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THE LUBRICANTS INFLUENCE IN TRANSMISSION OF VIBRATION AND NOISES FROM ALUMINUM INJECTION MACHINES

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Abstract. This paper proposed a comparative analysis of oil viscosity influence on vibration and noise during machine-tools operation. It takes two machine tools of aluminum injected, machine-tools identically of point of view technical and dimensional, one of them using VPD 5W40 oil, and other one a special additive oil named HFE 46. It wants to validate the fact, that using for lubrication machine-tools an additional oil HFE 46, improves the work and performance of the machine compared to anointing a normal lubricant cheaper.

Key words*:* lubricating oil, machine tool vibration.

1. INTRODUCTION

1.1. Generalities

As is known, the vibrating system is a response to an internal or external stimulus that causes the system to oscillate. There are literally [1], [2], hundreds of specific problems that can lead to exposure to excessive vibrations of a machine. If the machinery and equipment that are delivered are not designed, constructed, installed and aligned corresponding to its, their operation can be accompanied by a number of undesirable effects: dynamic vibration transmission to the foundation or their transmitting to neighboring construction elements. This leads to the development of poor performance and sometimes inadequate of the machine, in their role as functional.

1.2. Machines vibrating causes

There are a number of factors that may influence the performance of machine tools such as temperature, lubrication, calibration tools and industrial environment in which it is located. An aspect to be considered refers to the presence of vibrations in the mounted location [1]. Vibrations in production departments have several causes: the presence of the pneumatic presses, the power hammers, machine tools, cranes, fans, compressors, etc. So, due to various sources, vibration can have different behaviors and intensities. It is interesting to study the mechanical vibrations, in particular at the level of the hydraulic pump propagation of a machine tools of aluminum injected. The vibrations produced during operation of the machine can have very different causes [1]: – the nature of the technological process which it performs, the principle of operation of the machine and the drive unit, the construction and assembly errors of machine components, wear, etc. Nature technological process developed by the machine-machine causes vibrations produced by some types of technological machinery: crushers, vibrating screens, bucket elevators, forging presses, hammers etc. Some of the factors that may cause the occurrence of mechanical vibration are design mistakes or poor lubrication of machine tools. Also, the fluids for hydraulic installations must answer two important aspects: • hydrostatic power transmission; • ensuring lubrication of moving parts in the hydraulic system. Next, we will study the influence of moisture in the machine tools of injected, but you should to present some data about the characteristics of the oils.

2. OILS (LUBRIFIANTS) CHARACTERISTICS

2.1. Generalities

The nature of the lubricants are organic or inorganic minerals, that are used in order to reduce the friction between the two surfaces. Classification of lubricants is made by a very wide variety of criteria and standards, but in terms of general interest, one of the most important criteria is the *viscosity.*

Fig. 1 – Ball fall into the oil [12].

Viscosity (Fig. 1) is a measure of the internal friction of the fluid, it that comes to engine oils designating their fluidity, depending on the temperature. In general terms, it is the relative resistance to flow of a fluid or "the thickness of the film thereof. Viscosity index of oil is his tendency to change viscosity depending on temperature change. Multigrade oils, compared with monograde oils have a constant viscosity over a wide range of temperatures, which allows us to using the same winter and summer oils and facilitates starting. Viscosity classes the SAE (Society of Automotive Engineers) refers only to engine oils and mechanical transmissions oils. SAE classes are oil groups, characterized by a certain viscosity, at a certain temperature. The symbol of an oil consists of one or more capital letters followed by numbers that can express: the SAE viscosity class and the kinematic viscosity index in mm^2/s (cSt) at 40°C, 50°C or even 100°C. For example, VPD SAE 5W40 represents: "5" is the cold viscosity grade (index), the letter W means "Winter" and "40" is the viscosity index of the hot oil. So as, how an increasing the viscosity index at cold or warm is lower, the viscosity of the oil is lower and vice versa.

2.2. Viscosity lubricants calculus

In order to study the viscosity of the oil, we will study the motion of a spherical body (ball made of steel, copper and aluminum) in the two viscous liquids (normal oil and special oil with additives), the balls initial are resting and ulterior to determine the dynamical viscosity coefficient of fluid. Three tests will be performed every type of oil and with each ball (steel, copper, aluminum). Table 2 below is presenting dynamic viscosity values [η] and correcting viscosity [η'], as well as the errors that resulting [ε %].

Our attention are fixating on the additive special oil produced by ChemTrend, Italy, it called HFE-46 [Chem Trend company] in comparison with normal oil VPD SAE 5W40 [9, 10], both with the following characteristics:

- Appearance: Yellow fluid, Density at 15°C: ~ 0.92 g/ml after EN ISO 12185, Viscosity at 40°C: ~ 46 mm²/s, Viscosity index ≥ 180 after ISO 2909, Flash point: > 290 °C , Load stage ISO 14635 -1: > 12;
- Appearance: Yellow-brown, Density (at 20°C) 848 kg/m^3 after EN ISO 12185, Viscosity (at-30°C) 5 500 mm^2 /s, Viscosity (at 40°C) 83 mm^2 /s after DIN 51562, Viscosity Index 171 after ISO 2909.

The principle of determining the dynamic viscosity of the oil is simple, using the Stokes as follows: A ball is dropped in a viscous fluid, in that acting simultaneously three forces: the weight *G*, the force of buoyancy, *F* and the force of resistance, *R*; these last two forces opposing the movement (Figs. 2, 3). By moving the ball, fluid is driven neighborhood: the layer are leading in the immediate vicinity of the ball moves its speed, and the farthest-speed becoming smaller. In between neighboring layers are formed an internal friction or viscosity. In the case of low speed driving, under a laminar flow (vortex formation in the absence of liquid from the cell body), the drag force is given by Stokes

$$R = 6\pi\eta \cdot v \cdot r\,, \qquad (1)$$

where: η – intern friction coefficient (or fluid viscosity coefficient), *v* – ball velocity, and *r* – ball radius.

The experiments for determining the dynamic viscosity were performed in the laboratory at an temperature of 42°C (heated oil, because is the oil temperature of working machine). The dynamical viscosity was determined in the working conditions of the machine-tool to 42°C respectively. Since, it is known that it operates in temperatures scale between 40–48°C, above these values, the heating of the oil is signaled by a sound alarm. All three forces acting on the ball immersed have vertical direction. The weight of the ball is constant but the buoyant force and the resistance force are increasing with velocity; it is possible that at some point, the resultant of the three forces will become zero. If the balance of forces occurred since then, the ball moves because of inertia with a rectilinear and uniform motion with constant velocity v_0 (it is said that the ball is in dynamic equilibrium). In this case we can write:

$$\overline{G} + \overline{F}_a + \overline{R}_0 = 0 \quad ; \quad G - F_a - R_0 = 0 \tag{2}$$

$$G = mg = 4\pi r^3 \rho g / 3 \quad ; \quad F = mg = 4\pi r^3 \rho_l g / 3 \quad ; \quad R_0 = 4\pi r^3 \rho g / 3 - 4\pi r^3 \rho_l g / 3 - 6\pi\eta \cdot v \cdot r = 0 \tag{3}$$

$$\eta = G \cdot d^2 (\rho - \rho_l) / 18 \cdot v_0 , \tag{4}$$

where: $d = 2 \cdot r$; ρ – ball material density; ρ_l – fluid density; g – gravitational acceleration (g = 9.8 m/s^2); η – dynamical viscosity coefficient.

Formula (4) is valid if the ball falls into a liquid that extends to large distances around it. In fact, in the laboratory, this condition can not be achieved because the liquid is in a small vessel, which implies the presence of friction between the liquid and the walls of the vessel. Therefore, in the above formula to introduce a correction for dynamical coefficient, so that it becomes:

$$\eta' = G \cdot d^2 (\rho - \rho_l) / 18 \cdot v_0 \cdot (1 + 2.4 \cdot d / D), \tag{5}$$

where: D – internal diameter of cylindrical vessel where the ball is moving.

2.3. Describe of experimental viscosity test

The apparatus used in this work (Fig. 2a) consists of two cylindrical of glass vessels, identical with the diameter D, filled with an oil (oil superior – HFE-46 and polyalphaolefins (PAOs) – VPD SAE 5W40 synthetic oil, its must be with the physico-chemical different properties) and a mechanical system for removing the ball from the liquid. To measure the velocity balls (diameter of ball is d) it will use a system consisting of two optical gates (P_1, P_2) $P_1P_2 = h$, coupled to a software interface LabPro (Fig. 2b), which make the connection between experiment and computer. It will indicate that using diving balls to be build of the different materials (steel, copper, aluminum), it will use in our experiment a caliper and a laboratory balance to measure the mass of the balls.

Table 1

Probe laboratory dimensions

Ball mass m [kg]	Ball diameter d [m]	Material density ρ [kg/m^3]	Vessel diameter D [m]	Vessel high H [m]	Distance between P1 and P2 × [m]	Velocity v [m/s]
Steel 0.085	0.015	7860	0.15	0.20	0.17	0.028
Copper 0.089		8900			0.15	0.034
Aluminum 0.032		5083			0.12	0.0158

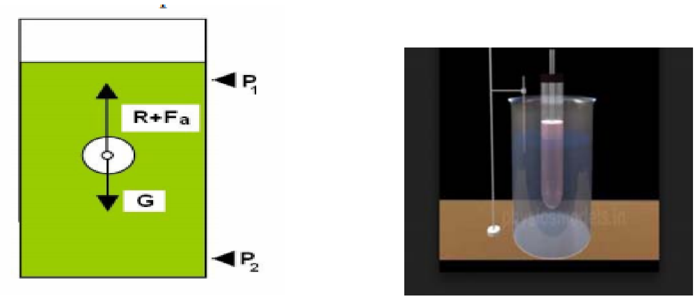
To determine the dynamic coefficient of viscosity η of the oils it will use the following steps:

1)Measure the average diameter of the balls d; 2) Measure the mass of the balls and and it is calculated their density; 3) Measure the inner diameter of the oil vessel D; 4) to perform a few preliminary experiments (we use different metal balls of the inside the plastic box upon the table in the vicinity), we will identify the top position of the optical gate P_1, and time automatically registered in the program of this, of course when the ball passing on this position P_1; 5) Then it will be measured the distance between the two optical gates P_1, P_2, so the infrared beam passes through the walls of the vessel; 6) Run the file "Stokes", introducing the distance P_1P_2 between the two optical gates, in the formula for calculating the velocity; 7) Click the "Collect" and all the balls are inserted in the cylindrical vessel (the program automatically registers the velocity ball) or $v = P_1P_2 / (t_2 - t_1)$ where (t_2, t_1 are the final and initial time of the moving); 8) It calculates the error ε; 9) The final result is written as relations (6–7)

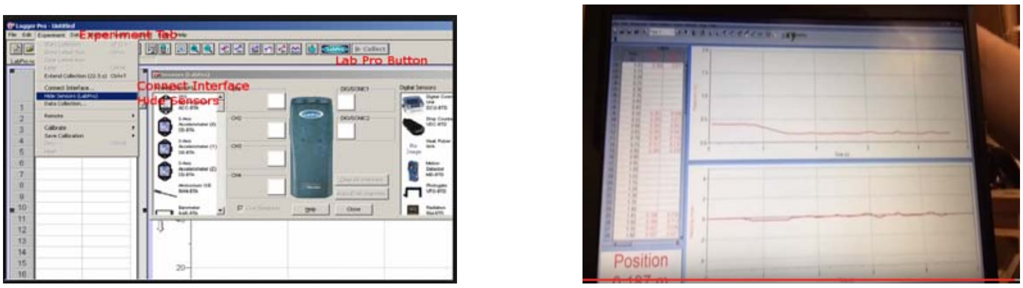
$$\eta = \eta' \pm \Delta\eta \qquad (6)$$

$$\varepsilon = \Delta\eta / \eta, \qquad (7)$$

where $[\eta]_{SI} = 1$ Ns/m^2.

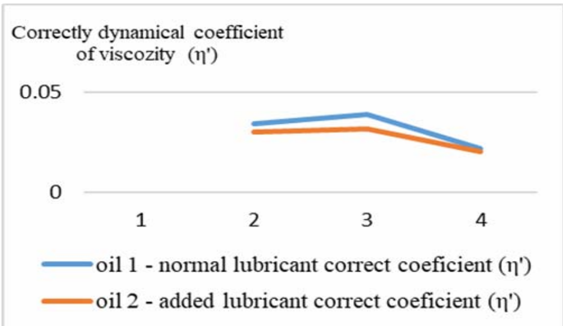


a.



b.

Fig. 2 – a) The fixing the repers P_1 and P_2 of the vessel, its will be necessary in the velocity ball measurement; b) LabPro interface.



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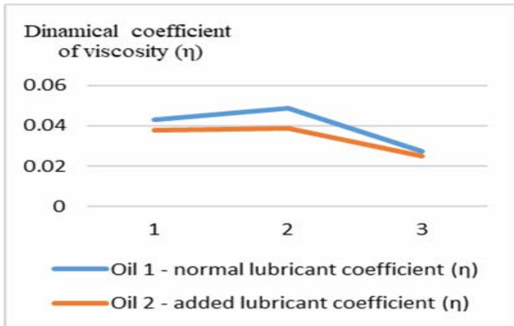

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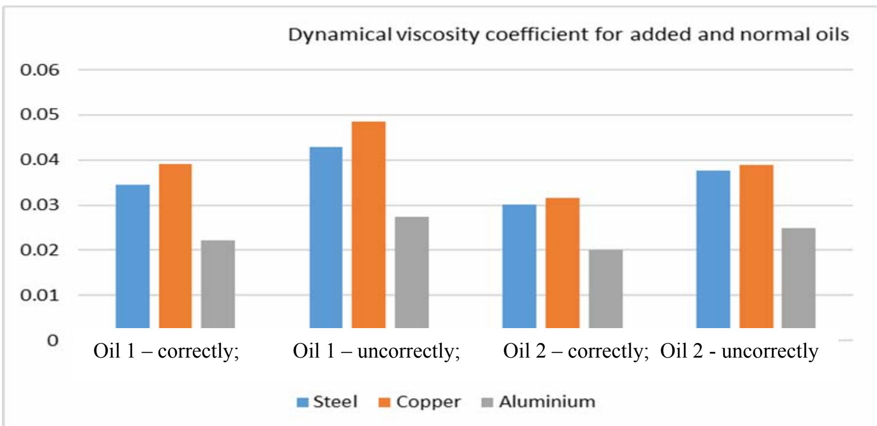

Fig. 3 – Density balls in the two oils, oil 1 – normal oil and oil 2 – added oil, where correctly means correcting coefficient of dynamical coefficient (η') and uncorrectly means normal coefficient of viscosity (η).

Table 2

Visco-dynamical coefficient of the studied lubricants (η)

Ball	Lubricant - VDP 5W40 la 42° C			Special lubricant - HFE 46 la 42° C		
	Correcting viscosity coefficient η' [Ns/m^2]	Viscosity coefficient η [Ns/m^2]	Eror ε[%]	Correcting viscosity coefficient η' [Ns/m^2]	Viscosity coefficient η [Ns/m^2]	Eror ε[%]
Steel	0.0345	0.0428		0.0302	0.0377	
Copper	0.0391	0.0485	1.206%-1.227%	0.0315	0.0389	1.218%-12.931%
Aluminum	0.0221	0.0274		0.0201	0.0249	

In the Fig. 3 it represents with *oil* 1 – a normal lubricant and with *oil* 2 – a special lubricant (additivat) by Chem Trend. It observed that all values of viscosity coefficients for oil 1 (normal oil) are bigger, in comparison with oil 2 (added oil), indifferent of materials ball (steel, cooper and aluminum), and indifferent of correcting (η') or not correcting (η) of dynamical viscosities coefficient. But, it notes that the bigger values of balls in the oils 1 or 2 are for the cooper, steel and latest the aluminum ball. It notes that, we obtained very good values of viscosities vis a vis of densities, especially in the oil 2 (additivat), regarding studied ball of materials. We talk about corrected (η’) and normal (η) dynamical viscosity coefficient used in the Fig. 3. We recall that, the dynamically corrected viscosity coefficient (η’)is necessary for the study of oil viscosity under laboratory conditions.

3. MECHANICAL VIBRATION MEASUREMENT

3.1. Vibration measurement

The purpose of this study, along with several other tests on hydraulic injection machine, are propose testing oil of CHEM Trend Italy regarding functionality of these machines, compared to other hydraulic fluid. Tests measuring vibration and noise were made during the day, inside the hall of Bialetti company in Romania. For example, a molding machine works with normally hydraulic oil and is called machine 2 (Fig. 4) and the second machine with special hydraulic additives oil, produced by the company CHEM Trend, which is called the machine 7 (Fig. 4a) that operate a hydraulic injection molding machine during a process performed completely on aluminum injection. It injected Bialetti coffee cups. The two machine (machines 2 and 7) were chosen because they had the same technical characteristics, motors and pumps were identical in the injection process [2, 3].

Fig. 4 – a) Injected pump; b) measure equipment.

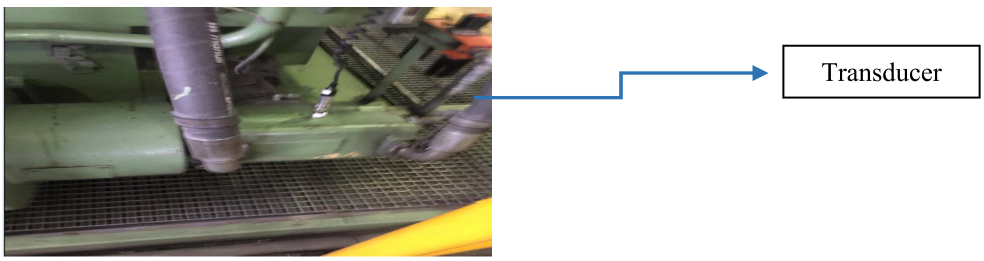

Fig. 5 – Accelerometer (transducer) position on the pump machine.

3.2. Machine 2 measurements

The reason of vibration measurements on these components of the machines have been analyzing vibration and noise during their operation.

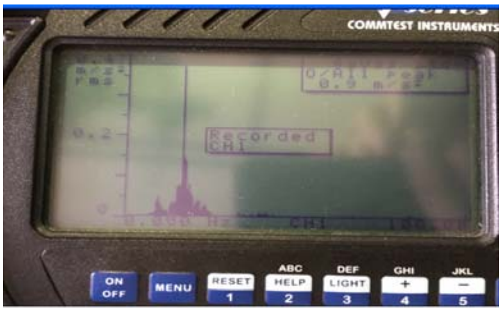

Fig. 6 – Vibration graphical displayof the equipment.

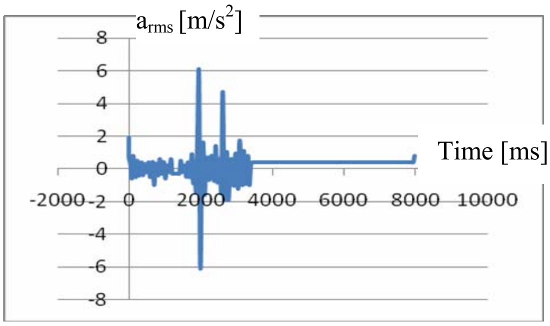

Fig. 7 – RMS acceleration exprimed in time (8 ms during injection pieces).

3.3. Machine 7 measurements

All measurements conditions shown in Figures 8–9 are the identically on both machines-tool (same power, same operating process, same duration etc.) all these in scope of validation the comparative experimental measurements between oils.

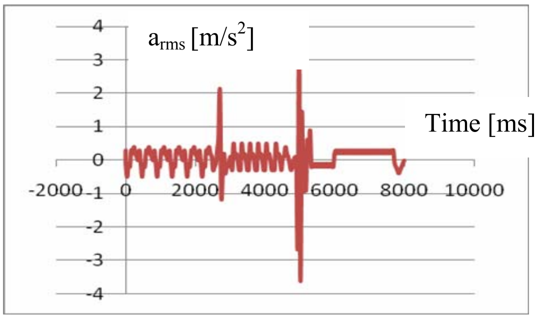

Fig. 8 – RMS acceleration machine 7, exprimed in time.

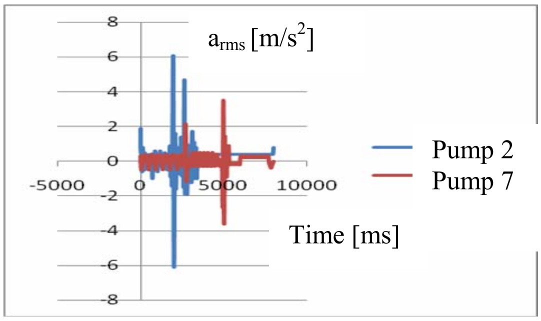

Fig. 9 – Comparative measurements between accelerations of machines 2 and 7 in time (8 ms).

The measurement of vibration of the machine 2 was effectuated with a monoaxial accelerometer as part of industrial vibration measuring device named VB 3 000 produced by COMTEST-New Zealand (Fig. 6), it has been fitted with a magnetic foot and it fixing on the pump 2 on the machine (Fig. 7).

The vibration measurements were made, in the same operating conditions in both time and frequency, and in the paper it is represented the graphical in time, only (Figs. 8–9).

3.4. Vibration analyse

Making a comparison between the average value of the measured acceleration, in time, at both pumps 2 and 7 of the machine, its shown in the Fig. 9, that peaks obtained are 0.6 m /s^2 on machine 2 that working with normal lubricating fluid. In comparison on the machine 7 where the peaks of the acceleration are smaller or very small (0.3 m / s^2) (red color), this demonstrated the effectiveness of the lubricant additive produced by Trend CHEM. Figure 9 shows the peaks obtained during the two stages of the injection process (8 s). It is clearly observed that the machine 2 has the highest peak values (blue line). With this comparison the our scope was validated, the pump 7 of the machine-tool works in good condition and were obtained the lower values of the accelerations (red line).

4. NOISES

4.1. Noises measurements

Noise measurements were made with a sound level meter in the real-time, instant measurements and to check on the noise in time from the start of injection to the end of this we had to video recorded these measurements. The ultimate goal was the comparing of these recording on the two machine 2 and 7. The microphone sound meter was placed near the noise source (the motor and the pump of the machine) Fig. 11.

Fig. 10 – Sonometer equipment use to noises measurements.

Fig. 11 – Measurement noises near pump of machine.

4.2. Noises analyzes

Unable to eliminate ambient noise from the hall, thus adding to the noise measured. But because background noise was about the same across the hall – where still operating five machine tools, still, the finally at results on the two machines (2 and 7) adds the environmental noises by the total sum. Also, the noise was measured in the same working conditions and surprising is that in entire process of injection (8s), it starting from the preparation machine till at removed abrasive parts, the actual injection process is in during 2–3s and includes the higher vibrations.

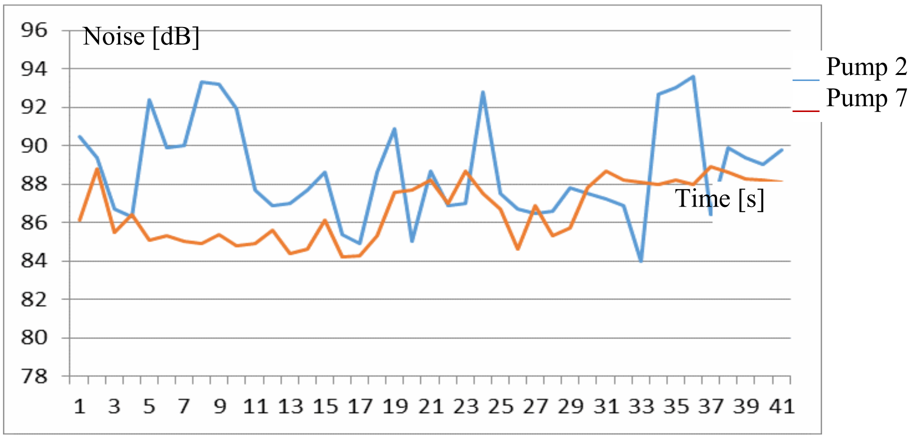

Fig. 12 – Noises measurements.

It was observed that in the two major moments of injection, the noise values were higher, and the difference in noise between the machine 2 and 7 (the lubricating liquid product CHEM TREND), its had not got more than 90 dB, even with the addition of ambient noise of hall. While in the case of machine 2 (normal lubricating liquid), in many cases it reaches values above 90 dB to higher than machine 7 (Fig. 12).

It can be, clearly, seen that at the machine 2 (the liquid lubricating normal) – the graphics blue, the noise level in decibels is much higher, than at the second machine 7 – the special lubricant produced by CHEM TREND – represented in red. The graphics peaks are observed at both machines, it coincides with the parts injection time, at this being added noise from other machines who efectuat the injection process in the hall (environmental).

5. CONCLUSIONS

In conclusion, we can say that the effectiveness of liquid lubricants additives produced by CHEM-Trend in Italy is proven clearly, proving as result of: to remember that the calculation of dynamical viscosity was determined in the working conditions of the machine – tool to 42°C respectively. Since, it is known that it operates in temperatures scale between 40–48°C, above these values, the heating of the oil is signaled by a sound alarm. (experiment Stokes tabel 2) – measurements of vibration and the noises, which are compared on the two identical machine tools (2 and 7), the same technical and operational conditions. The level of superiority of the CHEM lubricant in vibration and noises (Fig. 3, 9, 12), symbolized in red in the graph < 4 m/s^2 and < 90 dB can be observed by lower values compared to a usual lubricant (machine 2 – shown with the blue color on the chart till 6 m/s^2 and in noises > 90 dB). The results are particularly important because validated experimentally that, when it using a lubricating fluid of high quality of the machine tools, this fact improves performance of it, by reducing vibration, noises but the energy power too (this experiment will be treated in the next paper).

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