



## RESEARCH ON THE TRANSMISSION OF MECHANICAL VIBRATIONS THROUGH THE HUMAN

Aurica TRUȚA, Simona Camelia ȘARAMET, Mariana ARGHIR

**Abstract:** *Man is, mechanically speaking, a complex machine or a perfect robot. Located in a vibrational environment, it will take an amount of vibrational wave which it transmits its entire structure. The human body can behave both as a vibration damper or as an amplifier. In different environmental conditions it reacts in different ways.*

*Measurements on the human body, subjected to mechanical vibrations transmitted from a forge, have demonstrated their considerable transmission along the human body.*

**Key words:** : *mechanical vibrations, human operator, force, transmissibility*

### 1. INTRODUCTION

EU's current emphases reflect a continuing challenge to protect humans and the environment. In this context, it raises a question often raised in the past 20 years, but still have few tangible results. How the human body reacts under the action of mechanical vibrations? After prolonged exposure it deteriorates, and the result declared or not, is present in the body in the form of malfunctions more or less severe.

### 2. CADRUL LEGISLATIV

According to estimates made in some European countries, 4% to 7% of employees are exposed to potentially harmful whole body vibration [6].

European Union legislation and the legislation in Romania, provides daily occupational exposure limit value, calculated at a reference period of 8 hours must be about  $1,15 \text{ m/s}^2$  or have a vibration dose value about  $21 \text{ m/s}^2$ , and the amount of daily exposure action values, calculated on a reference period of 8 hours must be about  $0,5 \text{ m/s}^2$  or have a vibration dose value about  $9,1 \text{ m/s}^2$  [5].

### 3. VIBRATIONAL ENVIRONMENT FOR HUMAN OPERATOR

Man is, mechanically speaking, a complex machine or a perfect robot. Located in a vibrational environment, it will take an amount of vibrational wave which it transmits its entire structure. The human body can behave both as a vibration damper or as an amplifier. In different environmental conditions it reacts in different ways.

Locomotor apparatus is the most requested in such situations. Vertebral spine, called rachis, slightly curved, is the central structural element that supports the upper body and shelters the largest bus nerve, so that frequently the disorders and spinal deformities have neurological consequences.

Measurements on the human body subjected to mechanical vibrations transmitted in forging activity, have demonstrated their considerable transmission along the human body.

### 4. EXPERIMENTAL METHOD

Human operator position for the forging operation is standing and little bended forward.

Accelerometer for measuring vibrations was installed under the feet of the operator to sense its vibration. In the next phase the three-

dimensional accelerometer was attached to the human operator ankle (Fig. 1), followed by attachment to other important points on the body.



Fig. 1. The accelerometer position

Current operation of a hot deformation of one aluminum piece required a period of eight minutes for processing. A cylindrical piece with a diameter of 260 mm and height of 800 mm was manufactured and the result was a prism with base side of 180 mm and identical to the original height.

Number of shocks transmitted from the processing of a piece forging was 190 during the eight minutes. It processes about eight such pieces in 8 hours. It follows that the average number of shocks transmitted is 6080 per working day.

Performing calculations for five working days we get 30 400 of shocks, and for 22 days per month we get 668 800 shocks transmitted to the human operator only in a period of one calendar month.

Given the number of shots in a period of 8 minutes, the period can be calculated: 2.53 s. Frequency is 1/T so  $F = 1/2.53 = 0.395$  Hz.

According to SR ISO 2631-3 [6], severely limit discomfort, for a frequency about 0,40 Hz and an exposure time about 2 h, is 0,75  $m/s^2$ . For an 8 hour exposure, limit value of acceleration is 0,375  $m/s^2$ .

The maximum recorded value is 0,327  $m/s^2$  (Fig. 2), very near by the limit of serious discomfort.

The vibration intensity felt by the operator seems like that one from a car passing with 60 km/h speed, through a hole at a depth about 10 cm and a diameter larger than the diameter of the wheel car. Given the intensity of shock vibration we can imagine what impact have the 668 800 shocks during of a calendar month.

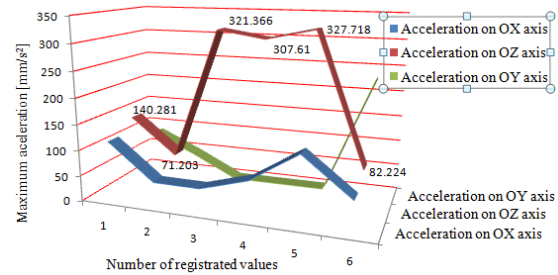


Fig. 2. The maximum acceleration recorded

For the processing pieces of cylindrical shape with a diameter of 250 mm and height 8 cm (Fig.3), having a hole in the middle with a diameter of 150 mm, the force used was lower and thus had a lower amplitude.



Fig. 3. Second form of pieces

In general there was a decrease of vibrations amplitude measured on the forehead (Fig. 4) than those measured on ankle (Fig.5). This decrease may be due to the fact that the measurements were not made simultaneously but were made successively (Table 1).

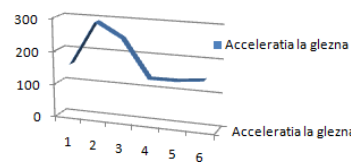


Fig. 4. Measured acceleration for ankle

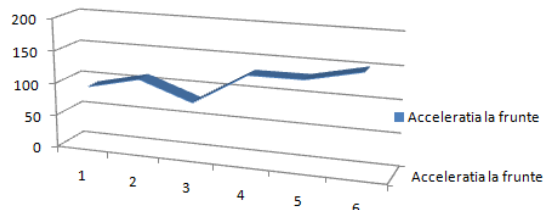


Fig. 5. Measured acceleration for forehead

Table 1

Measured value for ankle and forehead

158.489 291.743 248.028 135.207 136.301 145.211  
 92.151 110.917 82.509 131.522 132.282 150.487

**5. EQUATIONS**

To simplify the model, the human operator was considered in upright position. Transmission of vibrations to the operator's body is made from the support legs in one direction: vertical (Fig. 6).

Construction of mathematical model take into account about the seven masses considered in the simplified mechanical model. Appropriate damping and elasticity coefficients were adapted from literature [2],[1].

$$\begin{cases} m_1 \ddot{z}_1 + c_1(\dot{z}_1 - \dot{u}) + k_1(z_1 - u) - c_2(\dot{z}_2 - \dot{z}_1) - k_2(z_2 - z_1) = 0 \\ m_2 \ddot{z}_2 + c_2(\dot{z}_2 - \dot{z}_1) + k_2(z_2 - z_1) - c_3(\dot{z}_3 - \dot{z}_2) - k_3(z_3 - z_2) = 0 \\ m_6 \ddot{z}_6 + c_6(\dot{z}_6 - \dot{u}) + k_6(z_6 - u) - c_7(\dot{z}_7 - \dot{z}_6) - k_7(z_7 - z_6) = 0 \\ m_7 \ddot{z}_7 + c_7(\dot{z}_7 - \dot{z}_6) + k_7(z_7 - z_6) - c_8(\dot{z}_3 - \dot{z}_7) - k_8(z_3 - z_7) = 0 \\ m_3 \ddot{z}_3 + c_3(\dot{z}_3 - \dot{z}_2) + k_3(z_3 - z_2) + c_8(\dot{z}_3 - \dot{z}_7) + k_8(z_3 - z_7) \\ \quad - c_4(\dot{z}_4 - \dot{z}_3) - k_4(z_4 - z_3) = 0 \\ m_4 \ddot{z}_4 + c_4(\dot{z}_4 - \dot{z}_3) + k_4(z_4 - z_3) - c_5(\dot{z}_5 - \dot{z}_4) - k_5(z_5 - z_4) = 0 \\ m_5 \ddot{z}_5 + c_5(\dot{z}_5 - \dot{z}_4) + k_5(z_5 - z_4) = 0 \end{cases} \quad (1)$$

The system was solved by Simulink, Matlab. To solve the system in Simulink we have done some calculations.

$$\ddot{z}_1 = \frac{1}{m_1} [-(c_2 + c_1)\dot{z}_1 + c_2\dot{z}_2 + c_1\dot{u} - (k_2 + k_1)z_1 + k_2z_2 + k_1u] \quad (2)$$

The same calculations like in equation (2) were done for all seven equations.

Solving the equations results that almost all the vibrations are transmitted through the body to the head.

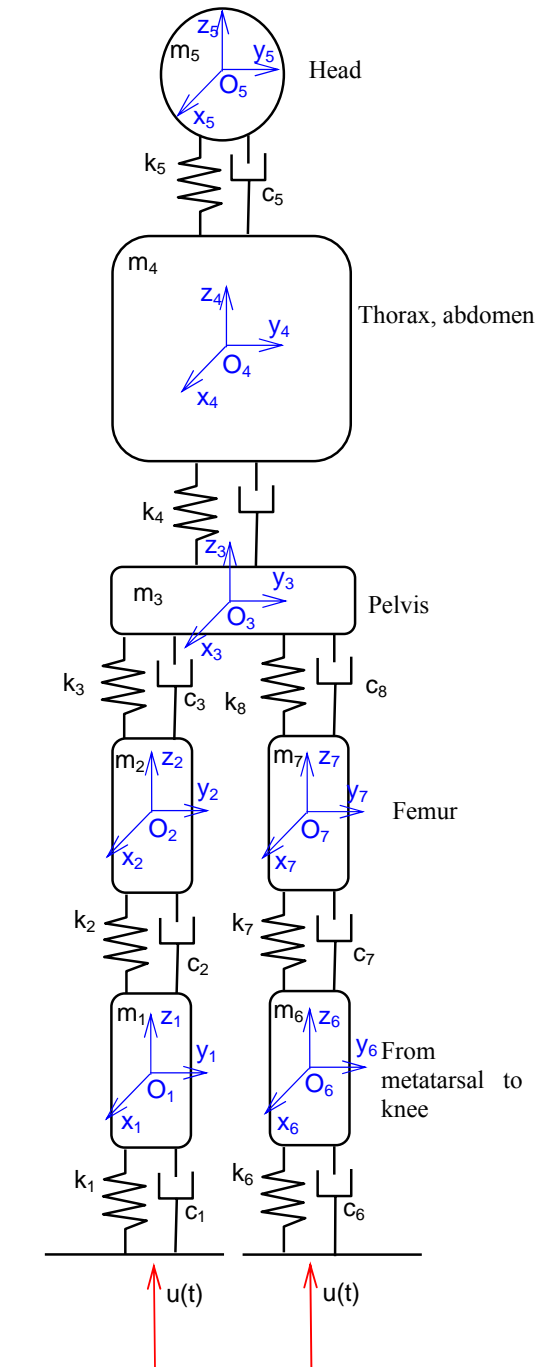
**6. CONCLUSION**

In the forging operation, the human body is exposed to severe mechanical vibrations. That vibrations are transmitted 90% to the head. Transmission of high-amplitude vibration to the head can cause diseases of skull components.

Also the large number of shocks transmitted to the operator in a period of one month is very high. The problem can be partially solved by limiting the exposure time.

**11. REFERENCES**

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**Fig. 6.** Biomechanical simplified model of the human operator in standing position

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- [5] HG 1876 *Hotărâre de Guvern nr. 1876 din 22 decembrie 2005 privind cerințele minime de securitate și sănătate referitoare la expunerea lucrătorilor la riscurile generate de vibrații.*
- [6] SR ISO 2631-3 *Evaluarea expunerii umane la vibrații globale ale corpului. Partea 3: Evaluarea expunerii la vibrații globale vertical ale corpului pe axa Z, în domeniul de frecvență de la 0,1 Hz până la 0,63 Hz.*

#### CERCETĂRI PRIVIND TRANSMITEREA VIBRAȚIILOR MECANICE PRIN ORGANISMUL UMAN

Accentele actuale ale UE reflectă preocuparea permanentă pentru protecția omului și a mediului înconjurător. În acest context se ridică o problemă des pusă în discuție în ultimii 20 de ani, dar care încă prezintă puține rezultate palpabile. Cum reacționează organismul uman supus acțiunii vibrațiilor mecanice? După o expunere prelungită acesta se deteriorează, iar rezultatul declarat sau nu, este prezent în corp sub forma unor disfuncționalități mai mult sau mai puțin grave.

Omul este, din punct de vedere mecanic, un mecanism complex sau un robot perfect. Așezat într-un mediu vibrațional, acesta va prelua o cantitate de unde vibraționale pe care le transmite întregii sale structuri. Organismul uman se poate comporta atât ca atenuator de vibrații cât și ca amplificator. În condiții diferite de mediu sau solicitare reacționează în moduri diferite.

Măsurătorile efectuate pe corpul uman supus vibrațiilor mecanice transmise de la o forță în activitate, au demonstrat transmiterea considerabilă a acestora de-a lungul organismului uman.

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**Aurica TRUȚA**, As. Cerc. Dr. Ing., Technical University of Cluj-Napoca, Department Computing and Programming, e-mail [auricatruta@yahoo.com](mailto:auricatruta@yahoo.com), [Aurica.TRUTA@mep.utcluj.ro](mailto:Aurica.TRUTA@mep.utcluj.ro), Office phone +0040 264 401667

**Simona Camelia ȘARAMET**, Drd. Ing., Technical University of Cluj-Napoca, Department Computing and Programming, e-mail [simonasaramet@yahoo.com](mailto:simonasaramet@yahoo.com), Office phone +0040 264 401759

**Mariana ARGHIR**, Prof. Dr. Ing., Technical University of Cluj-Napoca, Department Computing and Programming, e-mail [marianaarghir@yahoo.com](mailto:marianaarghir@yahoo.com), [Mariana.ARGHIR@mep.utcluj.ro](mailto:Mariana.ARGHIR@mep.utcluj.ro) Office phone +0040 264 401657