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CONTRIBUTIONS TO THE STUDY OF LOWER LIMB BIOMECHANICS OF A HUMAN SUBJECT UNDO TO VIBRATION. PART I: MECHANICAL SYSTEM

Mariana ARGHIR, Raul Ştefan FODOR, Alin-Cosmin TOT

Abstract: *In the paper makes a study on the behavior of complex biomechanical limb under the action of vibration. The request is applied through the sole of the foot and it propagates along the leg requested through thank and the femur. The second leg is placed on a surface considered fixed, therefore the linkage of given leg and the second leg, it may be considered a cylindrical joint in plane. Mechanical System (part I) is analyzed through integration into Matlab Simulink, and it has the system of differential equations (part II), which characterizes the dynamics of it. The integrated results obtained are comparable to those existing in the literature (part III).*

Key words: *biomechanics study, lower limb, human subject, vibrations.*

1. GENERAL CONSIDERATIONS

The human body is a mechanical system in the gravitational field of the Earth, that is under the mechanical law, but which presents certain particularities, due to its biostructure.

In general, the human body is made up of one or more mechanical systems with characteristics of mass damper and spring.

In this paper, is studying the action of mechanical vibrations of the lower limb of a human subject, which is considered as consists of five distinct elements: foot, leg – which shows two components: muscle and bone, adding knee and femur.

2. BIOMECHANICAL MODEL OF THE LOWER LEG SUBJECTED TO VIBRATIONS

A human operator, who is in a special expertise with vibration using a vibrating platform, originally as shown in Figure 1, who supports the other foot on the ground.

Therefore it can be concluded that the request lower leg has the vibration transmitted up through the inferior member, which in this way can be considered a fixed cylindrical joint.

Mechanical model is shown in Figure 1, and it prezints the mechanical system. It will be called 5LBGGF, specially made a system with five degrees of freedom which is composed of foot, shank, knee and femur. The meaning of notation is found in Romanian names, as they write: LaBa piciorului, Gambă, Genunchi şi Femur (5LBGGF).

Notations significance in Figure 1 are the:

z – vertical vibratory platform movement, which represents the human operator's leg excitation applied;
h – vibrating platform height;
c_1 – the damping constant of the foot, about the vibrating platform;
k_1 – the elasticity constant of the foot, about the vibrating platform;
m_1 – foot mass;
z_1 – vertical displacement of the foot;
c_2 – the damping constant of the calf (shank) bone relative to the foot;
k_2 – the elasticity constant of the calf (shank) bone relative to the foot;
m_2 – mass of calf (shank) bone (tibia and fibula);
z_2 – vertical displacement of calf (shank) bone;
c_3 – the damping constant of the muscle of the calf (shank) related to the foot;

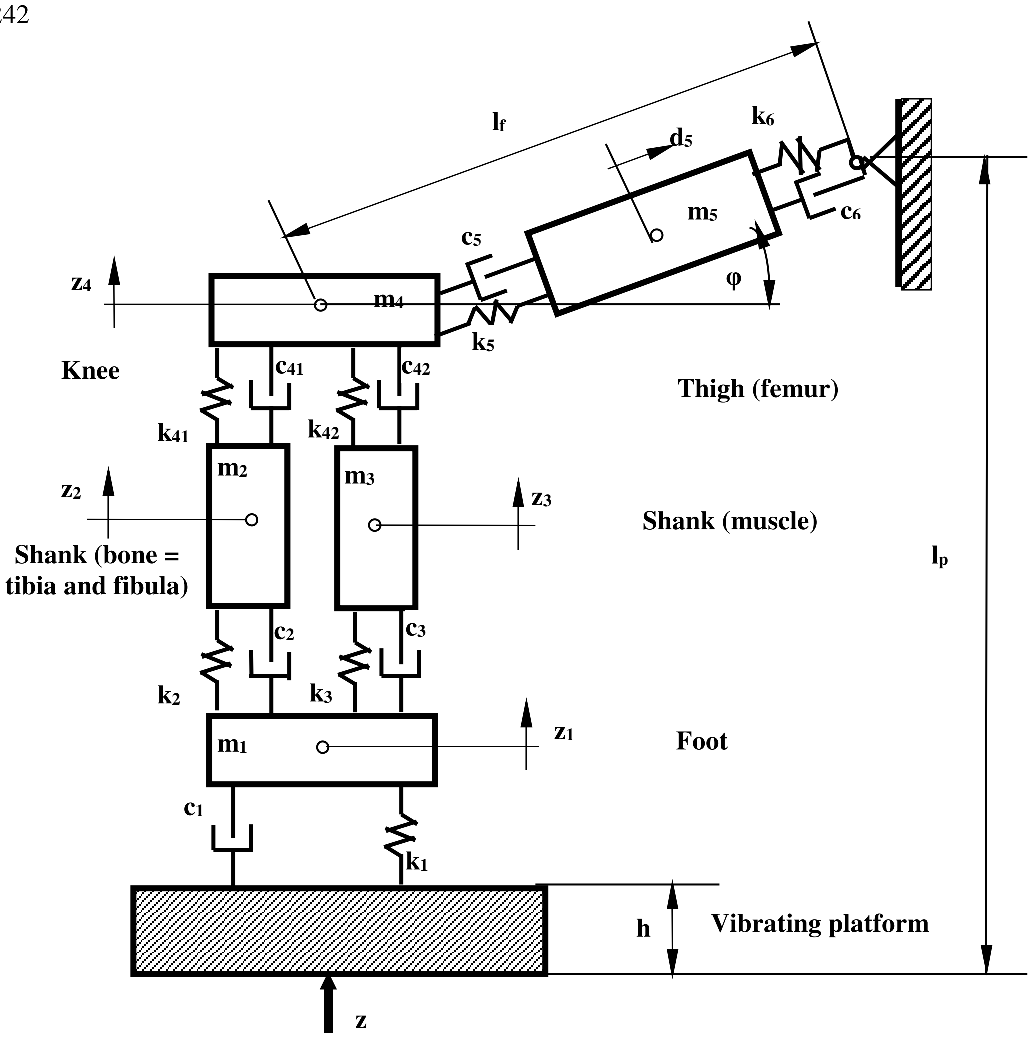

Fig. 1. Mechanical model of the 5LBGGF system, corresponding the human leg operator

k_3 – the elasticity constant of the muscle of the calf (shank) related to the foot;

m_3 – mass of the muscle of the calf (shank);

z_3 –vertical displacement of the muscle of the calf (shank);

c_{41} – the damping constant of the bone of the shank, reported to the knees;

k_{41} – the elasticity constant of the bone of the shank, reported to the knees;

c_{42} – the damping constant of the muscle of the shank, reported to the knees;

k_{42} – the elasticity constant of the muscle of the shank, reported to the knees;

m_4 – the mass of the knee;

z_4 – vertical displacement of the knee;

c_5 – longitudinal damping constant of the femur (bone + muscle), about the knee;

k_5 – longitudinal elasticity constant of the femur (bone + muscle), about the knee;

c_6 – longitudinal damping constant of the femur (bone + muscle), about the cylindrical henge in plane (considered fixed) of basin;

k_6 – longitudinal elasticity constant of the femur (bone + muscle), about the cylindrical henge in plane (considered fixed) of basin;

m_5 – the mass of the femur;

d_5 – longitudinal displacement of the femur (bone + muscle), slanted approach towards the horizontal direction;

φ – inclination angle of the femur to the horizontal direction;

l_p – leg length supported on the soil, considered until at the linkage (hip) with the second leg;

l_f – the length of the femur between the knee joint and hip.

3. CHARACTERISTICS OF MECHANICAL SYSTEM 5LBGGF

Mechanical system shown in Figure 1, constitutes a mechanical leg model of an human operator, subject to vertical vibration action, on a vibrating platforme, special expertise is a foot located on platform, the second leg is located on the ground, and upon him not actes the vibration of the platform [Tru 10].

Because, the foot located throughout the ground supports the body and the leg weight of the operator. The mass of the body and the foot sublected on the ground is greater than the mass of the leg subjected to vibration on the platform, therefore, can be considered that the hip (asimilated with a flat cylindrical joints) is fixed in space.

This simplifying hypothesis assumption applied material system assimilated to the limb of the operator, will be justified by determining from which joint movement will be negligible for lesser and it will be able to consider that going into the oproximation of the joint area.

For mechanic system the characteristic sizes are centralized in table 1, and their values were taken from literature [Abb 10], [Abd 08] and adapted to the requirements of the mechanical system, for an 80 kg [Fod 15b].

Table 1.

The characteristic sizes for mechanic system assimilated to the limb of human opperator

Crt. No.	Denomination	Symbol	U.M.	Value
1.	The mass of the foot	m_1	kg	1,13
2.	The bones mass of the shank	m_2	kg	2,1
3.	The muscle mass of the shank	m_3	kg	1,72
4.	The mass of the knee	m_4	kg	0,48
5.	The mass of the femur (bone and muscle)	m_5	kg	8
6.	Elasticity constant of foot	k_1	N/m	25.500
7.	Elasticity constant of shank bones , in relation to the foot	k_2	N/m	95.800
8.	Elasticity constant of shank muscle, in relation to the foot	k_3	N/m	5.000
9.	Elasticity constant of shank bones, in relation to the knee	k_{41}	N/m	65.000
10.	Elasticity constant of shank muscle, in relation to the knee	k_{42}	N/m	3.000
11.	Elasticity constant of femur in relation to the knee	k_5	N/m	18.941
12.	Elasticity constant of femur in relation to the basin	k_6	N/m	17.000
13.	The damping constant of the foot	c_1	Ns/m	1.716
14.	The damping constant of shank bones , in relation to the foot	c_2	Ns/m	369,1
15.	The damping constant of shank muscle, in relation to the foot	c_3	Ns/m	400
16.	The damping constant of shank bones, in relation to the knee	c_{41}	Ns/m	710
17.	The damping constant of shank muscle, in relation to the knee	c_{42}	Ns/m	500
18	The damping constant of femur in relation to the knee	c_5	Ns/m	1.000
19.	The damping constant of femur in relation to the basin	c_6	Ns/m	850
20.	Platform height	h	m	0,15
21.	The length of the foot on the ground	l_p	m	0,99
22.	The length of the femur	l_f	m	0,45

4. CONCLUSIONS CONCERNING THE MODEL 5LBGGF

Mechanical model of 5LBGGF is the simplified biomechanical model of a foot human operator, who is supported on a vibrating platform, and it is subjected to vertical vibrations of this deep.

The operator has one foot on the platform, the second is located on the ground and that is the reason that about it not acts the disruptive forces.

The connection between the requested vibration leg, and rest body leg on the ground – which supports the entire weight of the body – it makes with a cilindrical henge in plane.

It applies of the biomechanical system, be assimilated to a foot, a vibrating force, which delves through the sole of the foot, and it is propageted throughout the leg, until the cilindrical joint of the hip.

The system is considered to be made up of five distinct elements, as concentrated masses, positioned in the centre of the masses of each constituent parts. Connections between consentrate masses is achieved by elastic or/and damping elements with features primarily and mainly depreciation.

5. BIBLIOGRAPHY

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Contribuţii la studiul biomecanicii membrului inferior al unui subiect uman supus la vibraţii. Partea I-a: Sistemul mecanic

Rezumat: *In lucrare se face un studiu complex, biomecanic asupra comportarii membrului inferior sub actiunea vibratiilor. Solicitarea se aplica prin talpa labei piciorului si se propagă de-a lungul piciorului solicitat prin gambă şi femur. Cel de al doilea picior se considera asezat pe o suprafata fixa, de aceea legătura dintre piciorul solicitat şi cel de al doilea picior, se poate considera o articulaţie cilindrică plană. Sistemul mecanic (Partea I-a) este analizat prin integrarea in MatLab Simulinc a sistemului de ecuatii diferentiale (Partea II-a), ce caracterizeaza dinamica acestuia. Rezultatele obtinute sunt comparabile cu cele existente in literatura de specialitate (Partea III-a).*

Mariana ARGHIR, Prof. Dr. Eng., Department of Engineering Mechanical Systems, UTCN, E-mail: Mariana.Arghir@mep.utcluj.ro, Office Phone 0264.401.657.

Raul Ştefan FODOR, PhD Student, Department of Engineering Mechanical Systems, UTCN, e-mail: raulfodor@yahoo.com, Office Phone 0264.401.759.

Alin-Cosmin TOT, Dr. Eng., Department of Engineering Mechanical Systems, UTCN, E-mail: tot.alin.cosmin@gmail.com, Office Phone 0264.401.759.