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# THE EFFECTS OF OIL QUALITY ON THE PRODUCTION PROCESS AND WORK SAFETY FOR THE HUMAN OPERATOR

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***Abstract:*** *The paper will propose a study regarding a comparison of the transmission of mechanical vibrations for the person using two identical aluminum injection machines, which are supplied with two different oils (normal oil and additive oil), both from the point of view of improving production and safety at work.*

***Key words:*** *lubricant oil, machine tool, vibration, vibration transmissibility, person.*

## 1. INTRODUCTION

### 1.1. Generality

Vibrations are caused by an excitation source; they can be influenced by external or internal factors. In general, vibrations are undesirable, especially their occurrence in equipment or machine handled by human operators. Firstly, their effects can damage the internal structure of the equipment, but even more undesirable, in prolonged operating conditions and non-compliance with certain protective rules, they are also transmitted to the human operator of the handling devices, respectively they can be transmitted through the hand or the floor. All these statements will be explained in more detail, in accordance with specialized literature [1-4].

### 1.2. Industrial vibration machine

The reliability of machine tools and equipment can be influenced by several internal or external factors such as the wear of the components, the way of use, the specifics of its activity, and last but not least, the operational environment such as the ambient temperature, the internal temperature of the equipment and its lubrication [5-7], [8]. Mechanical vibrations affect machinery either through the specifics of its operation or through the wear of components or other disruptive factors.

Mechanical vibrations usually occur in pneumatic presses, rotary hammers, eccentric motors, compressors, etc. Due to the variety of ways in which they can appear, vibrations have different effects on the behavior of machine tools and machines in operation. The present work will analyze the mechanical vibrations propagated at the level of the hydraulic pump of an injection machine [6], [8].

As a way to minimize vibrations, the placement of machines on foundations with rubber carpets is used. And yet, they are not eliminated nor can they be eliminated from the operation process, therefore, the vibrations produced by the machine during operation can have very different causes such as:

The operational process, the way the machine works, component wear or faulty assemblies, etc.

The mechanical vibrations that appear as a result of the operating process can also be reduced by standardizing the mode of operation and operation of the machine. Usually, in eccentric engines, compressors, etc. the occurrence of vibrations is given by dynamic forces that occur during operation.

Unwanted vibrations that cannot be avoided could be reduced, either by redesigning and implementing some anti-vibration measures and components or by minimizing their transmission by using appropriate high-quality hydraulic oils [3, 7-10] concerning hydraulic pumps.

What we want to emphasize in this paper is the fact that one of the factors that cause the appearance of mechanical vibrations is the lubrication of the machine, so a defective or inadequate lubrication will generate vibrations in hydraulic pumps or other machines used in the industry.

From the point of view of lubrication, the hydraulic fluids intended for machines must fulfill at least two properties:

• The hydrostatic power of transmission should be high;

• Ensuring the quality of the lubrication of the dynamic components of the machine in the hydraulic system.

There is enough research into the transmission of mechanical vibration to the human body [2-4] research that demonstrates the origin and transmission of these vibrations. However, no work has strictly dealt with the transmission of mechanical vibration to humans, transmission due to the corresponding or inadequate lubrication of the machine tool used by it.

The studies to be presented in the paper, it wants to show this fact, namely that the proper lubrication of the machine tools diminishes the presence of the vibrations to it, respectively their transmission to the human operator that serves them. For this purpose, a proper lubrication of the machine tool can create two important events followed by any manufacturer:

a. Functionality in good conditions of equipment and machinery (machine - tool), which leads to higher productivity and maintenance with low costs.

b. Reducing the risk of occupational disease of personnel serving these equipment and machines.

Therefore, the occupational diseases are diseases caused by physical, chemical, biological, existing work processes, and overloading the various organs, apparatuses and systems of the body in carrying out work tasks.

Occupational professions in which tools and vibrating tools are used are often accompanied by occupational diseases such as tremors, whitening of the fingers or even their necrosis. In general, the sensitivity threshold for their appearance is around at 20-1000 Hz [11].

Their mechanical action manifests directly in the osteoarticular system of the upper limbs. They also have direct action on the local vascular system with the occurrence of vascular hypertonia, on the background of which the local syncope is triggered by noradrenaline released at the adrenergic termination of the sympathetic. The result describe in de literature [11] is damage to nerve trunks or related terminations, neuroses with stagnant, stable excitations in the brain, generating vascular and trophic disorders of the upper limbs. The most common syndromes are Raynaud's syndrome, following direct action on the vascular wall through a state of stagnant hyperactivity in the brain or alterations of the perivascular sympathetic which respond exaggerated to the action of physical stimuli such as cold.

In conditions described previously, these lead to the research that vibration transmissibility is not good for the human body.

In the next of the chapter are necessary to explain some notions of mechanical vibrations.

### 1.3 Notions of the vibrations transmissibility

Shortly, the paper presents some notions of the vibration measurements like the transmissibility and acceleration_rms of mechanical vibration that acts over the human body and over equipment, and these are caused by the oil quality (in this case).

Where acceleration_rms(root-mean-square) (m/s2) [3-4], is a mean of accelerations measured and has the expression:

$$a_{r.m.s.} = \sqrt{\frac{1}{T}\int_0^T a^2(t)dt} \tag{1}$$

where:

T - represented the vibration motion period [s];

*t* - represented time [s];

*a(t)* - represented the time variation of the acceleration [m/s$^2$].

the masses used in the paper are the mean masses for a number of human subjects and they are defined for wrist thru fingers, the elbow and the shoulder [kg].

the input forces on the hand – arm system can be expression as:

$$F_i = m_i \cdot a_i \text{ [N]} \quad (2)$$

where: "i = 1,2,3" - is an general index that corresponding, successively for: the wrist, the elbow and shoulder.

The transmissibility of mechanical vibration through the hand – arm system can be calculated with the following relation:

$$T = \frac{F_i}{F_{ti}} \quad (3)$$

where: $T$ – is the vibration transmissibility through input element;

$F_{t\,i}$ – represented the system transmitted force.

It is interesting the measurements of acceleration in locations: wrist, elbow and shoulder of point of view transmissibility of accelerations.

### 1.4 Oils generalities

Taking into account the study, the nextly will describe shortly some notions about the oils.

The brief definition of lubricants is that they are organic or inorganic minerals that are used to reduce friction between two contact surfaces of components. Lubricants can be classified according to several criteria, but the most important criterion is their viscosity [8-10]. if we were to define viscosity, it could be said that this is a measure applied in order to reduce the internal friction of the fluid, being applied to motor oils and this fact influencing the fluidity of the oils, which in turn also depends on the temperature. Viscosity is represented standardized by an oil viscosity index. Oil standardization is given by SAE (Society of Automotive Engineers) viscosity classes and refers only to engine oils and mechanical transmission oils.

In the paper the properties of oil are not presented of the reason of produce of factory confidentiality. It is named with the general name of the *normal oil* and *additive oil*.

## 2. EXPERIMENTAL RESEARCHES

The paper presents the *accelerations_rms* that were measured using two pieces of equipment, one for machine-tool (pumps) named Comtest and one for the human body named Svan, because the filters of vibration in the two pieces of equipment is different.

### 2.1. Experimental considerations regarding vibrations about human body

Measurements are performed on a person (man over 40 years) during the injection process of aluminum around 15 – 20 minutes. Machine - tools run at 1000 RPM (rotation per minutes) (Fig. 1). The values of the mechanical vibrations transmissibility from the wrist thru the finger to the shoulder are contained in the table 1 for 1000 RPM rotation velocities of the machine-tool.

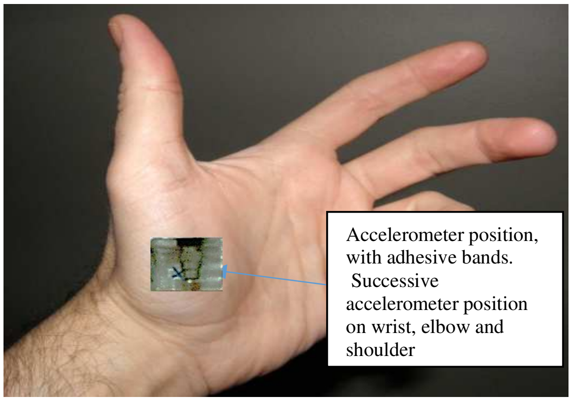



**Fig. 1** Hand position of manipulate of box molding.

A whole injection process takes about 8 seconds, so measurements were made for to three times over the injection time, at a machine velocity of 1000 RPM.

Accelerations of mechanical vibration were measured with vibration equipment from Svan using a mono-axial transducer that was fixed with the auto - adhesive band on the surface of the subject's skin, the accelerometer was fixed on the wrist, on the elbow, and finally on the shoulder and measure vibration along the system hand-arm.

The accelerometer is measuring successively (along of the hand-arm system), along three injection operations of aluminum and these are shown in the tables below. Several series of measurements were made, and the measurements presented are an average of them, see Table 1.

**Table 1**

Mechanical vibrations transmissibility over hand – arm system.

| **n [RPM]** | **1000** | | | | | |
|---|---|---|---|---|---|---|
| **T=2π/ω [s]** | **25.5** | **19.9** | **15.7** | **12.5** | **9.9** | **7.85** |
| The input force in the system F [N] | 0.5449 | 0.3727 | 0.5927 | 0.1652 | 0.3874 | 0.3322 |
| $F_{t\ (wrist)}$ [N] | 0.5895 | 2.5092 | 0.9279 | 0.6655 | 0.6403 | 0.7159 |
| $F_{t\ (elbow)}$ [N] | 1.5456 | 6.9839 | 1.8216 | 1.8952 | 1.5121 | 1.9584 |
| $F_{t\ (shoulder)}$ [N] | 2.5954 | 5.6012 | 5.8862 | 2.6296 | 2.4833 | 2.5232 |
| $T_{(finger - wrist)}$ | 0.9243 | 0.1485 | 0.6387 | 0.2482 | 0.6050 | 0.4640 |
| $T_{(finger - elbow)}$ | 0.3525 | 0.0533 | 0.3253 | 0.0871 | 0.2512 | 0.1696 |
| $T_{(finger - shoulder)}$ | 0.2099 | 0.0665 | 0.1006 | 0.0628 | 0.1560 | 0.1316 |
| $T_{(finger - wrist)}$ | 0.9243 | 0.1485 | 0.6387 | 0.2482 | 0.6050 | 0.4640 |
| $T_{(wrist - elbow)}$ | 0.3814 | 0.3592 | 1.3774 | 0.3511 | 0.4152 | 0.3655 |
| $T_{(elbow - shoulder)}$ | 0.5955 | 1.2468 | 0.3094 | 0.7207 | 0.6209 | 0.7761 |

The lower the transmissibility (T < 1) the better it is for the production process.

The measured output signals (Table 2) and the calculated quantities were viewed on the computer monitor with the help of Matlab software and in the device Svan 976 also [2-4]. All values of arms are compared with standard values give of the SR EN ISO 5349/2001 in the following chapter named Annalise of Vibration.

## 2.2 Vibration measurements on hydraulic pumps

The paper aims to carry out several lubrication tests and measurements of vibrations during testing with these oils. The tests are performed on the hydraulic machines for injecting aluminum into molds. The oils proposed for testing are the brand CHEM Trend, Italy, and a comparison will be made between them and the normal oils used to lubricate the pumps. It was desired that the vibration measurements [2-4] be performed on two similar hydraulic pumps that equip two symmetrical machines (Fig.3a and 3b) in terms of operating characteristics.

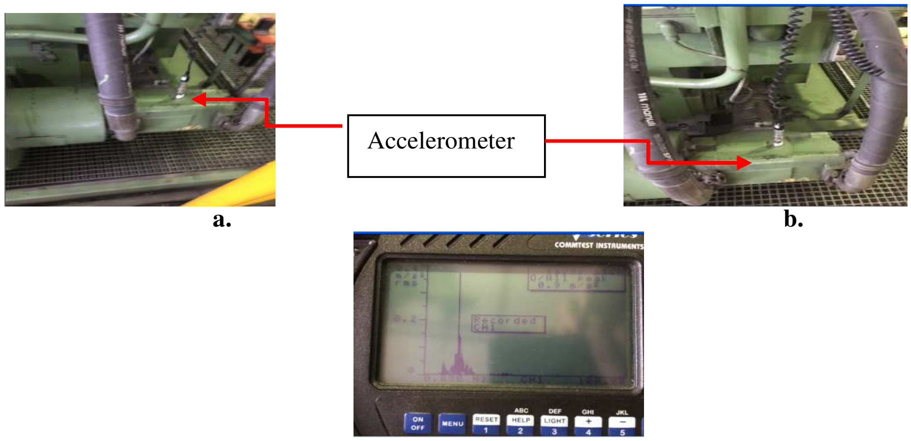
**Table 2**

Acceleration $a_{rms}$ in different locations of the hand-system: wrist, elbow and shoulder.

| **n** [RPM] | **1000** | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| **M₁** – palm **mass** [kg] | 0.45 | | | | | |
| **M₂** – hand mass [kg] | 1.15 | | | | | |
| **M₃** – arm **mass** [kg] | 1.9 | | | | | |
| $a_{rms-wrist}$ [m/s²] | 1.31 | 5.57 | 2.06 | 1.47 | 1.42 | 1.59 |
| $a_{rms-elbow}$ [m/s²] | 1.34 | 6.07 | 1.58 | 1.64 | 1.34 | 1.70 |
| $a_{rms-shoulder}$ [m/s²] | 1.36 | 2.94 | 3.0 | 1.38 | 1.30 | 1.32 |

The tests for measuring vibrations (Fig. 2) have been carried out during a day, inside the hall of the Bialetti firm, located in Romania and used the identically pumps of two machines

**Fig. 2** The injected pump machine.




c.

**Fig. 3** Position of the accelerometer on the machine an registered measurements.

The comparative analysis of the two machines (pumps) was carried out when one was working with the usual oil used in lubrication on Pump 1 (Fig. 3a) and one with additives on Pump 2. The vibration measurement of Pump 1 [2], [8] was carried out with a monoaxial accelerometer as part of the VB 3000 industrial vibration measuring device produced by COMTEST-New Zealand. It has a magnetic support that was fixed to the pump on the car (Fig. 3c).

Vibration measurements were carried out under the same operating conditions in both experiments for frequency and duration operating time, operating mode, etc. (Fig. 4-6) for both pumps.

## 3. VIBRATION ANALYSES

### 3.1 Vibration analysis of body human

The RMS accelerations were measured in the two situations presented previously and the data presented in Figures 4-6 for the two machines/pumps (1 and 2) resulted. It can be seen from the figures that there were peaks of 0.2 m/s2) for Pump 1, operating with normal lubricating fluid. Regarding Pump 2 represented by the red line, the acceleration values for it are lower and very low (< 0.05m/s2), which validates the quality and efficiency of the additive lubricating fluid produced by CHEM Trend.

In addition, the transmissibility vibration about a person presents a peak around half an interval of working, respectively about 4s from starting process.

Figure 4 shows measurements of the $a_{rms}$ acceleration on the person serving the aluminum injection machine during three consecutive process, of which the time of preparing it with new material was reduced. The element of the vibration input is the palm on which the accelerometer is fixed (wrist joint), and from this were beginning the comparative measurements in the direction of the vibration transmission, respectively the axis Oz, along of the hand-arm system (SR EN 5349/2001), respectively along the arm to the shoulder. On these, anatomically elements were fixed accelerometers and the measurements being performed successively on all anatomical locations. The comparison benchmark for $a_{rms}$ accelerations is those from the wrist, elbow until shoulder.

At the first analysis, it is noted that the highest values are obtained for the elbow and shoulder. At the other anatomical locations, a decrease in the measured accelerations is observed, and these are due to the adaptive and damping capacity to the shoulder.

However, from the second successive measurement (~ 16s), we notice that the body already shows signs of fatigue and the vibrations begin to increase. If the first measurements from the elbow and shoulder were very small, (Measurement 1 (~8s) and $a_{rms}$ = 1…2 m/s$^2$, at the measurement 2 (~20s) $a_{rms}$ = 3…6 m/s$^2$), now it's are reaching maximums four times the bigger then the norms imposed by SR EN 5349/2003 of 5 m/s$^2$).

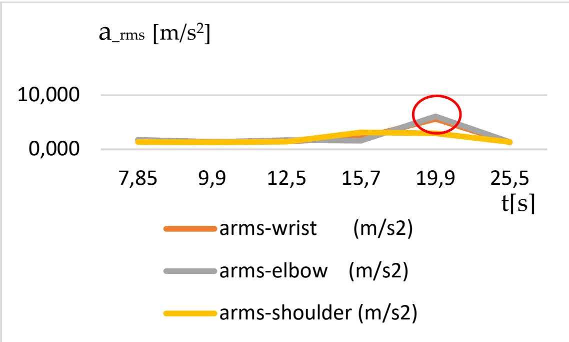



**Fig. 4** $a_{rms}$ measurements.

Figure 4 is a more explicit graphical view of the transmissibility of these mechanical vibrations from machine to human, during three injection operations, and as the reference element for the wrist, elbow, and shoulder joints. It can be seen, as explained in figure 5, that because of the damping of the muscles and the skin, these vibrations to the shoulder are attenuated, but they show a maximum of 0.6 on

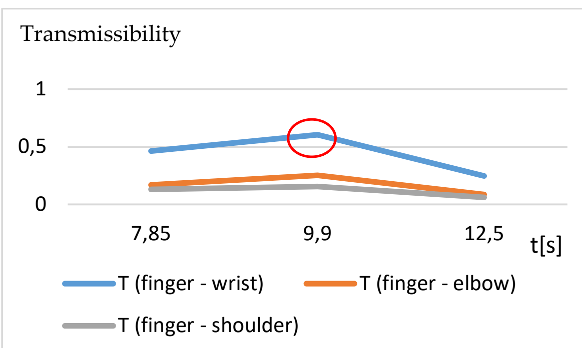



**Fig. 5.** Transmissibility vibration measurements as a point of input is the finger and output wrist, elbow and shoulder.


**Fig. 6**. Transmissibility mechanical vibration as a point of input are two consecutive anatomical element (finger-wrist, wrist-elbow, elbow-shoulder).

the wrist, 0.25 by the elbow and 0.15 by the shoulder, of the starting injection process then decreases significantly and then rises proportionally to the decrease.

This fact cannot be confirmed by figure 6, where the calculation of the transmissibility to the hand-arm system was made from the landmark in succession, respectively from the finger to the wrist and then to the elbow and shoulder. Here is a strange situation that has been verified in several stages, and these results have validated, respectively the highest final vibrations, are felt in the arm to the shoulder, followed by those measurements on the wrist and the less it is felt in the forearm, including the elbow joint. Hence, some conclusions can be drawn, the most common syndrome of mechanical vibration regarding the palm and fingers (is Raynaud's syndrome) and those in the shoulder joint, less the elbow [6].

### 3.2 Vibration analises regarding the machine – tools

The comparison between the RMS acceleration values obtained at the two pumps [4-6], data obtained in time and frequency (Fig. 7-9) are presented in Figure 9 (as a function of frequency) and in Figures 7-8 (as a function of time ), it is observed that the maximum values are (0.2 m/s2) for pump 1, operating with NORMAL lubricating fluid. Compared to Pump 2, the values represented by the red line, and the acceleration values are small (< 0.05m/s2), which demonstrates the efficiency of the additive fluid.

The peaks obtained in Figures 7 and 8 are during the two stages of the injection process which last 8 ms.

It is evident that with Pump 1, which uses normal oil, the acceleration values have large peaks (blue line) in contrast to the other curve where Pump 2 uses additive oil (red line).

## 4. CONCLUSIONS

The conclusions drawn from the paper would be that when using additive lubricants, the quality of production increases, and the vibrations occurring in the production process decrease.

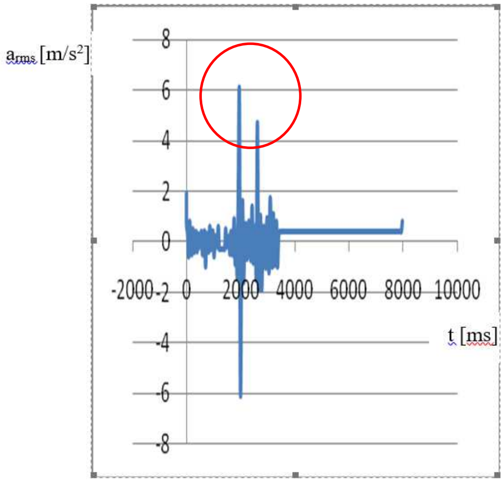



**Fig. 7** $a_{rms}$ acceleration for PUMP 1 exprimed in time (8 ms during injection pieces on the machine with normal oil).

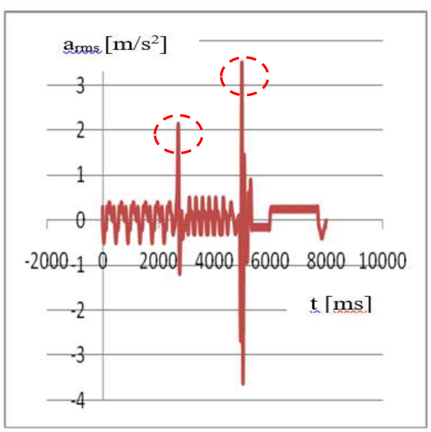



**Fig. 8** $a_{rms}$ acceleration for PUMP 2 exprimed in time (8 ms during injection pieces on the machine with additive oil).

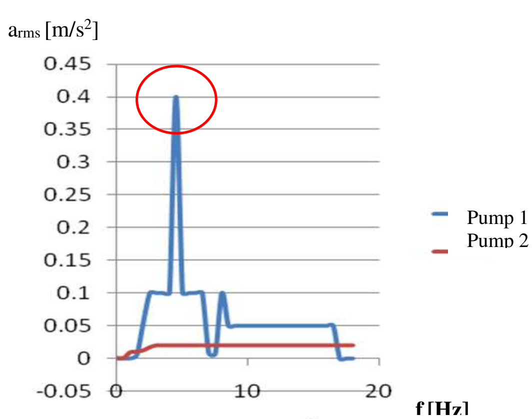



**Fig. 9** $a_{rms}$ function of for pumps 1 and 2.

The superiority of the additive used in Pump 2 (Fig. 7-9) symbolized in red on the graph can be seen by small acceleration values compared to the usual or normal lubrication (Pump 1 - symbolized in blue on the graph) used when injecting parts. These benefits of reducing vibrations also apply to the human operator, who during injection holds the pressing lever of the mold in which aluminum is injected. Therefore, the reduction of mechanical vibrations brings a positive contribution to the well-being of the human operator's mode of operation, respectively to his state of health.

The comparative results obtained from the two functional pumps lubricated with normal and additive oil are relevant because they confirm the fact that the use of a high-quality lubricant leads to the reduction of vibrations given by the operation of machine tools and implicitly increases their productivity, not least it reduces and ambient noise.

Each country has regulations regarding exposure to vibrations in the occupational environment (in Romania, HG 1876 / 22.12.2005), to avoid the occurrence of occupational diseases in people who carry out their activity in such environments.

The study of these experiments will not stop here, we propose to carry out vibration measurements on the other types of machines also, machines that will use these oils or other oils and we will make the comparative measurements. As well as this, we can make a profound analysis, in collaboration with the Institute of Public Health, in terms of medical data, interpretations of these data and eventually finding the another solutions.

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## 5. REFERENCES

[1] https://svantek.com/academy/body-vibration-effects-on-humans/ (accessed July 2023).

[2] Cristea A. F., Acxel E. F., Arghir M.; Study regarding the vibration transmission of the autovehicle about human body, Acta Technica

Napocensis, Series: *Applied Mathematics and Mechanics*, **2016**, vol.4, nr. 59, pp.379-382, ISSN 1221-5872.

[3] Cristea A. F., Acxel E. F., Arghir M. Study regarding the vibration transmission of the autovehicle about human body, *Acta Technica Napocensis*, Series: Applied Mathematics and Mechanics, **2016**, vol.4, nr. 59, pp.379-382, ISSN 1221-5872.

[4] Isa M.S.M., Mazlan A.Z.A., Hand-arm vibration transmissibility measurement from the petrol driven motorboat engine, 1896 (**2021**), 012006 *IOP Publishing* doi:10.1088/1742-6596/1896/1/012006.

[5] Owuna F.J. , Stability of vegetable based oils used in the formulation of ecofriendly lubricants – a review, Volume 29, Issue 3, September **2020**, pp. 251-256, https://doi.org/10.1016/j.ejpe.2020.09.003.

[6] Cristea A. F., Haragâş S. The lubricants influence in transmission of vibration and noises from aluminium injection machines, *Proceedings Of The Romanian Academy*, Series A, Volume 19, Number 1/**2018**, pp. 77–84, 2017, ISSN 1454-9069.

[7] Mat S.C. , Idroas M.Y. , Teoh Y.H. , Hamid M.F. , Physical, Performance, Combustion and Emission Characteristics of Melaleuca cajuputi Oil-refined Palm Oil Hybrid Biofuel Blend Energies, 11 (**2018**), pp. 1-20.

[8] Haragâş S., Cristea F., Kicsi V. The analysis efficiency of the demulation agent injected into aluminum molds, *Tribology International Journal*, tom. 177 (**2023**) 107950, pp. 1-9, doi.org/10.1016/j.triboint.2022.107950.

[9] Owuna F.J. , Dabai,M.U. Sokoto M.A. , Muhammad C. , Abubakar A.L. , Analysis of Blends of Vegetable Oils with Mineral Based Lube Oil, *J. Scient. Eng. Res*., 6 (**2019**), pp. 41-48.

[10] Madanhire I., Mbohwa C., Mitigating Environmental Impact of Petroleum Lubricants, **2016**, *Springer*, pp 239.

[11] https://oshwiki.osha.europa.eu/en/themes/vibration (professional illness, vibration) (update 2022), (accessed July 2023).

## EFECTELE CALITĂȚII ULEIULUI ASUPRA PROCESULUI DE PRODUCȚIE ȘI SIGURANȚA MUNCII PENTRU OPERATORUL UMAN

*Rezumat* Lucrarea îşi propune un studiu privind o comparație a transmisiei vibrațiilor mecanice pentru persoana care utilizează două mașini de injectare de aluminiu identice, care sunt alimentate cu două uleiuri diferite (ulei normal și ulei aditiv), atât din punct de vedere al îmbunătățirii producției cât şi al siguranței în muncă.

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