MECHANICAL MODEL OF THE HUMAN BODY SITTING ON A TRACTOR CHAIR

MODEL MECANIC AL CORPULUI UMAN AŞEZAT ÎN SCAUNUL TRACTORULUI

R. ILEA, CORNELIA TONEA

Agricultural and Veterinary University of the Banat, Timişoara, Romania

Abstract: *The elaboration of the mechanical model of human body sitting on a tractor chair needs the knowledge of the elastic and mass characteristic of the body. The complexity of the human body structure, as well the response of human organism or of different parts to external actions, needs more simplifications for obtain the human body model sitting on a chair or a vibrant platform. For the estimation of mechanical model parameters representing the human body sitting on a vibrant platform it is developed a program for calculus.*

Rezumat: *Elaborarea modelului mecanic al corpului uman aşezat în scaunul tractorului necesită cunoaşterea maselor şi caracteristicilor elastice ale corpului. Complexitatea structurii corpului uman, precum şi reacţiile acestuia la acţiunile exterioare necesită mai multe simplificări pentru obţinerea modelului mecanic al corpului uman aşezat pe o platformă vibrantă. Pentru estimarea parametrilor modelului mecanic al corpului uman aşezat pe o platformă vibrantă s-a utilizat un program de calcul.*

***Key words*:** *vibration, rigidity, amplitude, analytical model*
Cuvinte cheie: *vibraţie, rigiditate, amplitudine, model analitic*

INTRODUCTION

In the motion of a tractor, vibrations appear which are transmitted to the persons sitting on the chair. For their protection against the effects generated by vibrations it is necessary to introduce isolators which assure a small transmissibility.

In the last time, it was elaborated different methods which permit the observation and research of the response of the human body or its different components parts to the external actions. The purpose of laboratory experiments is the reproduction of the action in natural conditions, using the facilities offered by the laboratory researches and, at the same time permitting an exact determination of the mechanical action magnitude (entrance signal), the place where the action is applied and the reaction, that is to say the response (output signal).

For the construction of the mechanical model for the study of sitting on a chair human body it is necessary to know the elastic and masse characteristics of the body. In consequence, this paper intends the identification of the main elastic parameters of the organism, starting from some known experimental data concerning the resonance frequencies.

The elaboration on scientific bases of the action and protection against vibrations needs a detailed research of the human body behaviour from the physiological and functional point of view, and of the biological and biomechanical processes in the human body if on it, vibrating loads act for a short or long period of time.

MATERIALS AND METHOD

In function of the chosen organs in the abdominal cavity, the description of human body can have 65-70 rigid bodies, binded with non-linear springs and dampers, elements by which the rigidity and damping capacity of viscera (intestines, heart, lungs, etc.), muscles, discs between vertebra, ligaments, tissues, etc are located.

The first step in the study of a system or process is the realization of a model, easy to use, neglecting some characteristic elements of the system. So, the complexity of the studied structure, the anatomical description and the mathematical model of the human body, need more simplifications. The mechanical model of sitting human body under vertical vibrations is represented in figure 1.

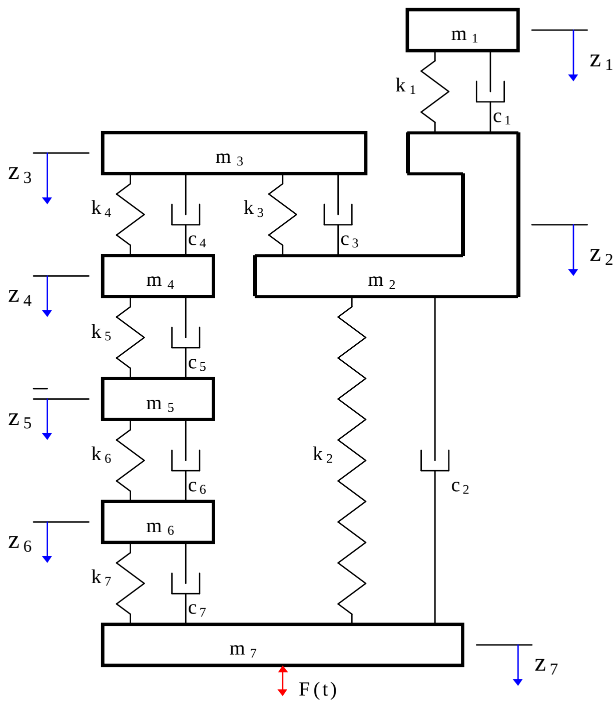

Figure 1 Mechanical model

For the dynamic model in figure 1 it was made the following hypothesizes:

a) The head and the atlas (first and second cervical vertebrae), thanks to the existent connections, are combined in one rigid body, named "head" and noted by m_1.

b) Because the measurement of the relative motion between vertebrae is not realized for the longitudinal excitation of the subjects, the rest of spinal column is combined in one rigid body, named "back" and noted by m_2.

c) For deformations, smaller then the ones which cause breaking of discs between vertebrae, the experience shows that the rigidity and damping in the spinal column can be represented by linear springs and dampers, noted by k_1 and c_1 for the cervical section and k_2 and, respectively c_2, for the thoracic and lumbar section in the case of the transmission of the longitudinal components of forces through the longitudinal discs and respective muscles. The pelvic rigidity and the corresponding damping are included.

d) Because the relative motion between ribs, between ribs and thoracic vertebrae and between rib and cartilages and sternum seems to be relatively small, insignificant for the longitudinal excitation of the subjects, the thoracic cavity is considered as a single body, named "torso" and noted by m_3. The arms and hips are, also, included in torso.
The rigidity and damping of the torso are represented by a non-linear spring and a non-linear damping element, noted by k_3, respectively c_3, for the transmission of longitudinal components of forces in the ligaments which connect the ribs with the vertebrae.

f) The thorax and abdomen viscera are considerate as three rigid bodies named: "Thorax" (heart and lung),"Diaphragm" (respiratory diaphragm) and "Abdomen" (liver, stomach, kidneys, spleen, gall, urinary apparatus, pancreas, intestines), noted by m_4, m_5 and, respectively m_6, with the rigidity and damping coefficients of the thorax and abdomen, represented by nonlinear springs and non-linear damping elements. These ones are marked by k_4 and c_4 for the thorax and k_6 and c_6 for the abdomen.

g) The rest of the body (the pelvis and the legs) considered together is named "Pelvis" and noted by m_7.

h) Because the rigidity of the joint increases with the deformation, the springs have to be considered hard, but for simplification, they are supposed as linear.

i) The perturbing forces which are considered as applied to the model are limited to sinusoidal and longitudinal displacements of the chair or the platform (the floor), and the response of the model is limited only to motions in vertical direction.
The initial data were taken from the specialized reference material. It was considered an 80 kg subject as a model, with a distribution of masses in accordance with the data from the table 1.

Table 1

The distribution of an average man's mass

ELEMENT	MASS	MASS [kg]	PERCENTAGE [%]
Head	M_1	5.44	6.819
Back	M_2	6.82	8.523
Torso	M_3	32.72	40.909
Thorax	M_4	1.36	1.705
Diaphragm	M_5	0.46	0.570
Abdomen	M_6	5.91	7.381
Pelvis	M_7	27.22	34.093
TOTAL:		79.93	100%

The masses of the head, torso and pelvis were determined experimentally, as being 5.44 kg for the head, 47.17 kg for the torso and 27.22 kg for the pelvis (which also includes the legs).

In the computer program it was used a percentage distribution of the mass, so that to be used for any value of the entire mass, not only for the subject whose body mass is 80 kg.

Then from the g) hypothesis, it results that the equalities k_5=k_4, and k_7=k_6 are valid.

Also, for the determination of the mechanical model parameters there were used the resonance frequencies known for different parts of the human body, frequencies obtained experimentally. So, in the case of vertical vibrations, the resonance frequency, for the thorax-abdomen system is in the range of 3-6 Hz, for the head 4-6 Hz, for the shoulder 4-6 Hz, and for the hip, the first resonance frequency is also in the range of 4-6Hz. So, f_{n1}=3-6Hz, f_{n2}=4-6Hz, f_{n1}=4-6Hz, f_{n3}=4-6Hz, f_{n1}=3-6Hz.

RESULTS AND DISCUSSION

The studied dynamic model is considered without viscous damping, for the determination of the constant values which characterize the elastic elements in the model.

The masses m_i, i=1..7, are considered to be fixed, one after another, in this way resulting for every mass a separate mechanical system with a single degree of freedom, system made up by the corresponding mass and the afferent springs.

From the experiments, for the component systems of the human body, the following resonance frequencies are established: for the thorax-abdomen system, a proper frequency of 3-4 Hz, for the hip 4-5 Hz, for the heard 4-6 Hz. It was also established for the hand-arm system, a maximum in the range of frequencies of 1-3 Hz.

In the case of the mass m_1, without damping, the differential equation of the motion is:

$$m_1\ddot{z}_1 + k_1 z_1 = 0$$

And so

$$k_1 = m_1 \omega_1^{\ 2}$$

In the case of the other masses, components of the mechanical model, it proceeds in the same way.

The differential equations of these masses are:

$$\begin{gathered}
\mathrm{m}_2\ddot{\mathrm{z}}_2 + (\mathrm{k}_1 + \mathrm{k}_2 + \mathrm{k}_3)\cdot \mathrm{z}_2 = 0 \\
\mathrm{m}_3\ddot{\mathrm{z}}_3 + (\mathrm{k}_3 + \mathrm{k}_4)\cdot \mathrm{z}_3 = 0 \\
m_4\ddot{z}_4 + 2k_4 z_4 = 0 \\
m_5\ddot{z}_5 + (k_4 + k_6)\cdot z_5 = 0 \\
m_6\ddot{z}_6 + 2k_6 z_6 = 0 \\
m_7\ddot{z}_7 + (k_2 + k_6)\cdot z_7 = 0
\end{gathered}$$

So, it will be obtained for the isolated masses in the model, the algebraic equations for the known proper pulsations of the considered subsystems:

$$\begin{gathered}
k_2 + k_3 = m_2\omega_2^{\ 2} - k_1 \\
k_3 + k_4 = m_3\omega_3^{\ 2}
\end{gathered}$$

$$k_4 = \frac{m_4 \omega_4^{\ 2}}{2}$$

$$k_4 + k_6 = m_5 \omega_5^{\ 2}$$

$$k_6 = \frac{m_6 \omega_6^{\ 2}}{2}$$

$$k_2 = m_7 \omega_7^{\ 2} - k_6$$

For the calculation of the elastic parameter values, utilizing the calculations presented above, it was used the Turbo Pascal computer language. But it might as well be used any other computer language (C, GWBasic, MathLab, Visual Basic) of course with some advantages and disadvantages depending on the facilities offered by the respective computer language.

The program "orizelas.pas" permits to the user to obtain the estimation of the mechanical model parameters representing a human body sitting on a car seat.

Inside the program, after the initial presentation, it appears a menu on the computer screen. It is possible to choose the implicit values for the inputs or the introduction of the values from the keyboard, being more options. In this way, the mass of the whole body can be given, or the masses of every component element of the model, and the pulsation or the frequency. In this way, the system can be applied using practically an unlimited combination of the input parameters.

As a result of the program running, the values of the studied mechanical model parameters, the elastic constant and the masses of the component elements are listed together with the possibility of printing.

CONCLUSIONS

After the introduction of the inputs mentioned before and the running of the program, we obtained the following results:

k_1= 5369.06 N/m;
k_2= 24502.72 N/m;
k_3= 31749.73 N/m;
k_4= 543.62 N/m;
k_5= 543.62 N/m;
k_6= 2362.34 N/m;
k_7= 2362.34 N/m.

It can be seen that the rigidities k_4,…k_6, corresponding to the elastic elements which link the thorax and abdomen organs among them, have smaller values than the hips and torso. These ones are also explained because the internal organs have a high mobility as a consequence of the high elasticity of the diaphragm, and the air volume which is behind it, in the lungs a thoracic cavity.

Consequently, the calculation program in the paper uses as input, data which are in fact obtained experimentally and in accordance with the presented algorithm, it processes these data, constituting in this way a very special instrument useful for researches in this field.

LITERATURE

1. BRÎNDEU, L., *Vibrații şi vibropercuții*, Ed. Politehnica, Timişoara, 2001.
2. BRÎNDEU, L., *Mecanică şi vibrații – Culegere de probleme pentru calculator*, Ed. Politehnica,

Timişoara, 1993.
3. CONSTANTIN, F., CÂNDEA, I., *Stabilirea unei metodici privind cercetarea experimentală a suspensiei tractoarelor pe roţi*, A 8-a Conferinţă cu participare internaţională Vehiculul şi mediul CONAT '96, vol.V, secţia a III-a, Tractoare şi maşini agricole, pp 165-170, Braşov, 1996.
4. MUKSIAN, R., NASH,C.D., *On frequency dependent damping coefficients in lumped – parameter models of human body beings,* J. Biomechanics, vol.9, pp 339-342, Pergamon Press, 1976.
5. OLARIU, V., ROŞCA, I., BARBU, D., *Biomecanica, vol.I,* Ed. Macarie, Târgovişte, 1998.