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MODELLING OF MECHANICAL HAND-ARM SYSTEM UNDER VIBRATION ACTION

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Abstract: *Machines in operation can expose the workers to mechanical vibrations transmitted by hand, which can affect the comfort, eficiency of work and in some cases, health and human security. A new model for human body or for a part of it will be made function of the data that is presumed known and function of the goal that it has to be achived. This model can be then used for future studies refering to the vibration action on the specific body.* ***Key words:*** *vibrations, hand-arm vibration, mechanical model of hand-arm system, vibration simulation.*

1. INTRODUCTION

The biomechanics of human movement can be defined as the discipline that describes, analyzes and evaluates human motion.

The definition of the biodinamics that best describes it from the point of vieww of most scientists would be that given by Gowaerts namely that biomechanics is the science concerned with the study of repercussions of mechanical forces on the functional structure of man, with regard to architecture of bone, joints muscles, as determinant factors of the movement.[1]

Increased technical performance of machines and mechanisms which man uses determines the tolerance threshold of the human body and to determine the behavior of the different parts of the accelerations, decelerations, noise vibrations, etc.

Results obtained from studies conducted so far in biomechanics are used in the design of modern cars: working machines, machine tools, road or space machines, industrial equipment, household items and sport equipment.

2. MECHANICAL MODELLING

For correct modelling a phenomenon is necessary to know observe the phenomenon as closely possible taking into account the complexity of the model, which need to be suitable for the proposed goal. A model that is to simple may exclude a lot of different important aspects of the phenomenon but a more complex model can make the research heavy and expensive.

Generally a modell can be:

- *functional* - outlines different components of the sistem and reflects the connections between them;
- *for calculus* - it is a theoretical model that begins with a set of hypothesis and then establishes a number of calculus relations which describe the phenomenon;
- *experimental* – is a physical object, a device or a equipment which reproduce the phenomenon.

The three types of models coexists and together era describing the phenomenon with all the limitations and advantages and drawbacks that are implied.

3. MECHANICAL MODEL OF HANDS

Human hand-arm system is a high degree complexity system.

For executing a simple hand movement are involved many factors (static or dynamic) that affect system behaviour. Also the tissues that are composing the system have different mechanic, visco-elastic and inertial properties.

This properties are characteristic to the system and can be used as general characteristics for all human bodies, for an overall analysis.

For the modelling it is considered the human body in standing with extended arms through which is getting the oscillatory movement , in the case of using a hammer drill producing vibrations. The human hand-arm sistem is composed respecting the anatomical structure of the elements of the actual body. Will be considered only the translation allong Oz, from taht reason we dont have any rotations and the modell has only 7 **d**egrees **o**f **f**reedom For simplifying the notations wass named 7MABT.

The figure1 presents the simplified model of the hand-arm ensemble of the human body. For hand, forearm, arm and body is considered an element of mass a spring and a dumper so the model is formed from seven masses, eight springs (k_1,...,k_8), and eight dumpers (c_1,...,c_8), the antrophomorphic data are presented in the table 1 and the coefficients used further in table 2.

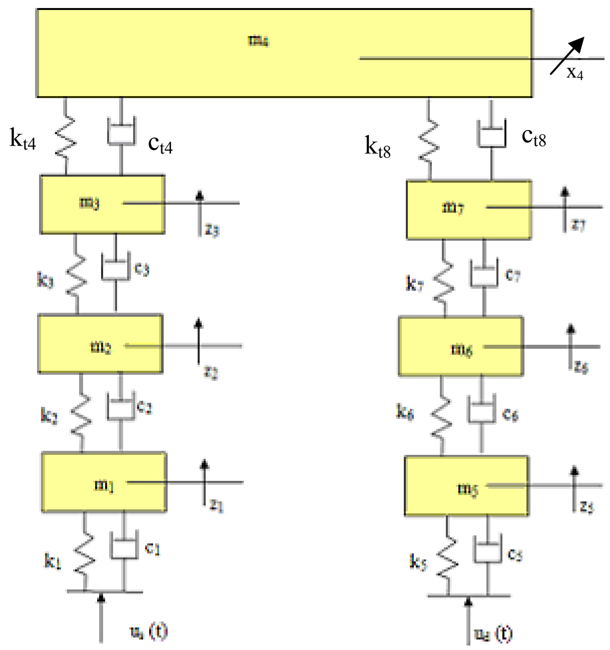

Fig 1 Model with 7 d.o.f of extended arms (particular case for using a hammer drill)

Tabel 1

Antrophomorphic data of human hand-arm system

Characteristic	**Symbol**	**Value**	**Unit measure**
Hand mass	m_1, m_5	0,552	Kg
Forearm mass	m_2, m_6	1,615	kg
Arm mass	m_3, m_7	2,801	Kg
Body mass	m_4	38,461	kg

Was consideranted a subject with a reference total body mass of 85 kg

Taking into account the fact that mass distribution for the hand-arm system is: *0,65%* for hand, *1,9%* for forearm, *3,3%* for arm and *45,5%* for body [3], the antrophomorphic data will be presented in table 1.

Tabel 2

The characteristics of the coefficients for the considered model [2]

Characteristics		**Value**	**Measuring unit**
Symbol	**Name**		
k_1, k_5	Elasticity constant of the palm	155,8x10^3	[N/m]
k_2, k_6	Elasticity constant of the hand	23,6x10^3	[N/m]
k_3, k_7	Elasticity constant of the forearm	444,6x10^3	[N/m]
k_{t4}, k_{t8}	Elasticity constant of the arm	50,25x10^3	[N/m]
c_1, c_5	Dumping coefficient of the palm	30	[Ns/m]
c_2, c_6	Dumping coefficient of the hand	202,8	[Ns/m]
c_3, c_7	Dumping coefficient of the forearm	500	[Ns/m]
c_{t4}, c_{t8}	Dumping coefficient of the arm	50	[Ns/m]

Will be applied simetry for both hands.

This data will be used for elaboration of the mechanical modell and mathematical model (relation 1) of human hand-arm system.

To obtain the mathematical model for the mechanical model from figure 1 will be written the dynamic equilibrium equations for each of the 7 masses.The system of differential equations for the model is deduced by applying Mass Center Theorem for each subsystem.

In this situation the system of equations is:

$$\begin{cases} m_1\ddot{z}_1 = -c_1(\dot{z}_1-\dot{u})-k_1(z_1-u)+c_2(\dot{z}_2-\dot{z}_1)+k_2(z_2-z_1) \\ m_2\ddot{z}_2 = -c_2(\dot{z}_2-\dot{z}_1)-k_2(z_2-z_1)+c_3(\dot{z}_3-\dot{z}_2)+k_3(z_3-z_2) \\ m_3\ddot{z}_3 = -c_3(\dot{z}_3-\dot{z}_2)-k_3(z_3-z_2)+c_4(\dot{x}_4-\dot{z}_3)+k_4(x_4-z_3) \\ m_5\ddot{z}_5 = -c_5(\dot{z}_5-\dot{u})-k_5(z_5-u)+c_6(\dot{z}_6-\dot{z}_5)+k_6(z_6-z_5) \\ m_6\ddot{z}_6 = -c_6(\dot{z}_6-\dot{z}_5)-k_6(z_6-z_5)+c_7(\dot{z}_7-\dot{z}_6)+k_7(z_7-z_6) \\ m_7\ddot{z}_7 = -c_7(\dot{z}_7-\dot{z}_6)-k_7(z_7-z_6)+c_8(\dot{x}_4-\dot{z}_7)+k_8(x_4-z_7) \\ m_4\ddot{x}_4 = -c_{t4}(\dot{x}_4-\dot{z}_3)-k_{t4}(x_4-z_3)-c_{t8}(\dot{x}_4-\dot{z}_7)-k_{t8}(x_4-z_7) \end{cases} \quad (1)$$

4. MathLAB Simulink DETERMINATION OF DISPLACEMENTS

Using 4th and half order Runge-Kutta method from Simulink (ODE45 function) we determine the displacements obtained in every part of the human hand-arm system.

Equations from previous section were precessed and then transposed in MathLab Simulink software using particular blocks related to each mathematical operations.

5. RESULTS

The displacement variation for the coordinates z_1 and z_5, respectively z_2 and z_7 and respectively z_3 and z_7 are identicaldue to the simetry of the model considered.

Comparing the displacement variations for the hand-tool, hand, forearm and arm we can observe that the displacement obtained in the body, due to the coefficients of tissues, need a time to stabilize. This is due to the action and reaction from the subsystems of the model.

The displacement transmitted from the source of vibration is a sine-wave with 26 nm amplitude and a frequency of 50 Hz.

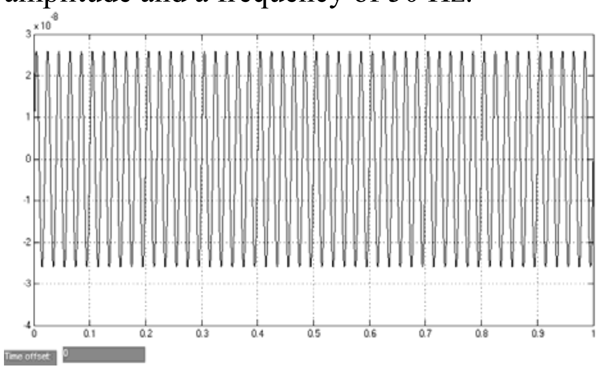

Fig 2 Displacement of the vibration from source

The magnitude of the diplacement vibration in the next segment of the model increases until a maximum of 29 nm, then it will be stable around that value.

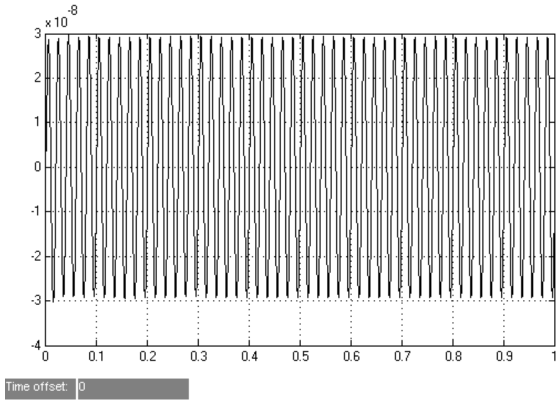

Fig 3 Displacement obtained in the hand

In the next subsistem of the model, considered the forearm of human body, we can observe an decrease in the diplacement magnitude of vibration till 7,5 nm and can be observed that the signal needs a time for stabilization.

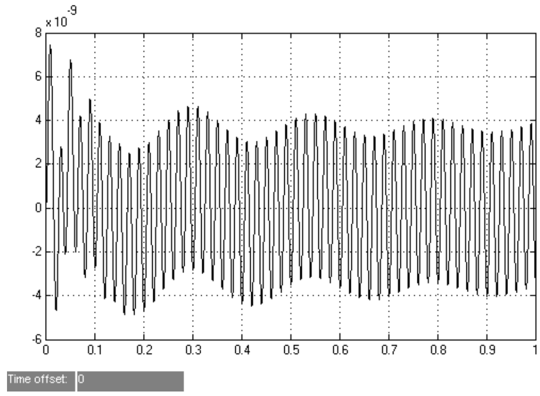

Fig 4 Displacement obtained in the forearm

Analysing the data from the next graphical reprezentation we obtain that the magnitude of the diplacement vibration increases until a maximum of 9,5 nm.

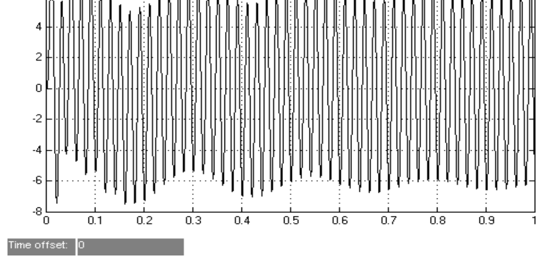

Fig 5 Displacement obtained in the arm

In the next segment of the model the displacement is decreasing till the value of 2,5 nm due to the tissue characteristics of the human body.

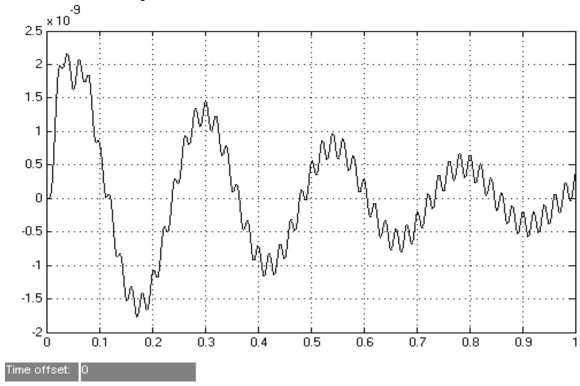

Fig 6 Displacement obtained in the body

5. CONCLUSION

The displacement of the vibration increases in the hand due to the fact that the frecquency used for simulation is close to the resonanace frecquency of the hand then tends to increase along the model components till at the trunk were it drops due to the dumping capacity of the body.

For all graphical representations we can remark that the obtained displacement value of the vibration needs a time for stabilization. This amount of time tends to be higher along the model components.

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Modelarea sistemului uman mână-braţ sub acţiunea vibraţiilor mecanice

Rezumat: Mașinile în exploatare pot expune operatorii la vibrații mecanice transmise prin mână, acestea pot afecta confortul, eficiența în lucru și, în unele cazuri, sănătatea și securitatea umană. Un nou model pentru organismul numan sau pentru o componentă a acestuia se va propune în funcție de datele care se presupun cunoscute și funcție de obiectivul care trebuie atins. Acest model poate fi ulterior utilizat pentru studii referitoare la acțiunea vibrațiilor asupra organismului uman în condiții specifice.

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