpose of this article is to analyze loads and to answer the question are these loads acceptable. In this article it is showed how much energy does the worker need for specific activity. Also the needed nutrition is given to fulfill daily needs. Only if the worker`s health is saved, the satisfaction from both sides is present.

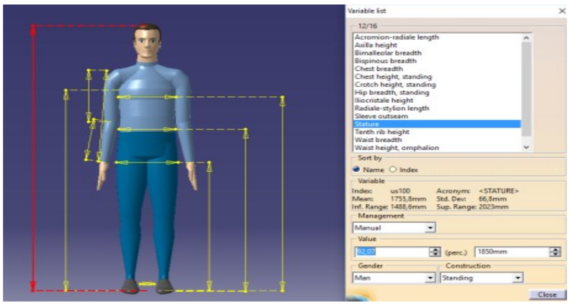
II. Goals of Research

In this article it is needed to perform the analysis of workers load who is loading 2500 kg of cement from storage to truck. Through the analysis, it is needed to give the answer if organism is overloaded or acceptable. It is also needed to examine the load of muscle system which is used during the working cycle. At the end, it is supposed to establish diet according to organism load. The company has one worker who loads cement with these anthropological characteristics:

Gender: male; height: 185 cm; weight: 85 kg.

2.1. Defining main Problem

It is needed to load 2500 kg of cement from the storage to the truck. The buyer has specified that size of cement doesn't matter, only the load time.



Picture 1. Anthropology characteristics of worker

The shortest way for the worker from storage to the point of load is 40 m. He takes the cement packages from the floor, then takes them to truck and goes back to storage. The height of the loading point in truck is 80 cm. After he takes the cement in the truck, he goes back for the another one. The mass of one bag: $m_1 = 25$ kg

Number of required packages:

$$n_1 = \frac{m_{uk}}{m_1} = \frac{2500\ \text{kg}}{25\ \text{kg}} = 100\ \text{bags}$$

Path distance: $l_1 = 40$ m
Lifting time: $t_{pod1} = 4$ s (measured) Walking speed with load: $v_{ht1} = 0,8$ m/s
Load transfer time:

$$t_{ht1} = \frac{l_1}{v_{ht1}} = \frac{40\ \text{m}}{0{,}8\ \frac{\text{m}}{\text{s}}} = 50\ \text{s}$$

Load lowering time: $t_{st1} = 2$ s (measured) Walking speed without load $v_{hp1} = 1$ m/s
Idling time:

$$t_{ph1} = \frac{l_1}{v_{hp1}} = \frac{40\ \text{m}}{1\ \frac{\text{m}}{\text{s}}} = 40\ \text{s}$$

Total time of 1 cycle : $t_{c1} = t_{pod1} + t_{ht1} + t_{st1} + t_{ph1} = 96$ s
Total working time : $t_{uk1} = n_1 * t_{c1} = 9600$ s $= 160$ min
Working cycle: $t_{rad} = 40$ min; $t_{odm} = 15$ min;

Total working time with breaks : T = 4 * t_{rad} + 25 min + 4 * t_{odm} =

=185 min + 60 min = 245 min

2.2 Time Analysis Conclusion:

Worker does his job for 4 h and 5 min. Working norm given from employer is T_n = 4 h and hourly rate is 10 KM. If the laborer is working for 20 working days, during the period of 6 months, we can calculate how much does this job costs.

6*20*40 KM = 4800 KM

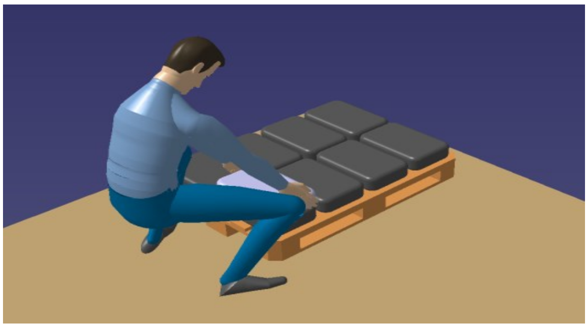
III. Analysis of Characteristic Positions in Work

It is needed to analyze 3 critical positions during the laborers work:

- Crouching position during the load lifting;
- Standing position with the load in hands;
- Position during load disposal.

3.1 Determination of Carachteristic Positions

3.1.1 Crouching Position



Picture 2. Crouching position

Picture 3. Standing position

3.1.2 Crouching Position During the Load Lifting

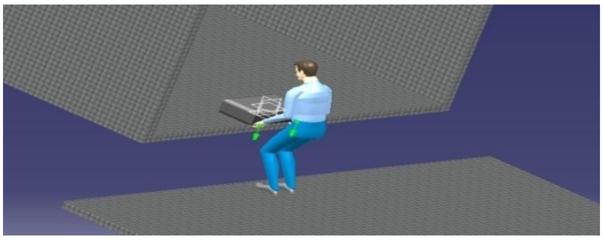
Laborer is getting low, (picture 2), hands are spread out and he is starting to accept the cement from up to the bottom. Legs are widespread, he is bent in the back region. From the facts above, we can see that this position might be critical based on the loads on legs, muscles and back due to the position and also from the load.

3.1.3 Standing Position

On the picture number 3 we can see that the laborer stood up, he put cement closer to himself which means that the moment in the L4-L5 has decreased. Hands are under the package, wrapping it from the lower side, widespread so the weight will be equally distributed. Laborer is upright and the pressure on the abdominal region is decreased. In this position, laborer is carrying cement for 40 m, then he puts it on the ramp in the truck which is 80 cm high and he ends the cycle.

3.1.4 Position During the Postponement of Cement

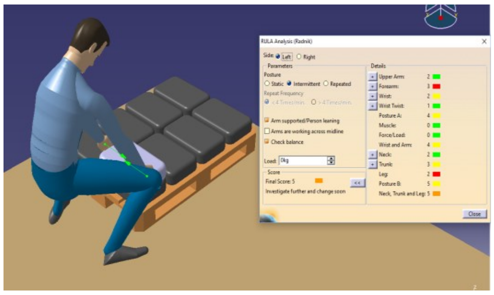
From this position we can see that the laborer is slightly bent forward because he needs to put the cement on the ramp so he can compensate the height difference (the vertical distance from the floor in the position 2 is 1140mm, and for this one 800mm). The pressure in L4-L5 is little increased. Hands are half-extended.



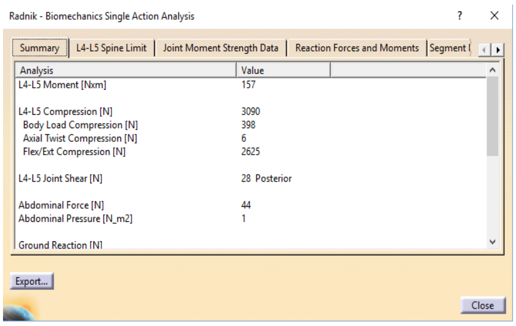
Picture 4. Position of laborer during the postponement of cement

IV. Load Analysis of 25 kg

4.1 Position 1 (RULA analysis)



Picture 5. Analysis for position 1



Picture 6. Biomechanical analysis for position 1

The parameter is given for the activity which is repeating less than 4 times per minute. Both sides are equally loaded and the mass of cement is 25 kg. On the picture number 5 we can see that the loads are especially expressed in the zone of forearm and legs (mark 5) and also in the zone of neck, belly and legs (mark 5) so the total mark is 5.

4.2 Position 2 (RULA Analysis)

From the picture number 7, we can see that the total mark is 2 for the given parameters and the only less risky factor is mass regarding the load which has mark 3. The total mark

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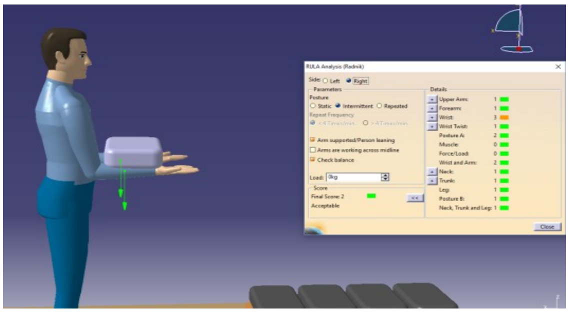
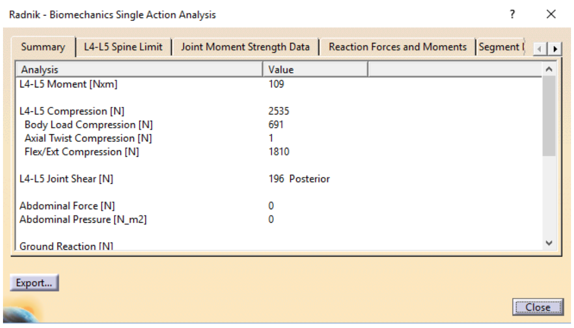
only needs the additional research of possibility but it is not dangerous for laborer.

Picture number 8 shows that the loads are in accordance with the limitations, 4-5 moment is 109 kg, abdominal is not present because laborer is in standing position. Pressure in L4-L5 is 2535 N/m^2 which is 865 N/m^2 less than allowed.

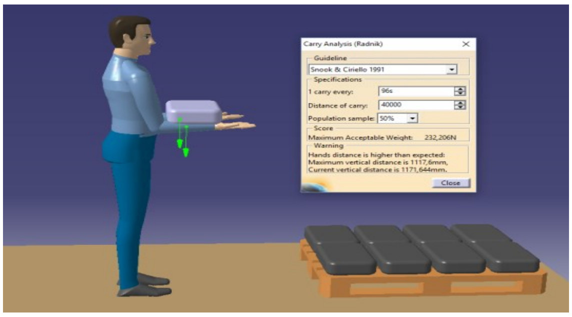


Picture 7. Analysis of position 2



Picture 8. Biomechanical analysis of position 2

4.3 Carry Analysis



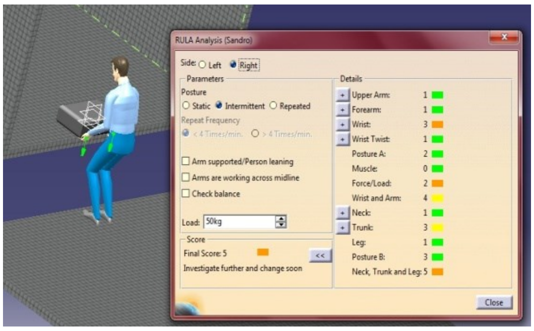
Picture 9. Carry analysis for specific activity

On the picture number 9 we can see that recommended weight for our parameters is 232,206 N, if we transform N to Kg we get: m_{pr} = 232,206/9,81 =23,67 kg which is 1,33 kg less than our given weight. This means that the mass of 25 kg will not represent a problem for organism load.

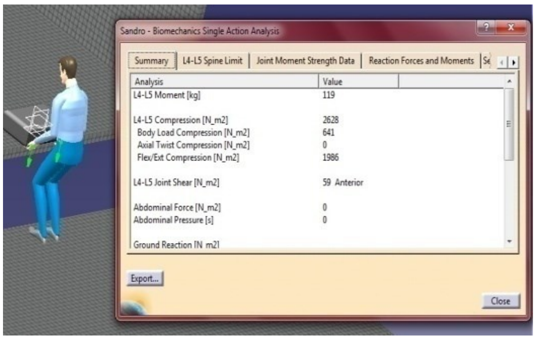
4.4 Position 3 (RULA-analysis)

From the picture number 10 we see that the laborer is smoothly bended, hands are half-extended so he is eligible to reach the edge of truck on height 800 mm. Total mark is 6.

We see that L4-L5 moment is 119 kg, L4-L5 shearing is 59 N/m^2 and the pressure on L4-L5 is 2628 N/m^2 so it is 772 N/m^2 less than acceptable limits or 22,7 %. This position is not bad based on the loads, but it has bigger concentration of strain on hands and joints from the influence of mass so we need to work additionally, but it is acceptable for L4-L5 loads.



Picture 10. Analysis for position 3



Picture 11. Biomechanical analysis

V. Calculation of Work Energy and Required Diet for Laborer

5.1. Calculation of Work Energy

Work which is used on holding the cement during the movement between the platforms is possible to express as product of force in hands and the path which is crossed. On this way, the work for hands is summarizing with the spent work on lifting, spinning and dropping the cement so we can get the total work which is spent on hands during the work activities.

Force in hands is calculating as a summation force, which burden both hands and is given from the mass of cement weight which laborer carry and based on gravity acceleration:

$$F1 = m \cdot g\ [N] = 25 * 9,81 = 245,25\ N$$

m [kg] - weight of cement,
g[m/s^2] – gravity acceleration of earth.

The path which hands pass holding the cement represent length which laborer passes from the place of cement assumption to the truck and it is measured from the cement brunt in the starting and ending position. The path during lowering is measured from the standing position to the last position in which he leaves the cement in the truck and the distance is measured between the load brunt.

The work which represents force on the path is calculated from the formula below:

$$A\ 1 = F1 \cdot s\ [J] = 343,35 * 22 = 5395,5\ N$$

F [N] – Force which affects hands,
s [m] – Path which hands crosses holding the cement in 3 positions.

Force needed for transferring cement from one place to another is calculating with this formula :

$$F = m \cdot g \cdot \mu \ [N] F1 = 25 \cdot 9{,}81 \cdot 0{,}5 = 122{,}625 \ N$$

F [N] – Force which affects hands,
g [m/s2] – Gravity acceleration of earth,
μ - coefficient of friction between foot and floor, frame value is 0, 5.

Power used during 1 shift is given with the formula below:
$E = A \cdot f \cdot P \cdot \Theta$. $E1 = A1 \cdot f \cdot P \cdot \Theta = 5395{,}5 * 0{,}69 * 2{,}41 * 2 = 17944{,}35$ J/RC
A[J] – Total work for cement transfer,
f – Frequency repeating of activity per minute,
P – Period of activity duration,
Θ – Factor of fatigue, which depends of frequency and mass of cement.

It goes in the following limits: 1.1 – easy chores and 2. – heavy chores.

5.2 Calculation of BMR Energy

The amount of energy required for organism for its functioning (breathing, work for organs, food sorrowing, exchange of matter) is called main metabolic rate.

We are using Harris –Benedict`s formula:
For male subjects:

$$BMR = 65{,}51 + (9{,}563 \cdot M) + (1{,}85 \cdot H) - (4{,}676 \cdot Y) \ [kcal/day]$$

Where is:
- M [kg] -mass of subject,
- H [cm] -height of subject,
- Y[god] –years of examinee

BMR = 65, 51 + (9,563·85) + (1, 85·185) - (4,676·26) = 1099,039 kcal/day

1 kcal = 4,186 kJBMR = 4396,156 J/day BMR = 4396,156 /3 = 1465,385 J/RC

Total power used in the working cycle represents the sum of BMR and power used during one shift:
$E_{u1} = E_1 + BMR = 17944{,}35 + 1465{,}385 = 19409{,}738$ J/Rc = 19,40 kJ/Rc

The formula used for calculating energy needs: EP = ITM · 24 · ffa [kcal]
Where is:
ITM [kg] –ideal body weight
- 24 - fast, oriented value basal metabolism expressed as kcal/kg/hour
- ffa - factor of physical activity
- ffa = 2,10

Table 1. Weight coefficient of physical activity

Gender	*Easy physical activity*	*Medium physical activity*	*Heavy physical activity*
Male	1,56	1,78	2,10
Female	1,55	1,64	1,82

The ideal body weight : ITM = (TV (cm) – 100) – ((TV (cm) – 150)/4) [kg]

Where is: TV [cm] – body height ITM= (185 – 100) – ((185 – 150)/ITM= 76,25 kg

5.3 Proposal of Menu

EP = 76,25 · 24 · 1,78 =3257,4 kcal = EP/3= 1085,8 kcal/RC

Average energy value of meal during one week is 1085,8 [kcal].

Table 2. Monday

Meal					*Total*
Beef and potatoes	Beef	Potatoes	Cake	Pastry	1058,4
	250 [g]	240[g]	100[g]	100[g]	
	364 [kcal]	174 [kcal]	250[kcal]	220[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1008					

Table 3. Tuesday

Meal					*Total*
Minced meat and spaghetti	Minced beef	Spaghetti	Juice	Pastry	1113
	200 [g]	300[g]	water	200[g]	
	436 [kcal]	324 [kcal]		300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1060					

Table 4. Wednesday

Meal					*Total*
Beans	Sausage	Beans	Cake	Pastry	1056,3
	250 [g]	300[g]	100 [g]	200[g]	
	357 [kcal]	149 [kcal]	200 [kcal]	300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1006					

Table 5. Thursday

Meal					*Total*
Beef meat with potatoes	Beef	Potatoes	Juice	Pastry	1072,05
	260 [g]	240[g]	0,5 [l]	200[g]	
	397 [kcal]	174 [kcal]	150 [kcal]	300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1021					

Table 6. Friday

Meal					*Total*
Grilled chicken and potatoes	Chicken	Potatoes	Salad	Pastry	1114,6
	300 [g]	240[g]	200 [g]	200[g]	
	387,5 [kcal]	174 [kcal]	200 [kcal]	300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1061,5					

VI. CONCLUSION

By the help of software package CATIA, we are capable on the most qualitative way to simulate, optimize, do the judgement and analyze tasks in the variety of business activities.

In this project is showed how it is possible to use one software package. Many analyses are presented such as biomechanical, carry, RULA. We could see that there were none big loads during the specified work so it means that laborer will not have any health issues. The goal of every designer and engineer is to be sure that these problems will not be present. Every year there is a lot of loss because of the injuries and illnesses which are present on the job, so if we do the optimization and analysis of working place, manager will have many savings and also the laborer will be healthier.

There is an option to use the palette machine to save the time needed for discharge of cement for 4 times, which means that the laborer will do his job on more efficient and faster way and he will save his health. He will only need 1 hour to finish specified activity. The loads will rapidly decrease and the amount of cement will be much bigger.

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