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ERGONOMICAL ASPECTS REGARDING MECHANICAL VIBRATION DAMAGES TO THE LUMBAR SPINE

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Abstract: *This paper considers how the lumbar spine can be damaged while driving as a result of mechanical vibrations. The study is done by constructing a dynamic model of the lumbar spine and developing a simulation program by using the Mathlab software, to simulate the the vibrations that occur while driving.*
Key words: *lumbar spine, vibration, dynamic model*

1. INTRODUCTION

Most people are probably aware that driving is detrimental to the general health of the spine, and many authorities believe it is an aetiological factor in many conditions. The most obvious reasons are the loss of the lumbar curve during prolonged driving and the vibration and jolting to which the spine is subjected.

Mechanisms of violent trauma are dealt with only briefly because they are not of widespread interest, and there is a little scientific work to support the classifications of injury that are currently accepted. On the other hand, a great deal of effort has been spent on trying to understand the origins of limited structural failure in spinal tissues, because such failure is extremely common, and may be both preventable and treatable. Mechanisms of sacroiliac joint damage are not discussed because of lack of relevant experimental data.

Not everyone with back pain has a damaged back, and many patients have no detectable spinal pathology of any kind. Evidence is mounting that mechanical back pain can arise directly from high (but non-damaging) stress concentrations within innervated tissues.

Fatigue damage can accumulate rapidly if the spine is exposed to mechanical vibrations, for example by sitting on a tractor seat. Vibrations frequencies close to the natural resonant frequencies of the seated human spine (4-5Hz) cause the largest vertical accelerations and the largest inter vertebral movements. Considerable muscle tension is then required to hold the upper body steady.

In erect standing, the resonant frequency can rise to 5.5-7Hz, depending on posture, but a distinct resonance is lost when the knees are flexed. Increased muscle tension associated with vibrations would increase disc creep, and cause back muscle fatigue, both of which could lead indirectly to back pain.

2. DYNAMIC MODEL OF THE LUMBAR SPINE

The dynamic model of the lumbar spine is considered as in fig. 1. The upper body, formed by the head, arms and the chest, is considered to be combined into a single rigid body. Each lumbar vertebra is considered to be a rigid body with the mass L_j (j=1,2..5). As for the pelvis and legs, is also considered to be a single rigid body sat on the car seat.

For deformations smaller than those that cause inter vertebral disc ruptures, the experience shows that the backbone rigidity and amortization can be represented by linear springs and linear amortizations, denoted with k_{ub} and c_{ub} for the thoracic section, with k_j and c_j (j=1,2..5) for the lumbar sections, and with k_p and y_p for the pelvic section.

For the dynamic model of the lumbar spine, initially were determined the differential equations of motion of the seven masses, assuming that the support platform has a imposed harmonic vibration: $y_f = y_{0f} \cdot \sin \omega t$. If y_i (i = 1, 2…7), the system of differential equations of motion written in matrix form becomes:

$$[A]\cdot\{\ddot{y}\}+[C]\cdot\{\dot{y}\}+[K]\cdot\{y\}=\{F\} \tag{1}$$

Where :
[A] – inertia matrix;
[C] – amortization matrix;
[K] – stiffness matrix;
{y} – displacements vector;
{F} – disruptive force vector.

By immediate algebraic transformation, the equations system (1) transform in input-status-output equations:

$$\begin{aligned} \dot{\underline{x}} &= \underline{A}\cdot\underline{x}+b_u\cdot\underline{u} \\ \underline{y} &= \underline{C}\cdot\underline{x} \end{aligned} \tag{2}$$

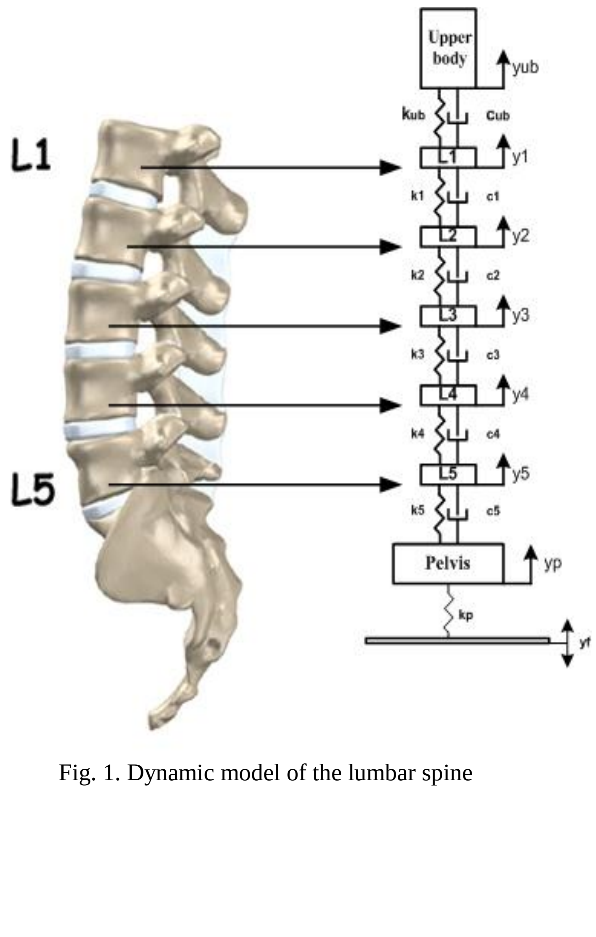

Fig. 1. Dynamic model of the lumbar spine

3. RESULTS

To analyze the mechanical model of the seated human body, it was developed a simulation program by using the Mathlab software.

The mechanical model construction for the seated human body dynamic study, require indication of the elastic characteristics and body mass. Therefore in this study we preset the main parameters of the body from some known data, standards and experiments on mass distribution and resonance frequencies.

Initial data were taken from literature. It was considered a standard model weighting 80 kg and mass distribution that can be specified based on previous research. In addition, under the simplifying assumptions accepted, the equalities K4 and K5 = K6 = K7, are presumed valid.

After running the simulation program these graphs were obtained for each mass:

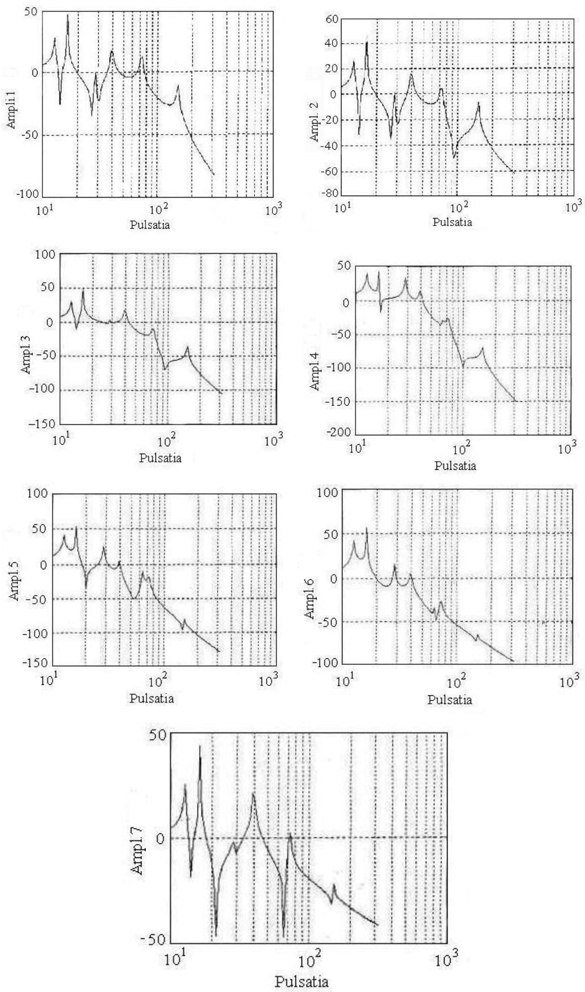

Fig. 2. Pulse-amplitude characteristics of the masses.

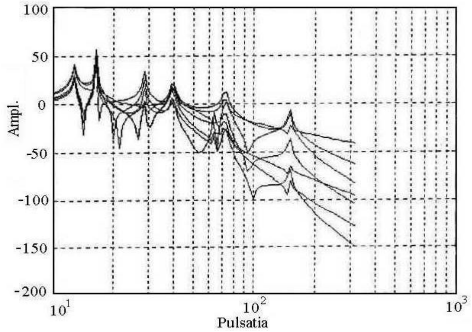

Fig. 3. Pulse-amplitude characteristics overlapped.

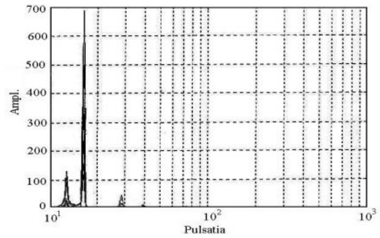

Fig. 4. Pulse-amplitude characteristics presented linearly

4. CONCLUSION

Seats can be designed to attenuate vibration. Most seats exhibit a resonance at low frequencies, which results in higher magnitudes of vertical vibration occurring on the seat than on the floor! At high frequencies there is usually attenuation of vibration. In use, the resonance frequencies of common seats are in the region of 4 Hz. The amplification at resonance is partially determined by the damping in the seat. An increase in the damping of the seat cushioning tends to reduce the amplification at resonance but increase the transmissibility at high frequencies. There are large variations in transmissibility between seats, and these result in significant differences in the vibration experienced by people.

A simple numerical indication of the isolation efficiency of a seat for a specific application is provided by the seat effective amplitude transmissibility (SEAT). A SEAT value greater than 100% indicates that, overall, the vibration on the seat is worse than the vibration on the floor. Values below 100% indicate that the seat has provided some useful attenuation. Seats should be designed to have the lowest SEAT value compatible with other constraints.

A separate suspension mechanism is provided beneath the seat pan in suspension seats. These seats, used in some off-road vehicles, trucks and coaches, have low resonance frequencies (around 2 Hz) and so can attenuate vibration at frequencies above about 3 Hz. The transmissibility of these seats are usually determined by the seat manufacturer, but their isolation efficiencies vary with operating conditions.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Brîndeu L., Silaș Gh., Toader M., Popa C., Ștefan C. *(2000). Methods for identifying the mechanical characteristics of human body seated in the car,* Analele Univ. Oradea, Fasc. Mec. Secț. Mec. Vibr. Rez. Mat, vol. II.

Brîndeu L., Popa C., Ștefan C., Hegedus A. *(2000). Identification of Human Body Model, Sitting on a Vehicle Chair*, 3th. Mini. Conf. on VSDIA, Budapest, Nov. 6-8.

Brîndeu L., Popa C., Szeidert I. *(2000). A mathematical model of the human body in the case of standing position, Simp. Şt. Internaţional* "Universitaria ROPET 2000", secţ. Ing. Mec., Petroşani

Muksian R., Nash C.D.Jr. *(*1976). *On frequency dependent damping coefficients in lumped – parameter models of human body beings, J. Biomechanics, vol.9, pp 339-342,* Pergamon Press

Muksian R., Nash C.D.Jr. *(*1974). *A model for the response of seated humans to sinusoidal displacements of the seat,* J. Biomechanics, vol.7, pp 209-215, Pergamon Press