Studies Regarding Vibration Transmitted, Using an Additional Damper, Mounted an the Hand-Arm System

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Abstract. The paper is a continuation of other studies and wants to demonstrate what negative effects (diseases) produce the vibrations transmitted to the hand until arm, without or with a supplementary vibration attenuator. Thus, the paper deals with both the theoretical and experimental mode of their diminution when mounted or not, a vibration attenuator. The attenuator will testing in terms of blood pressure in the hand-arm system, through the IGB index (ankle-wrist coefficient). Therefore, the paper is approaching from an engineering point of view through modeling, design, and the measurement and from the medical point of view through IGB index measurements as a validation measure.

Keywords: Supplementary attenuator · Transmitted vibration of the operator

1 Introduction

1.1 Generalities of Medical Nature

The paper comes with the supplementary additions and validates the results presented in other papers, on this studied. Such as, the vibrations on the hand-arm system are transmitting during the work process. This paper wish of new validate of the recently studies regarding the effect of the vibration about hand, in the work process.

Regardless of the industrial activity from which it comes, vibration acts on the human body and it can cause discomfort to the operator, might been changed its activity or even have negative influences on the health of the human operator, subjected to its. The action of vibrations with a frequency between 20–200 Hz [3, 9] determines osteo-musculoskeletal syndrome that evolves with pain, joint swelling, and limitation of movements, in this, the examination radiological highlights the narrowing of joint spaces and tendons and inflammatory phenomena occur in the muscles. Vibration exposure has found to be associated with a reduction in grip strength of the hand at the handling, and their neglect can lead to incapacity for work.

This paper might been compared with the similar theoretical studies, in terms of vibration transmissibility but without/with additional attenuator. The novelty of this paper consists in the fact that the obtained results was been wanted to validate other studies and to strengthen the fact that the vibrations of the hand-arm system are

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transmitted along for the forearm. In these cases, it was been measured and it has been calculated the IGB indices and displacements caused of the vibration in the work process. All this was been demonstrated using an additional vibration attenuator, which was been realized practical and patented.

In the paper, we will refer to human operators who are daily expose to vibrations through the regular use of portable machine tools (all these respecting the OSM protective rules regarding measurements). They might been present different forms diseases with different severity, from reducing peripheral circulation to stopping circulation in the extremities.

In the next subparagraph will been presented some possible occupational dis-eases related to the transmission of vibrations, like vascular disorders.

In this way, the two most serious conditions are relates to Raynoud syndrome, and another related to carpal tunnel syndrome. Raynaud's syndrome is a disorder of blood circulation in the fingers. It affects the reaction of the fingers to the cold producing the crisis of the "white fingers" by strongly reducing the circulation. At first, whitening attacks refer to the extremities of one or more fingers, but gradually if the exposure to vibration continues or increases in intensity this fact is dangerous (Figs. 1, 2, 3).

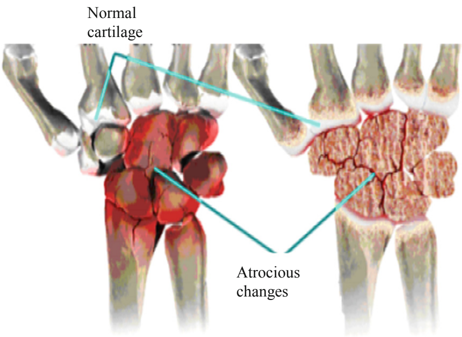


Fig. 1. Bone changes due to osteoarthritis [1].

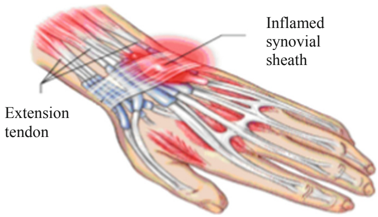


Fig. 2. Tenosynovitis (inflammation of the tendon sheath) [1].

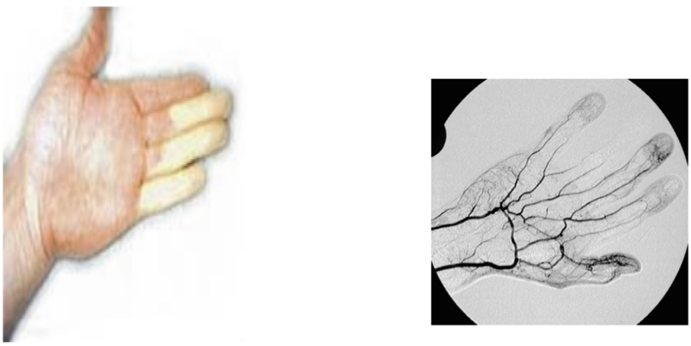


Fig. 3. Upper limb diagnosis [1].

One of effects of the illness caused by the action of vibrations on the hand could be the carpal tunnel syndrome [4], but this could be aggravate of the other work conditions like irritation of the median nerve (tingling, numbness in the thumb etc.), respectively dexterity (Fig. 4).

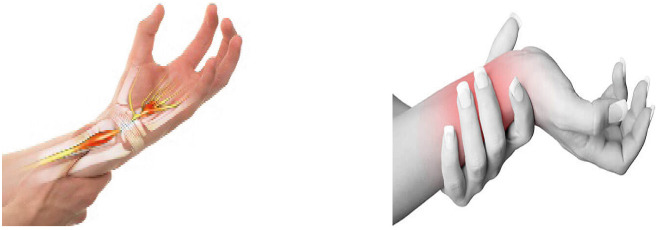


Fig. 4. Tendonitis and carpian tunnel syndrome [1].

2 Mathematical Model

For the hand-arm system, the soft tissues might been describe the phenomenological, as a viscous-elastic medium for which were substitute of the dampening and rigidity coefficients [3]. In this way, the differential equations of motion could take the form given by the relation (1) [2]:

$$[m] \cdot \{\ddot{u}(t)\} + [c] \cdot \{\dot{u}(t)\} + [k] \cdot \{u(t)\} = \{F\} \quad (1)$$

The mechanical hand-arm system is composed of 5 springs and 5 shock absorbers c0, c1, c2 located along the Oz axis, i.e. along the forearm and c3, c4 located along and perpendicular to the arm, and the springs that give the system rigidity and they are placed similar. The real model was been simplified to a model with concentrated masses in the center of mases, and the wrists were considered, in this case, rigid without elasticity or damping. If the additional shock absorber has been add, it mounted in parallel with the forearm and was fixe between the wrist and elbow. The supplementary attenuator has an attenuation and a stiffness c5, k5.

In the relation (1), u(t) is the displacement along the Oz / Ox axis of the three bodies that make up the hand-arm system.

The initial condition of the operator are there: position vertically, scale 0–20 Hz frequency, shoulder at 0° degrees, and gripping device is in palm.

Using as excitation source (drilling machine) and take in account SR-EN ISO 5349/2003, paper analyses only main vibration transmitted after Oz axis (along the hand-arm system).

Figures 5 represent the system solutions (1) obtained of the integration with Runge Kutta of 4–5 order.

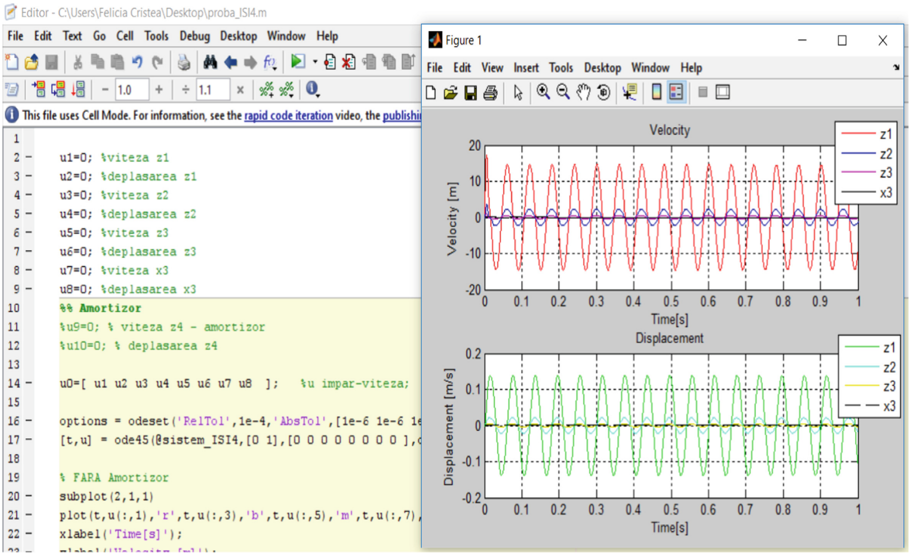


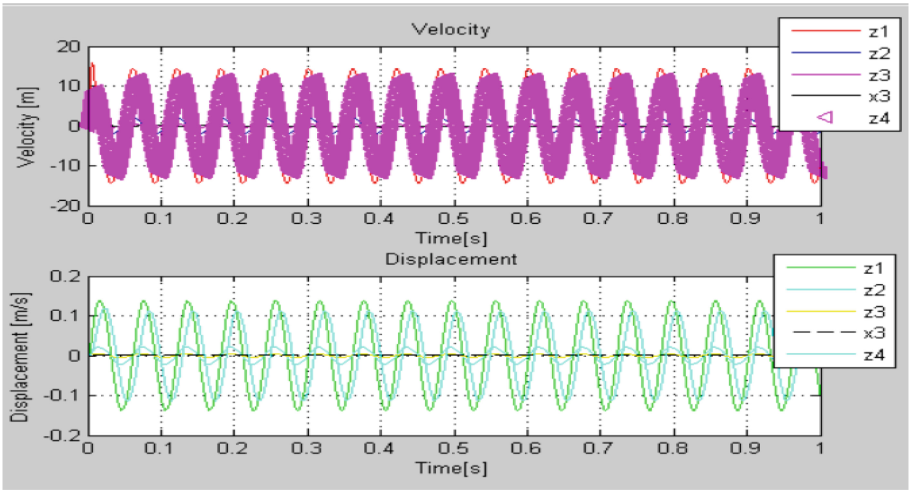
Fig. 5. Theoretical displacements and velocities of the system without supplimentary attenuator.

2.1 System with Supplimentary Damper Montated Along of the Forearm

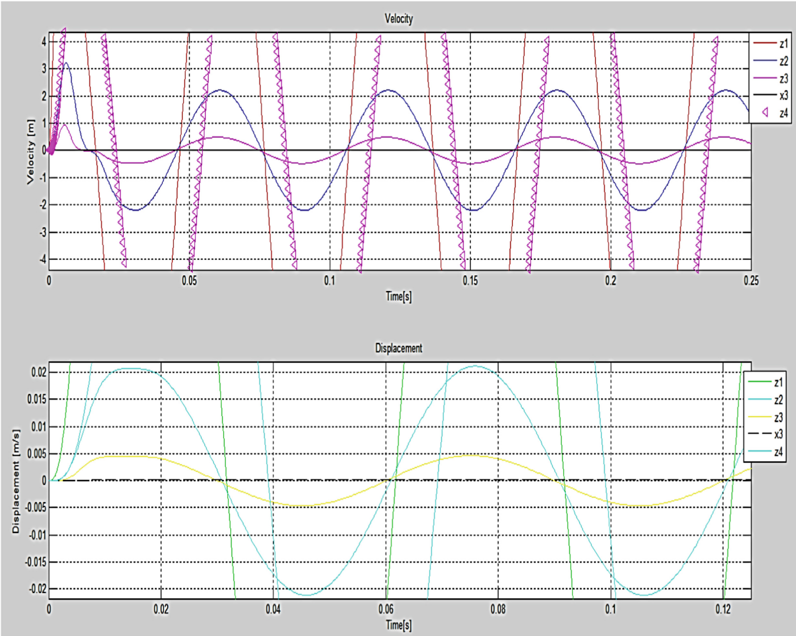
The paper, in the next figures, will be analise the transmissibility of the hand-arm system (theoretical), in presens of not of supplimentary damper/atenuator.

Solving the Eqs. (1) by double integration to find out the velocities and displacements of the bodies, was performed with the Runge Kuta method of order 4–5, by running in Matlab [3, 5, 6].

Figure 6 represents the system solutions, there obtained from the integration.



a.



b.

Fig. 6. Theoretical velocities and displacements corresponding of the system with supplimentary attenuator. a. Results of displacements and velocities, b. ZOOM of velocity and displacement.

3 Measurements

3.1 Experimental Vibration Measurements on the Hand-Arm System

The study, it use the same drilling machine similar with it the other researches (1000 RPM).

The measurements sets were perform on a group men (15 men), of the appropriately age (between 40–50 years), weighing medium and over 1.70 m tall. The measurements have indicate the RMS (root mean square) accelerations displaying on the device vibrometer and interest us only the measurements after Oz axis (along of the forearm). The accelerometer fixed directly under the metallic bracelet by tightening it (Fig. 6b) and directly on the arm (taped).

The results are analyzing in the Figs. 9, 10, 11 for all the cases taken into account by the experiment and taking into consideration the anatomic location (wrist, elbow and shoulder.

In this paper is presented a new idea, this is the design of a vibration attenuator device, which will be fixed along of the forearm. The scope of this attenuator is minimizing the transmitted vibration from hand to the shoulder. The dissipater (attenuator) has the next components: 2 dampers type FA 1008 VB, fixed with a complex bracelets. The damper device in parallel, between the wrist and elbow (Fig. 7). It was respected the theoretical weight of the attenuator/dissipater, respectively 0.5 kg.

The vibration attenuator contains the next elements: Attenuator (**element 1**) are fixing in the structure (2 pcs.); It extension which has the role of supporting the attenuators (element 2); Mobile bracelet (element 3). Fix bracelet (element 4). Magnetically support of accelerometer.

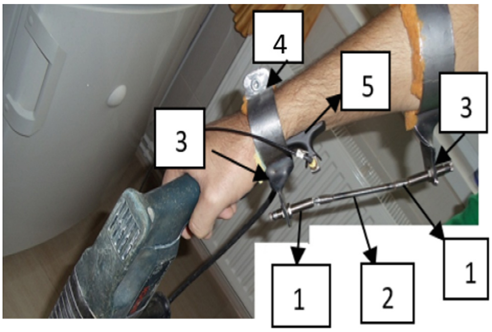


Fig. 7. Vibration damper device [10].

Firstly, theoretically, the hand-arm system is analyze in terms of transmitting vibrations from the excitation source using or not an additional shock absorber. Figure 8, referring to the hand, shows the blue curve (theoretical) 0.04 m without damping, as it is above the gray curve 0.015 m, with additional damping. Which indicates that the extra shock absorber reduces vibration, and to the theoretical form we are talking about in now [7, 8].

The Table 1 presents the experimental displacements for the hand-arm system without/with supplementary attenuator.

Table 1. Experimental displacement (peak).

	Without		With		Difference [%]
Theoretic	Hand	0.04	Hand	0.015	37%
	Forearm	0.006	Fore arm	0.002	33%
	Arm	0.058	Arm	0.0005	33%
Experimental	Hand	0.058	Hand	0.03	51%
	Forearm	0.008	Fore arm	0.004	50%
	Arm	0.0018	Arm	0.001	55%

The peaks of vibrations are reduced toward forearm using a damper and theoretically (according to the modeling), but also to the experimental mode (Table1) in percent. In this studies was observed that the reduction of vibrations with additional attenuator both in theory (33–37%) and in practice is minimized by more than 50–55%. This fact can only be gratifying and useful for the human operator who handles vibrating machines and devices. In this way, the chances of being affected by occupational diseases being small (White Fingers Syndrome).

The experimental displacements are stable, without the disturbances, from the beginning of the movement.

The measurements were performed in 8 h with the 2.5 s cycles and theoretical analize has been raportated at the them.

3.2 Theoretically and Experimentally Results – Without/With Attenuator

Figure 8 analyzes the behavior of the hand-arm system both theoretically and experimentally, when there is no additional attenuator and according with the Table 2. Its shows that the experimental vibrations on the hand - arm system have higher values than those resulting from the theory, but they respect the shape except for some jumps that mark imbalances, being superior in value to the theoretical ones.

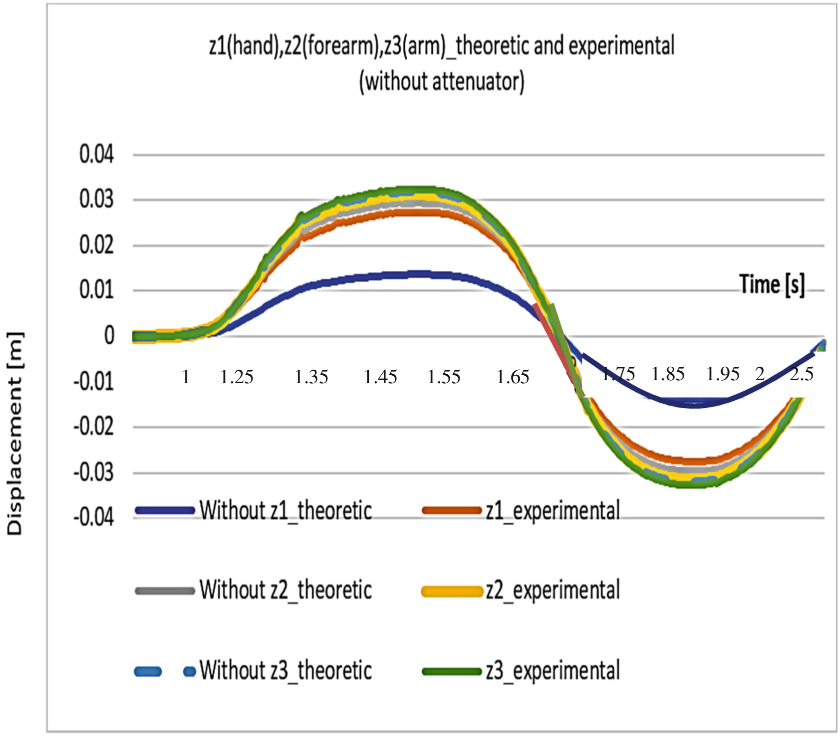


Fig. 8. Hand-arm system without supplementary attenuator.

Figure 9 analyzes the behavior of the hand-arm system when there is an additional attenuator and according with Table 1. Shows again that, the experimental vibrations on the hand-arm system have higher values than those resulting from the theory, but they respect the shape, and are superior in value, compared to the theoretical ones resulting from the presented simulation in the percentages of the Table 1. Those small jumps, in the shape of the graph, are the points where the percussion comes into operation, this contributing to the increase of the excitation values.

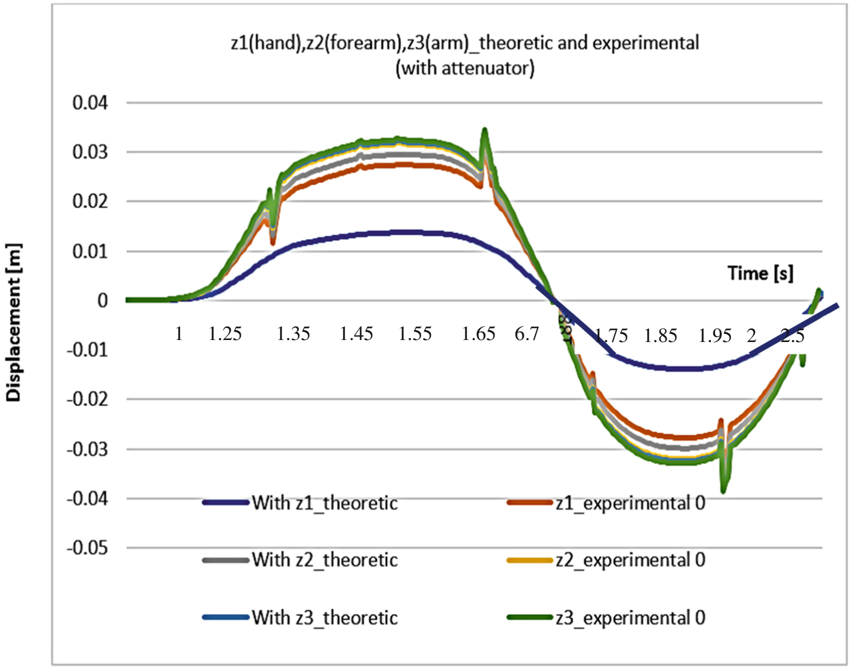


Fig. 9. Hand –arm system with supplementary attenuator.

3.3 Medical Investigation

To determine blood pressure in peripheral vessels, the Ankle-Arm Index (IGB) can be determined, which is a fast, noninvasive method used to diagnose arterial disease. This measurement helps the doctor to make a first assessment of the foot-hand sanguine circulation, but also vice versa and to monitor over time, its improvement or worsening.

The index is obtain by dividing the blood pressure from one ankle to that of the wrist.

$$IGB = \frac{P_{ankle}}{P_{forearm}} \tag{2}$$

Table 2. Diagnostic index [8].

Index	Diagnostic
<=1.41	uncompressible;
1.40–1.00	normal
0.99–0.91	in limit
0.90–0.41	unnormal
<=0.40	serious

Fig. 10. Diagnostic equipment _ IGB.

The paper aims to analyze a set of tests on blood circulation to the hand-ankle (Fig. 10), at rest (horizontal position) and in operation (vertical position), for a group of 15 people, aged 40–45 years old, men, who operate in a work environment with vibration transmissibility (the subject handles with a percussion drilling machine). Analyzing the blood pressure in the wrist before using a vibration attenuator and after using it, during the drilling operation. It was, three sets of measurements performed, and was using their arithmetic mean in the paper.

Such as, while the human operator is lying horizontally, a technician measures blood pressure in both arms, using an inflatable cuff.

Then a doctor measures the blood pressure in two arteries at the ankles, using the inflatable cuff and a portable Doppler ultrasound device, which pressed on the operator's skin, he is already in a working position, vertical. The Doppler device uses sound waves to make sounds and allows the doctor to measure the pulse in the arteries of the ankle after the cuff is deflate.

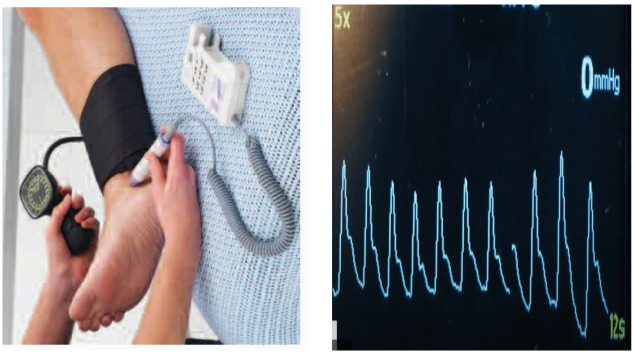


Fig. 11. Measurements of IGB.

Figures 11 show how to measure pressure. This presents an exception, respectively at rest the pressure is compare in the sitting position, and in the working position, it is compare in the vertical position.

The pressure in the blood vessels can vary depending on this position, this pressure is adding to fatigue, other disease, age and sex.

The IGB analysis for subjects is giving by the following graphs.

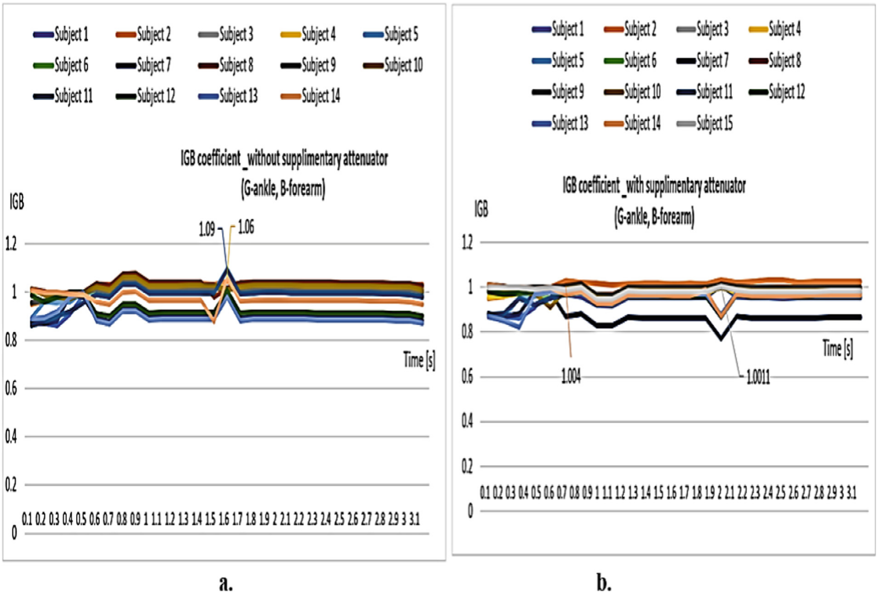


Fig. 12. IGB index.

The Figs. 12a, b show us that IGB values without supplementary attenuator along of the forearm is bigger, and when this is mounted, they are these values are smaller, for all of the 15 subjects. In addition, we observe the peaks of the graphical shapes, that show instability in the pressure of blood in some moments, but these are ok, in case of attenuator supplementary.

4 Conclusions and Discussions

These conclusions are the result of some measurements performed with the installation of an additional vibration attenuation device (patented), which validated the fact that:

Vibrations were been transmitted from the source of excitation through the hand to the arm, and their effects over time could cause occupational diseases [3].

The paper monitors whether the measured values (Fig. 9) of the vibrations fall within certain limits, compared to those imposed by the standard SR EN ISO 5349/2003.

It is observed that the experimental results obtained are in the hand of 5.8 cm without additional attenuation (in the warning area according to the standards) and are reduced to 0.05 cm with additional attenuator, this being a significant variation and a confirmation of the fact that the additional attenuator has an important role in this transmission.

However, this reduction at the elbow is not brings significant with the additional attenuator (0.1 cm), it being quite small and without its use (0.18 cm). We can say that the additional attenuator has a vital role in attenuating the transmission of vibrations to the hand, where in fact occupational diseases occur frequently.

A comparison was been made with the standards in force (we mention that they refer to accelerations not to displacements. It mentions that the transformation of these accelerations into displacements by special software (using mathematical integration methods), showed us that the values obtained from measurements do not exceed these limits of the RMS acceleration of 5 m/s^2 (and expressed in displacements of 0.06 m) for 8 h daily at work, but are found near them (0.058 m) called the high-risk warning area.

In this case, taking into account the values obtained from the measurements, we can say with certainty that: non-compliance with breaks and the presence of overtime, can lead to the cumulative effect of vibrations, and this can degenerate at first with symptoms of numb fingers, low dexterity, and finally, the appearance of an occupational disease in the hand [1].

Under certain conditions at work, the transmitted vibrations increase, but as is normal, some of them are been attenuated by muscles, skin, blood system, so that up to the shoulder, to be greatly attenuated.

As this paper has shown, the big problem that arises is the fact that these vibrations transmitted largely to the hand and less to the forearm.

The paper also highlighted the fact that, they decrease in a short time, almost 100%, when using the additional vibration attenuator, which brings improvements in the comfort of the human operator and over time, prevents the occurrence of occupational diseases (the sanguine system-most often found in White Fingers Disease).

The maximum values must be avoided, and this is done by wearing protective equipment (specialized literature, provides rubber gloves) and respecting breaks in work. The other recommendation for prevention are:

From a medical point of view, we can say that carpal tunnel syndrome can be aggravated if in main, the wrist is repeatedly stretch and excessively.

Repeated use of equipment brings upload with a supplementary effort about of the wrist and contributes to the swelling and compression of the median nerve of this.

Minimizing repetitive handling when is possible.

It is recommend involving one or both hands for something difficult;

Avoid taking the object in the same position for a long time.

It is also, desired to ergonomic the vibration damping device so that it can be easily transported and handled.

Conflict of Interest. Hereby mention that, I have no conflict of interest regarding this paper.

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