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HIGHLIGHTING BY MEASUREMENTS OF THE MECHANICAL VIBRATIONS PRODUCED BY A FANUC MACHINE TOOL ON A "FEMALE" HUMAN OPERATOR

Aurora Felicia CRISTEA, Adela Bianca CRĂCIUN (HOSU), Mariana ARGHIR

Abstract: The paper is part of the doctoral thesis, which studies the action of vibrations on an operator, who serves a FANUC machine tool when idling. In the work, measurements are made on the operator when transmitting vibrations from the machine tool through the operator's feet, who is placed on a pedestal on which there is a rubber mattress. Measurements are made with the SVAN 958 vibrometer, step by step on both legs, up to the abdomen, which constitutes the lower part of the body of the "female" operator, considered a solid, with the three characteristics, of mass. Shock absorber and spring. Through these measurements, it is sought to prove that the health of the "female" operator is affected by exposure to vibrations.

Keywords: vibration measurement, female operator, interpretation of results.

1. INTRODUCTION

The measurements are experimental part to the doctoral thesis, that refers to the vertical transmission of vibrations through the operator, from the soles of the feet, through both feet, to the abdomen, which is the part that sums up / cumulates the vibrations transmitted through both feet [1]. The body segments referred to in this study are: the foot, ankle, calf, knee joint, femur, hip joint, abdomen – which together with the upper body form an assembly assimilated to a rigid solid [1].

The vibration measurement procedure is according to the specifications in the literature [2] – [4], and the analysis of vibrational accelerations is highlighted and correlated with references [5] – [7].

The measurements are made on a "female" operator, 45-years-old, weighing 78 kg and 170 cm tall. The operator is medically healthy and does not complain of pain or discomfort in his current activity. By performing vibration measurements, there is no action on bodily integrity.

For her the way in which the measurements will be made was presented, the source of the

vibrations being the FANUC machine tool [8] – [9], the vibration recording device [10], the triaxial accelerometer, which is attached to the area of estimation of the accelerations of the windings [11].

The estimation of vibrations on the different parts of the body does not affect the health of the operator, but she must accept the measurements, therefore the investigation method and the sequence of operations were presented.

The "female" operator has given her consent to carry out the measurements of the vibrations transmitted by the machine tool during the production process.

2. WORKING CONDITIONS OF THE OPERATOR

The "female" operator subjected to vibration measurements during the production process of a numerically controlled machine tool is positioned in the surveillance area of the machine, in a standing position, with the triaxial accelerometer attached to the various parts of the body. The machine tool is in operation, idling, and the measuring device is connected to the

accelerometer and is operated by a researcher, initiating vibration measurements.

In order to understand the location of the operator during the measurement, figure 1 shows the machine tool in operation and the position of the pad, on which the operator will sit.

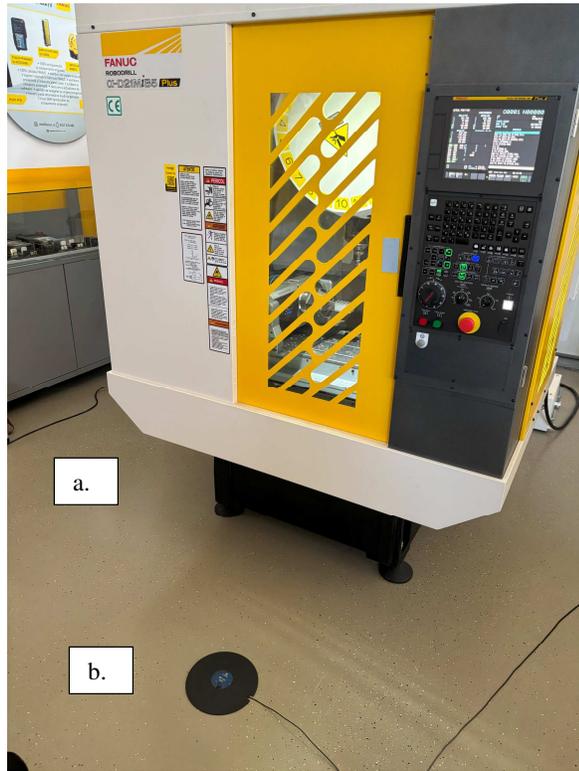


Fig. 1. Place of vibration measurements.
 a. Machine-tool in working time;
 b. The pad on which the operator will stand.

3. THE CONDITIONS FOR THE FEMALE / OPERATOR

The machine tool operator is subjected to vibration measurements in 13 different segments, six on each leg and one measurement on the abdomen, according to the segmental theoretical study carried out in the paper [1].

The sequence of measurements is performed from the sole of the foot, on each foot by highlighting the measurement points, the position of the accelerometer, the correspondence between the channels of the measuring device with the axes of the investigated body and the results obtained by the vibrometer, by interpreting the data.

3.1. Vibrations measured under the sole of the foot

The measurements made on the 'woman' operator start with the right foot, but for a good interpretation the vibrations on the pad enter through both legs, so the image represents the operator on the pad, standing.



Fig. 2. The operator "woman" with socks on the pad

From the accelerometer, the vibratory movement is recorded in the measuring device for 5 seconds. From the image shown in figure 2 and similar ones, the direction of the channels in the accelerometer is identified and the axes of action in the body are established. The tables directly show the axial correspondence of the measured accelerations, highlighted by the SVAN 958 vibrometer.

Table 1.

Measured accelerations for the "woman" on the pad with socks

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1-axa y	0.053088	0.095609	0.043551	0.022387	0.03931	2.371374
2	Ch2-axa x	0.080168	0.139959	0.065313	0.031952	0.057478	2.508996
3	Ch3- axa z	0.068077	0.131522	0.060534	0.026853	0.049831	2.535129

The meaning of the notations in the table:

- ✓ **PEAK** – peak size or amplitude,
- ✓ **P-P** – Peak to peak – double amplitude, or the distance between the extremities of the recording,
- ✓ **Max** – the maximum value recorded for each measurement,
- ✓ **RMS** – Root Means Square – is a crucial metric that represents the effective value of a fluctuating signal, like vibration, over a period of time. It essentially provides a single value that indicates the overall magnitude and energy content of the vibration, making it useful for assessing the severity and health of machinery,
- ✓ **VDV**– Vibration Dose Value - It's a metric used to quantify human exposure to vibration, particularly in situations involving intermittent or impulsive vibrations,
- ✓ **CRF** – Crest value of Frequency - contact resonance frequency.

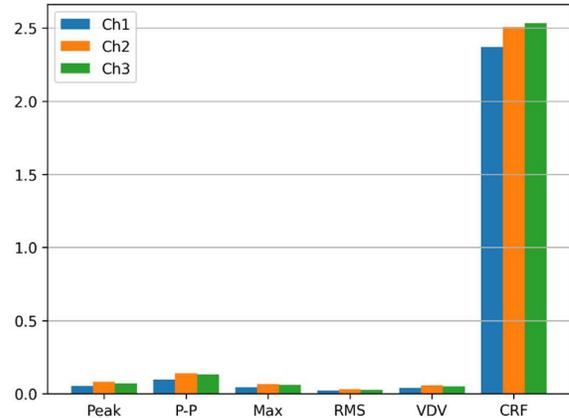


Fig. 3. The result of measuring the accelerations for the "woman" on the pad with socks

3.2. Vibrations measured below the ankle on the right leg

On this position of the accelerometer, two rows of measurements are made; the first has the accelerometer positioned directly on the skin, and the second with the foot shod with socks.

3.2.1. Accelerometer positioned directly on the skin

Table 2.

Measured accelerations for the "woman" accelerometer positioned directly on the skin

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.205826	0.399485	0.166725	0.071367	0.211106	2.884032
2	Ch2- axa z	0.268534	0.482503	0.234693	0.087801	0.254683	3.05844
3	Ch3- axa y	0.206776	0.401791	0.183021	0.076033	0.223872	2.719568



Fig. 4. Accelerometer fixed to the skin under the ankle of the right foot

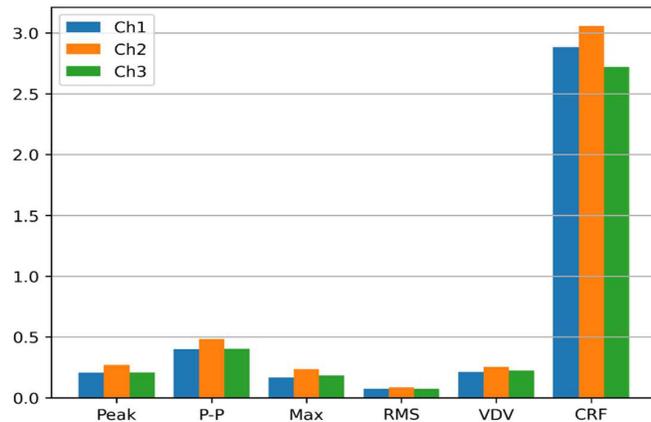


Fig. 5. The result of the accelerations measurements for the "woman" under the ankle of the right leg with the accelerometer fixed on the skin

3.2.2. Accelerometer positioned on socks



Fig. 6. Accelerometer attached to socks below the ankle of the right foot

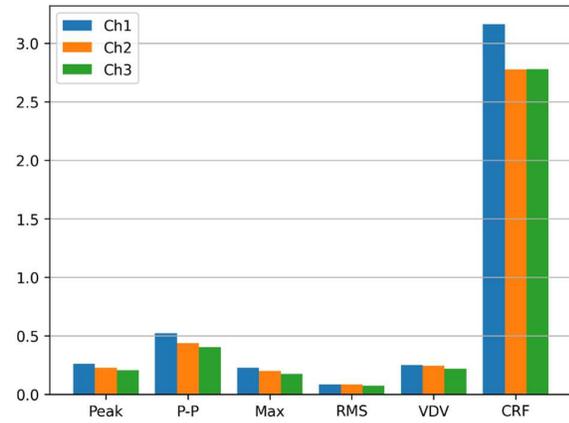


Fig. 7. The result of vibration measurements for the "woman" under the ankle of the right foot on socks

Table 3.

Measured accelerations for the "woman" accelerometer positioned on sock

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1-axa z	0.223872	0.376704	0.18218	0.072527	0.180094	3.08674
2	Ch2-axa x	0.225944	0.427563	0.176604	0.077179	0.194089	2.927521
3	Ch3-axa y	0.174783	0.332277	0.151182	0.068786	0.16885	2.540973

3.3. Measurement of vibration over the ankle on the right leg

For the sake of simplicity of the presentation, it is specified that the measurements made on the "female" human operator for each positioning of the accelerometer are performed in sequence:

- Positioning the triaxial accelerometer;
- Creating the image, for directing the axes of the body, corresponding to the vibrometer channels;
- Taking measurements;
- Extracting data from the vibrometer's memory.
- Graphical representation of accelerations.



Fig. 8. The operator on the pad, with the accelerometer positioned over the ankle directly on the skin



Fig. 9. Detail of fixing the accelerometer on the operator under the ankle of the right leg directly on the skin

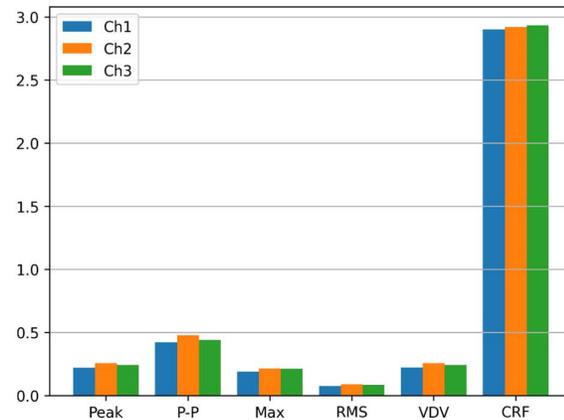


Fig. 10. Result of the measurement of accelerations over the ankle of the "female" operator for the accelerator fixed directly on the skin

Table 4.

Measured accelerations for the "woman" accelerometer positioned on the right leg over the ankle for the accelerometer fixed directly on the skin

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.218273	0.421211	0.187499	0.075249	0.222075	2.900681
2	Ch2- axa z	0.25439	0.476431	0.213304	0.087096	0.256153	2.920788
3	Ch3- axa y	0.242661	0.439542	0.209652	0.082699	0.241268	2.93427

As previously specified, the tables for extracting the data from the vibrometer will be presented in succession with the example of the position of the accelerometer and the fixation mode. Then, in another subchapter, the graphic records of the six accelerometric quantities

highlighted during the measurements will be presented.

3.4. Centralizing tables of the accelerations of the vibration measurements performed on the 'female' operator

Table 5.

Measured accelerations for the "woman" accelerometer positioned below the knee, directly on the skin on the right leg

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.162555	0.3155	0.126038	0.067764	0.106047	2.398833
2	Ch2- axa z	0.348739	0.674528	0.294103	0.197469	0.265155	1.766038
3	Ch3- axa y	0.23632	0.446684	0.203236	0.106414	0.162181	2.220752

Table 6.

Measured accelerations for the "woman" accelerometer positioned over the knee for the accelerometer fixed directly on the skin for the right leg

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.178238	0.318787	0.143054	0.080631	0.143054	2.210548
2	Ch2- axa z	0.359749	0.529054	0.247742	0.096494	0.198381	3.728207
3	Ch3- axa y	0.418794	0.63314	0.247457	0.096161	0.208209	4.355119

Table 7.

Measured accelerations for the "woman" accelerometer positioned on the right leg below the thigh for the accelerometer fixed on textile material

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.232541	0.405509	0.209652	0.083368	0.195884	2.789331
2	Ch2- axa z	0.228034	0.430031	0.18281	0.091517	0.202535	2.491724
3	Ch3- axa y	0.157398	0.314051	0.130167	0.054954	0.13122	2.864178

Table 8.

Measured accelerations for the "woman" accelerometer positioned on the abdomen fixed directly on textile material

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.200217	0.394912	0.161065	0.086497	0.157398	2.314728
2	Ch2- axa z	0.223615	0.416869	0.187499	0.097387	0.177828	2.296149
3	Ch3- axa y	0.279254	0.550174	0.214783	0.086596	0.183443	3.224779

Table 9.

Measured accelerations for the "woman" accelerometer positioned left foot, below the ankle, with textile

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1-axa z	0.223872	0.376704	0.18218	0.072527	0.180094	3.08674
2	Ch2-axa x	0.225944	0.427563	0.176604	0.077179	0.194089	2.927521
3	Ch3-axa y	0.174783	0.332277	0.151182	0.068786	0.16885	2.540973

Table 10.

Measured accelerations for the "woman" accelerometer positioned left foot over the ankle, directly on the skin

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1-axa z	0.210378	0.401791	0.171593	0.097051	0.142561	2.167704
2	Ch2-axa x	0.191205	0.36141	0.143549	0.094624	0.13366	2.020691
3	Ch3-axa y	0.133968	0.180509	0.099541	0.044157	0.073621	3.033891

Table 11.

Measured accelerations for the "woman" accelerometer positioned left leg, below the knee, without textile

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1 -axa z	0.210378	0.405042	0.147741	0.093648	0.139637	2.246467
2	Ch2 -axa x	0.275423	0.425109	0.210378	0.116815	0.168267	2.357762
3	Ch3 -axa y	0.138197	0.263633	0.110662	0.07145	0.101742	1.934194

Table 12.

Measured accelerations for the "woman" accelerometer positioned left leg, above the knee, without textile

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	0.255859	0.395367	0.232274	0.07709	0.135363	3.318945
2	Ch2- axa z	0.266379	0.447198	0.212324	0.093111	0.164437	2.860882
3	Ch3- axa y	0.210378	0.396735	0.164248	0.081377	0.140929	2.585235

Table 13.

Measured accelerations for the "woman" accelerometer positioned left leg, thigh, with textile

Nr. Crt.	Canal	Peak [m/s ²]	P-P [m/s ²]	Max [m/s ²]	RMS [m/s ²]	VDV [m/s ^{1.75}]	CRF [m/s ²]
1	Ch1- axa x	6.426877	12.38797	3.758374	1.661499	3.999447	3.868121
2	Ch2- axa z	9.749896	18.34425	6.950243	3.455413	7.735707	2.82163
3	Ch3- axa y	3.940034	7.055048	2.190282	1.127197	2.567438	3.495425

3.5. Graphical representations of the accelerations measured on the "female" operator with the SVAN 958 vibrometer

An operator, who supersedes a machine tool during work, finds himself (Fig. 1) under the

action of the vibrations produced by it. The area where the operator is located is highlighted in the present work by a pad, which will represent the place where the operator on whom the vibration measurements are made will be placed.

The graphic representations of the quantities recorded by the vibrometer will be presented in the same sequence in which the measurement data are tabulated, with the specification of the defining elements

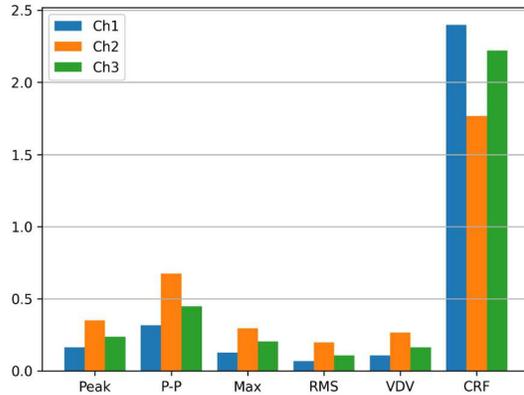


Fig. 11. Graphical representation of the accelerations measured on the "female" operator on the right leg below the knee, directly on the skin

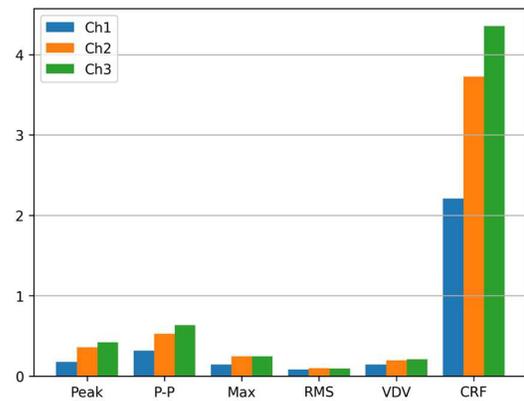


Fig. 12. Graphical representation of the accelerations measured on the "female" operator on the right leg over the knee, directly on the skin

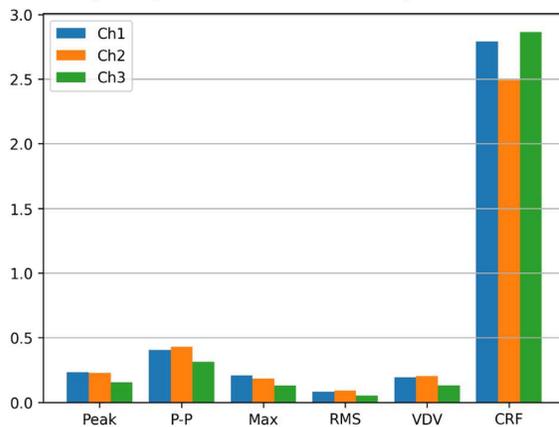


Fig. 13. Graphical representation of the accelerations measured on the "female" operator on the right leg below the thigh, on textile material

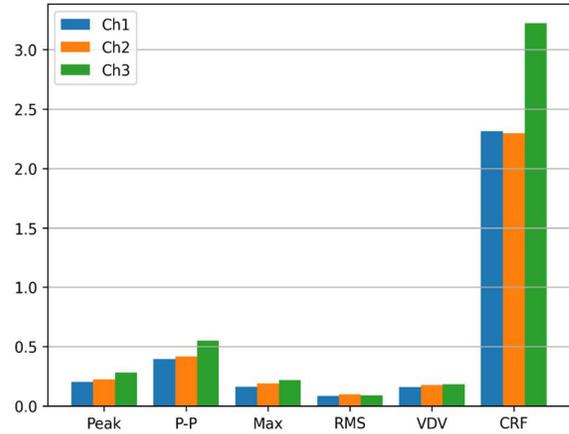


Fig. 14. Graphical representation of the accelerations measured on the "female" operator on the abdomen, on textile material

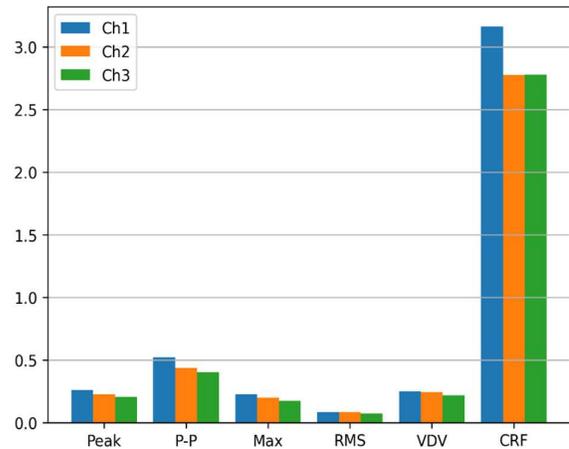


Fig. 15. The result of vibration measurements for the "woman" under the ankle of the left foot directly on the skin

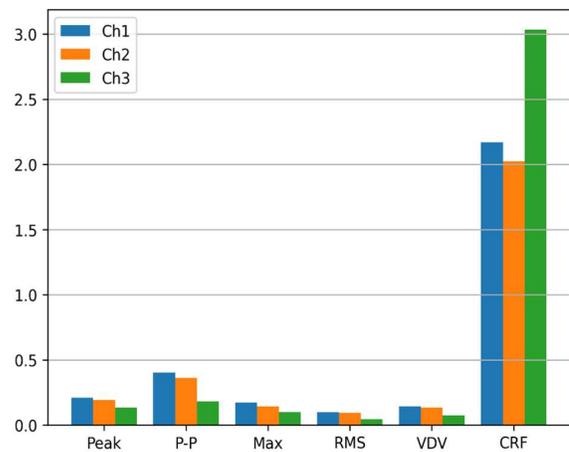


Fig. 16. The result of vibration measurements for the "woman" over the ankle of the left foot directly on the skin

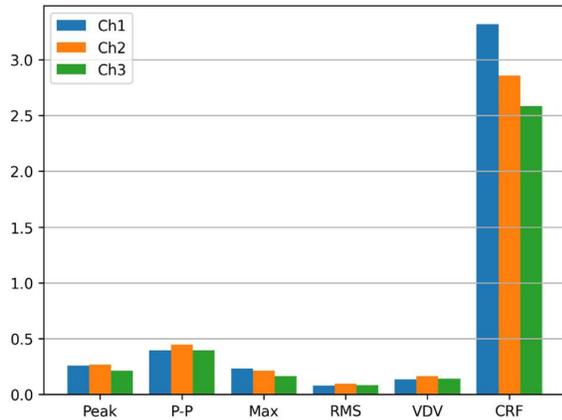


Fig. 17. Graphical representation of the accelerations measured on the "female" operator on the left leg below the knee, directly on the skin

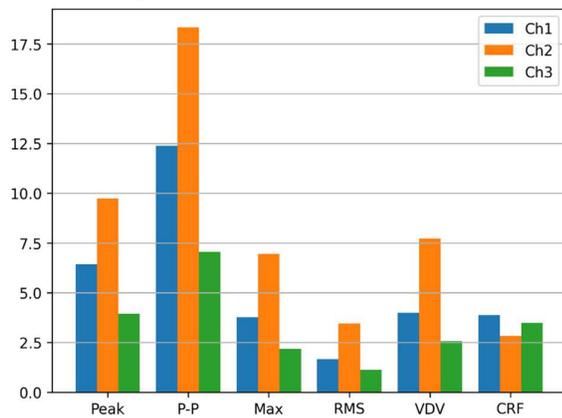


Fig. 18. Graphical representation of the accelerations measured on the "female" operator on the left leg over the thigh, with textile

4. CONCLUSIONS

This paper studies the action of vibrations, which act on the operator "female", who serves a machine tool, with numerical control during the production process.

The upper part of the body sums up the vibrations transmitted through the legs; the entrance being made in the abdomen. The successive position of the accelerometer started on the right leg until the abdomen, and go down on the left leg.

In this paper, we try to demonstrated that, all are given in the literature, as studies [12], [13], [14], [15], [16], [17], [18] are the important studies for the action of the vibrations over the human bodies. The [19], [20] refences proposed that the 3D is the solution for the human body

representation, if the vibrations are presented over the human body

The conclusions of the measurements can be expressed as follows:

1. The abdomen together with the upper part of the body is considered to form a rigid solid, which reacts to the vibrations transmitted. In the measurement situation, the super part of the body is not subjected to the vibrations with a very great action. The VDV is less than the normal values given in literature.
2. If the "female" operator is right-handed, smaller values appear from the representations for the segments on the right side, compared to those on the left side.
3. The opportunity to study the prothesis of the computational part of the leg, can be realized if they are the measurements of the vibrations transmitted through the legs, as given in this paper, for the "female" operator.
4. The results of made and presented measurements in this paper, an human operator "female" can given her activity to look at the mechanical process of production on the machine – tool with numerical program in the assurance conditions.
5. The paper contributes to the study of vibrations acting on the operator "female", who serves a numerically controlled machine tool, without causing health damage to the human body during processing.

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Punerea in evidenta prin masuratori ale vibrațiilor mecanice produse de o mașină-unealtă FANUC asupra unui operator uman “femeie”

Rezumat: Lucrarea este parte a tezei de doctorat, in care se studieaza actiunea vibratiilor asupra unui operator, ce deservește o masina-unealta FANUC la mersul in gol. In lucrare se efectueaza masuratori asupra operatorului la transmiterii vibratiilor de la masina-unealta prin picioarele operatorului, care este asezat la local de munca pe un postament, pe care se gaseste o saltea de cauciuc. Se fac masuratori cu vibrometrul SVAN 958, pas cu pas pe ambele picioare, pana la abdomen, care constituie partea inferioara al corpului operatorului “femeie”, considerat un solid, cu cele trei caracteristici, de masa. Amortizor si arc. Prin aceste masuratori se cauta sa se dovedeasca faptul ca starea de sanatate a operatorului “femeie” un este afectata de expunerea la vibratii.

Cuvinte cheie: masurarea vibratiilor, operator femeie, interpretarea rezultatelor.

Aurora Felicia CRISTEA, Assoc. Prof. Dr. Eng., Technical University of Cluj-Napoca, Department of Mechanical System Engineering, B-dul Muncii, Nr. 103-105, Cluj-Napoca, ROMANIA.

Adela Bianca CRĂCIUN (căs: HOSU), PhD Stud., Eng., Technical University of Cluj-Napoca, Department of Mechanical System Engineering, B-dul Muncii, Nr. 103-105, Cluj-Napoca, ROMANIA.

Mariana ARGHIR, Professor, dr. Eng., Technical University of Cluj-Napoca, Department of Mechanical System Engineering, e-mail: marianaarghir@yahoo.com, Tel: 0264.401.657, B-dul Muncii, Nr. 103-105, Cluj-Napoca, ROMANIA.