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STUDY WITH OPTICAL METHODS OF THE MECHANICAL VIBRATIONS ACTION OVER THE HUMAN BODY.

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Abstract: The paper contains the theory regarding the optical methods for the measurements of mechanical characteristics. The mechanical vibrations action on the human body can be measure with the optical methods. In the paper there are the comparisons between the classical method of measurement (using the device SVAN 958) and the optical methods with the principal of Moiré of projection. The measurement results are the same that means the Moiré of projection method can be apply for the vibrations measurement on the human body. This is the first application for Moiré of projection method in the vibrations measurement and it is a very important fact because the optical method is without touch.

1. Introduction

Mechanical vibration measurement by optical techniques (no contact) is much used today in industry and in other research sectors. Because optical techniques can be applied to humans must be used in a laser pulse, whether purchasing images using a camera (> 10 000 images/s) [1], [4].

The realization of three-dimensional measurements of the absolute without contact is made with the help of acoustics captivators (acoustic holography, localization techniques) and by techniques of absolute measurements (radar, sonar). Three-dimensional measurement without contact can be achieved by optical captivators (absolute measurements through Stereoscopy, Fotogrametry, structured light Projection, Triangulation), but you can also perform relative measurements by the method of projection, Interferometry Moiré, Holography and numerical Holography [2].

Three-dimensional measurement techniques without contact are generally based on an optical fundamental principle. They constitute a means of making and performing complex measurement without contact. Some of these techniques are based on biological models that are very complex for the human body study.

2. Moiré of Projection Method

2.1. The General Knowledge

The phenomenon of Moiré pattern is used to measure the landscape on a surface. There are several variants of Moiré methods [3]:

- Moiré geometrical website: method in which they appear is overlapping network fringes control over the distorted pasted directly on the network;
- Moiré-screening: where fringes overlapping projected image appear on the object and the projected on a flat surface;
- Moiré site of shadow: fringes appear overlapping between the network and their shadow on the object;
- Moiré-site by reflection: fringes appear overlapping lines network control with those obtained by reflection on the reflecting surface of the object studied;

- Moiré techniques were developed for the measurement of strains in the plan or outside of the plan object.

The phenomenon of Moiré is the emergence of the interference fringes near its representing the locus of points of equal displacement of the object, which appear to overlap Optics (remotely) or mechanical (with contact) of two networks of lines or points, which is not the same as the orientation, shape, or distance between lines.

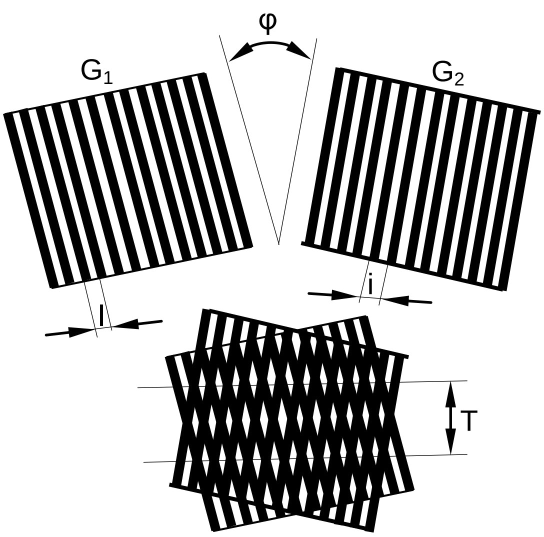
This method of measuring 3D is composed of two stages. In the first step in the emergence of the phenomenon of Moiré pattern consists of a third networks by overlaying two grids of lines. The second stage, called the phase offset method consists in determining the field phases starting from a certain number of images shifted between them with a φ phase angle. This field allows the characterization of the phases of a network of fringes.

2.2. The Principle of the Phenomenon of Moiré pattern

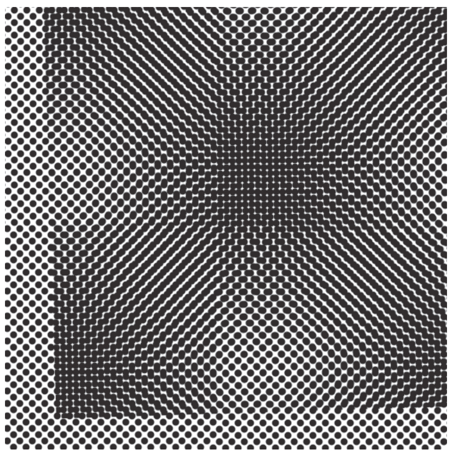
The principle of the Moiré pattern is based on an optical phenomenon. This phenomenon occurs when two grids are overlaid. The phenomenon of Moiré is the overlap of two physical networks making it appear a third network visible which is based on the first two. Networks can be of different natures, they may be predominantly geometric lines, cross-lines, circles, ellipses, etc.

The simplest Moiré phenomenon which may encounter is that which consists in the overlap of two networks of lines identical with an angular gap (Fig. 1). By Moiré effect means a single fringe interference array representing the locus of points or lines of equal displacement i, which appear to overlap (no contact) optical or mechanical (with contact) of two networks of lines G1 and G2 or points as shown in Figure 1.b when the two lines are parallel networks (the angle φ is zero) is observed by single fringe field (just dark or light). When networks of lines are rotated by an angle φ is observed a similar period of Moiré fringes T, as in Figure 1.a, is given in the following relation:

$$T = \frac{i}{2\sin\frac{\varphi}{2}} \tag{1}$$



a)



b)

Fig. 1. The principle of overlap of the two networks to get single fringe Moiré pattern with an offset angle between the two networks: a) the two networks of lines; b) two network points [4]

2.3. The principle of the method of the Moiré pattern projection

Moiré pattern projection method is an optics method, which consists in designing a network of single fringe, with the help of the projector on the body surface. When the network meets the surface of the body of single fringe measured, the network is distorted by the shape of the surface and the image is recorded by a CCD (Charge Coupled Device) camera.

The geometry of the surface is obtained by processing (treatment) of digital images. If the surface is perfectly flat, the intensity of the fringe shift designed alternate light and dark in the regular artistic circles of a step "p" is given by the relationship (2), when it is assumed that fringes are aligned on the y axis [2]

$$I(x,y) = I_o\left[1 + \gamma\cos\left(\frac{2\pi x}{p}\right)\right] \tag{2}$$

where: I(x,y) is the intensity in the specificate point, with the coordinates x and y; I_0 – is the average intensity; γ – is the contrast. The intensity has the harmonically (periodical) variation between the $I_0(1 + \gamma)$ and the $I_0(1 - \gamma)$.

The principle of this method lies in the overlap of two service network on the same photographic plate in double exposure. The first image contains the observation of the design of a network on a plane of reference, and the second image corresponds to give network designed on the object (Fig. 2).

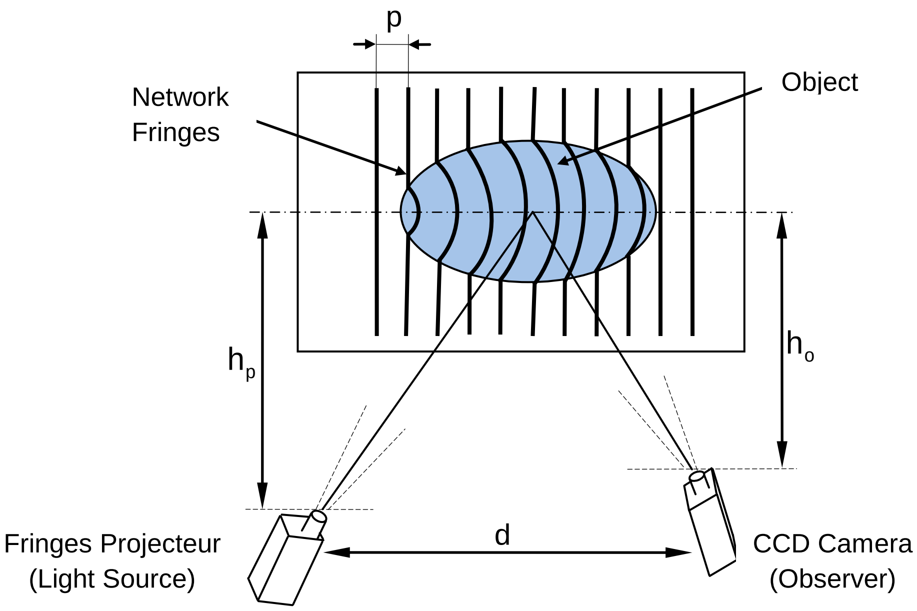


Fig. 2. Moiré projection method [5]

Where: d – represents the distance between the observer and the projector; h_p – distance projector – network; h_o – distance network – camera; p – step of fringes network.

For Moiré pattern projection method, it is sufficient to move the Network Physics in his plan. If the hypothesis of parallel beams is maintained, the relief is then proportional to the difference between the reference network and the network object.

Accuracy is enhanced when phase-offset is used. This allows the analysis of the network of single fringe turning it into a field phase φ. Precision obtained with this technique is around about 10 mm.

Principle of Moiré pattern projection light beam with coherent temporal gap allows real-time measurement of fields with very large amplitudes of vibration. These fields of amplitudes may be measured either directly on the surface of the human body or on the surface structure of mechanical interaction with the human being.

3. Measurement of Human Vibrations

3.1. Directions of vibrations propagation on the human body

Regional or local vibrations appear in the contact areas of the body parts in vibration. Most often in contact with sources in the vibration are the legs (i.e. the hands and feet) and the thoracic part (i.e. the back when the man is seated on a surface that vibrates) and more rarely the head and back. Perceptibility vibrations transmitted to the hand or arm is often felt in other parts of the body, most often to the head.

The expression "local vibration" suggests that the effects of the vibrations are located near the point of contact of the vibratory source. Duration of effects cannot be determined exactly, because the vibrations are passed on from hand to body, and their effects are manifested in various forms [5].

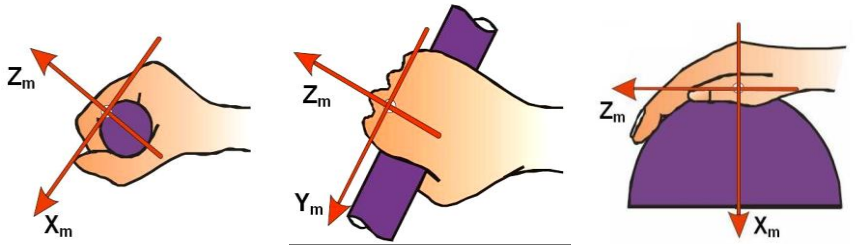
It is known that the main causes of transmission of the vibrations from hand tools and appliances are working in the industry, construction, mining, where hand tighten and or press gear vibration.

In the case of transmission vibration hand-arm vibration sources are generally tools rotating or strikering; power Windows, pneumatic or hydraulic. In this category: boring machines with percussion, hammers and chisels pneumatic vibratory plates for concrete and Earth, striking the Earth for mechanical tampers etc.

Vibrations are transmitted to the human body directly, through contact with vibrating tools such as pneumatic hammer, or indirectly through other objects (an example being the transmission of the vibration of the machine tool via the resistance structure of the building to personal image does not have direct contact with the machine tool that produces vibrations).

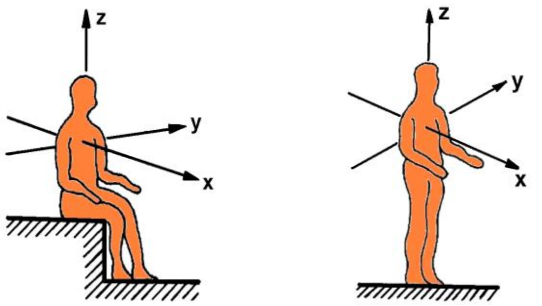
The vibration amplitude, frequency and duration of exposure to vibration in physical sizes are easily led the experiment. The mode of transmission of vibration to the human body is by:

- On the vibration of) the action of certain parts of the body, the hand-arm system is the most exposed (Fig. 3.);
- Action on whole-body vibrations, met at positions standing, sitting, lying or undefined position (Fig. 4. Fig. 5).
- Coordinate system (with the index m at hand) is defined for both fastening position (Fig. 3 a. and b) when the Palm is closed, and how to contact with the source of the oscillation (Fig. 3. c) when the palm is open.



a) b) c)

Fig. 3. Basicentrice axes of vibrations transmission at hand-arm system



a) *b)*

Fig. 4. Directions of mechanical vibration actuators transmitted on the human body: a) seated; b) standing.

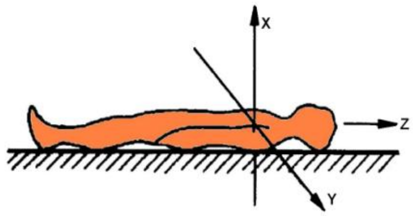


Fig. 5. Directions of mechanical vibration actuators transmitted to the human body lying

3.2. Measuring of vibrations through the projection Moiré method

Through Moiré pattern projection method can measure the topography of an object, results in the form of a cloud of points. It can be applied to objects from a few centimeters square feet up to several square feet.

The time of acquisition and calculation for measuring the topography throughout the field is a few minutes, compared with three-dimensional measuring machines which can go up to several hours of purchase.

Reconstruction can be done on the entire surface of the human body or parts of it: the hand, arm, spinal column, head, feet, etc.

3.2.1. The Software "Project" for vibrations measuring by Moiré projection method

The Software "Project" is based on relationships corresponding to the vibrations measuring by Moiré projection method and allows the calculation of the relief, but also distort of a piece Moiré projection by method associated with the technique of gap phase of the three images. Method for obtaining relief needs of two sets of images: the first with the reference plane and another with the subject studied. The Software was developed under Windows 3.11 and is compatible with when Win95 version.

Minimum system configuration for running of the software "Project" is a PC Pentium 133 MHz, 32 MB RAM, 1 GB HD. minimum computer screen Resolution should be 800 x 600 pixels. Space required on hard drive for the installation software is 1.3 Mb.

The Software consists of several parts:

- acquisition of images;
- analysis of the images;
- reading the disk images, colors, posting images and recovery profiles in grayscale.

3.3. Vibrations analyser SVAN 958 and software for measuring vibration

The SVAN 958 (Fig. 6.) is a digital vibration analyser with four channels, what measure and analyse the sounds and vibrations in the field of 0,5 – 20 Hz. is specially designed for the measurement of vibration on the human body signals being consistent with SR ISO 2631/1, 2, 5 and SR ISO 5349/1, 2. The device uses traducers single axis or with three axes and each of the four data channels can process simultaneously, having independent settings for each channel (e.g. the type of traducers, filters and time constants of the translator r.m.s.). The device is specialized for measuring vibrations acting onto the human organism, with differentiated on the two systems standardized: the human hand-arm system and the system of the entire human body.

The device can perform measurements in real time [6]:

- on 4 channels in the frequency band of 1/1 octave, 15 filters with centre frequency between 1 Hz and 16 Hz (Type 1, IEC 61260) and in the bands 1/3 octave, 45 filters with centre frequency between 0 Hz and 20 Hz (Type 1, IEC 61260) that include static analysis of the channels;
- 4 channel FFT spectrum analysis to include the cross up to 1,600 lines;
- sound intensity, depending on how the setting chosen.

Fig. 6. Apparatus SVAN 958 for measuring the vibrations and noise: a) device; b) main menu of the appliance

4. Measurement of vibration on the human hand-arm system

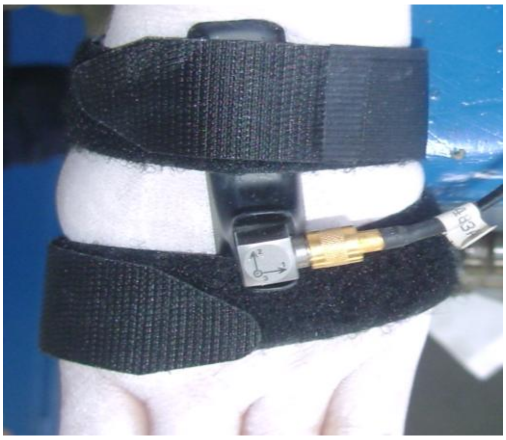
4.1. General Conditions

Vibration measurements were performed on human hand placed on the car carrier of vertical boring MA x 750. Volunteer undergo experiments was informed of the details of the experiment and the risks to which they are subjected by applying vibrations produced by the machine-tools on his body. For measurements made on the car roof was chosen as a subject of genus male, age 24 years healthy from the physically point of view.

4.2. Vibrations measuring of boring vertical machine MA x 750 to light running with 180 rot / min

4.2.1. Vibrations measuring with the vibrometre SVAN 958

The device was used to measure noise and vibration apparatus to the SVAN 958 [6], which was connected to a transducer Triax K3, this was fixed with a screw on a metallic support slightly and so the database resulting from measurements include data on the three coordinate axes. Together with its support accelerometer (Fig. 7) was mounted on the human body with the help of bands well tightened around anatomical locations measured.

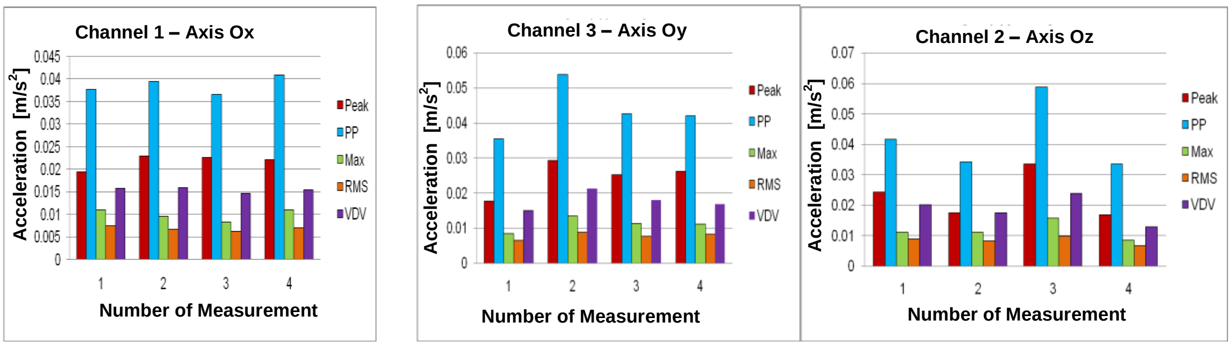


Directions represented on one represent the directions for the three channels that has made acquiring data. If the measurement at hand is, as seen in figure 7, direction "1" represents the axis of the Ox to the body, according to the system of axes described in Chapter 3.1. Direction "2" is the axis of the Oz in the positive sense, and the direction of "3" represents the axis Oy in the positive direction of the axis.

Fig. 7. The accelerometer mounted on hand

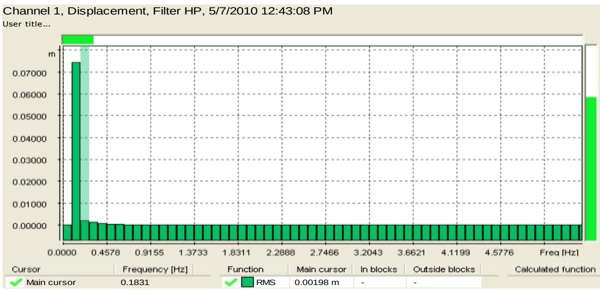
Measurements have been executed at the Technical University of Cluj-Napoca, on a machine for drilling of vertical type MA x 750, with characteristics: the motor power of P = 3 KW; for 180 rpm.

The conditions under which measurements were made were the following: the human operator and has kept right hand on fixed column of vertical boring machine; the measurements were made at the morning (10 a.m.); during the measurements was boring a cylindrical piece with a diameter of 60 mm, drilling was accomplished with the speed of advance of = 0.1 mm/Rev.

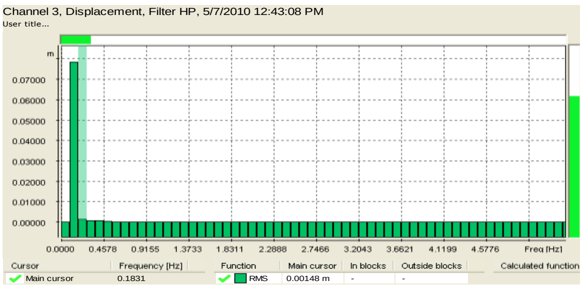


a) b) c)

Fig. 8. Accelerations Peak, Peak to Peak, RMS, Max [m/s^2] and VDV [m/s^2] corresponding to the measurements carried out in idling car-gear axes: a) Ox; b) Oy and c) Oz



a)



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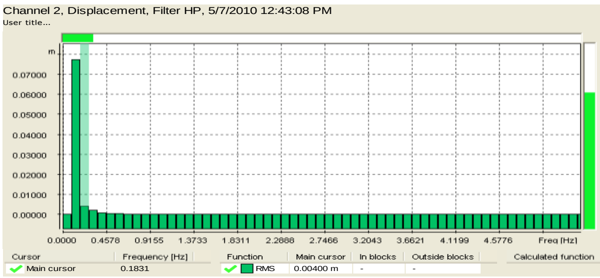


c)

Fig. 9. The spectrum of movement at idling of machine-tools with speeds of 180 RPM: a) on the axis Ox; b) on the axis Oy; c) on the axis Oz

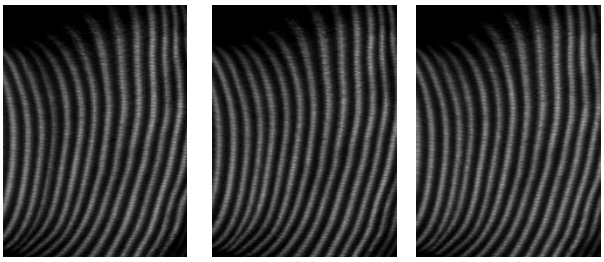
- The maximum value of movement on the axis of the Ox is of 0.00198 m and is found in the right frequency of 0.1931 Hz.
- The maximum value of movement on the axis Oy is 0.00148 m and is found in the right frequency of 0.1831 Hz.
- The maximum value of movement on the axis of the Oz is 0.00400 m and is found in the right frequency of 0.1831 Hz.

4.2.2. Measurement of vibration on hand at idling light running of the machine boring MAx750 with Moiré projection method

Measurement of vibration of vertical boring machine at idling speed and load of the main axis of the rotation of 180 rpm, in the direction of Oy with speed advance = 0.1 mm/Rev. Using an projector was lighting the place on the hand which happened metrics to be able to see it as more clearly fringes Moiré pattern (Fig. 10). Were designed three grids of projection over hand with phase difference between them, in order to be able to measure the amplitude of vibration when the images are off between them with an angle of 120 °. For the acquisition data was in need of a data acquisition system [5].

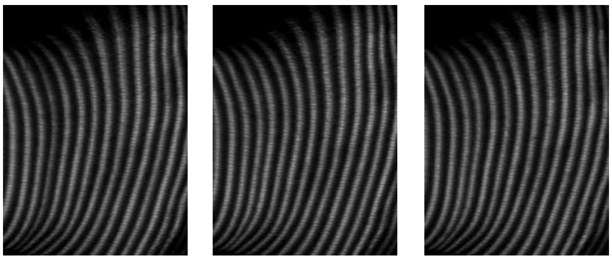
Fig. 10. The position of hands on vertical boring machine

To the processing of the results was necessary to acquire three images in static drive boring stopped (Fig. 11a, b, and c) which have been phase differences between 120 ° and three images with the machine for drilling at idling (Fig. 12 a, b, and c) also phase differences with 120 ° between them. For the purchase of images was used CCD camera. For the purchase of images was released by getting service window of the software "Project".



a) b) c)

Fig. 11. Calibration



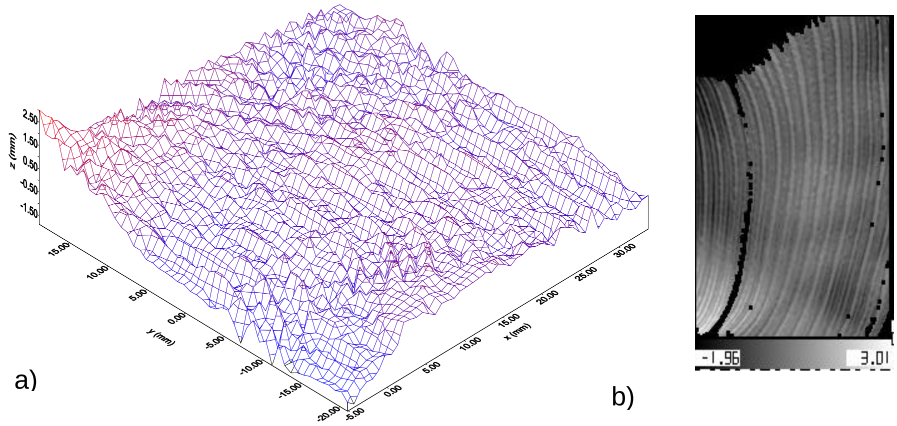
a) b) c)

Fig. 12. Machine for drilling at idling

The characteristics of the mask were set for the level of gray at the threshold of the mask of 15, and at the threshold of the batch of 1. The point of reference to changing the phase is 0, the horizontal position is 21 pixels vertically, and all of 114 pixels.
Characteristics of the optical Setup for measurements
The distances between: - the projector – Device = 990 mm; - CCD Camera-Projector = 955 mm; - CCD Camera-Device = 890 mm.

Step of the network of lines is 0.5 mm. focal length is 100 mm. These sizes are needed to calculate the topography and distorting the play. The gradient elected was

0.185639 (mm/pixel). The measurements result is given in the figure 13, and it is 4.97 mm. This is in the same scale of the classic measurements (Fig. 9).



a) b)

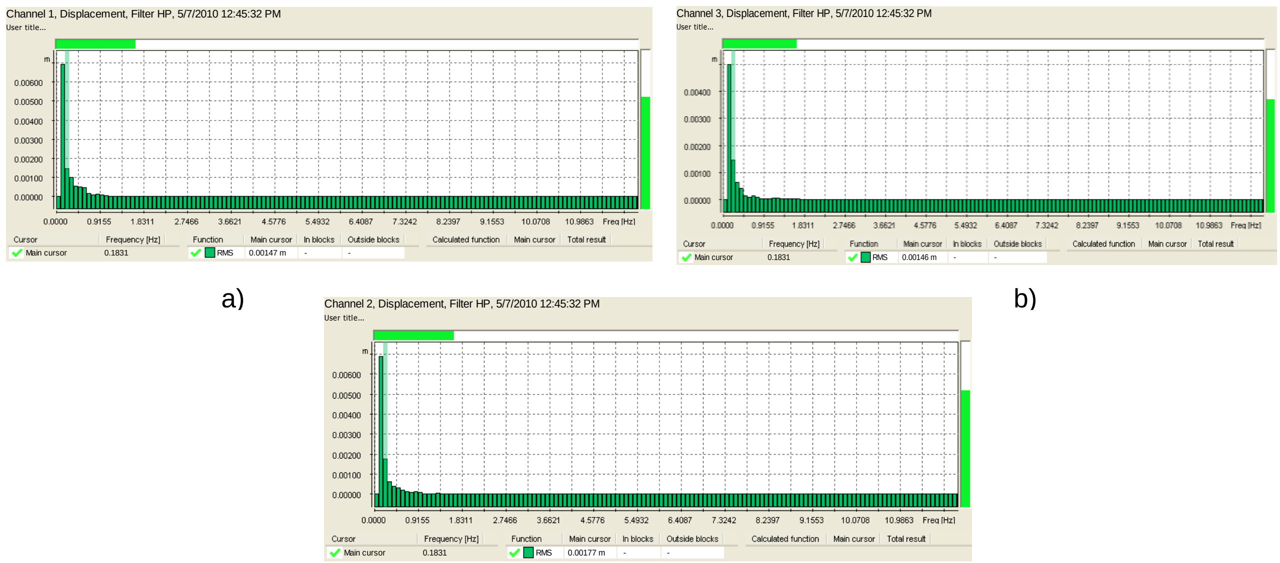
Fig. 13. a) Image of deformation in 3D); b) Value of deformation

4.3. Vibrations measuring of boring vertical machine MA x 750 walking in the task

The values are obtained from measurements on boring machine in the task at the speed of main axle rotation of 180 rpm and the speed of advance = 0.16 mm/Rev

4.3.1. Measurement with SVAN 958

The values are obtained from measurements on boring machine in the task following the same steps as in the previous situation. The results are given in the figure 14.



a) b)

c)

Fig. 14. The spectrum of movement of machine-tools in the task with speeds of 180 RPM: a) on the axis Ox; b) on the axis Oy; c) on the axis Oz

- The maximum value of movement on the axis of the Ox is of 0.00147 m and is found in the right frequency of 0.1831 Hz.
- The maximum value of movement on the axis Oy is 0.00117 m and is found in the right frequency of 0.1831 Hz.

- The maximum value of movement on the axis of the Oz is 0.00146 m and is found in the right frequency of 0.1831 Hz.

4.3.2. Measurement with Moiré projection method

They have completed the same steps for measuring vibrations on hand at riding under load equally with those who have traveled for measuring vibrations on hand from idling. Have purchased six images of which: three images in static that have been phase differences with 120 ° between them and the three drive boring to walk under load from a drills for drilling ø 14 mm in one piece cylinder diameter 60 mm given the speed of rotation of 180 rpm and the speed of advance = 0.16 mm/Rev. The measurement result is given in the figure 15, and it is 16.61 x 10^{-1} mm = 1.661 mm.

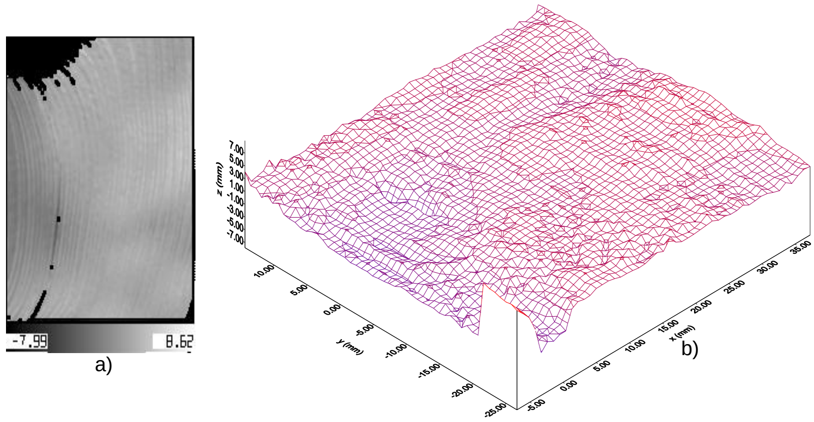


Fig. 15. a) The value of the deformation; b) Image of deformation in 3D

5. Conclusions

In this paper was demonstrated that the Moiré projection method can be apply to measure the vibrations on the human body. There are the following conclusions:

1. The results of vibration measurements are the same using both methods: classical method and Moiré projection method.
2. The classical method with vibromètre need to apply the accelerometer on the skin of the human subject and this disturbs sometimes the working process.
3. The Moiré projection method is without touch, but it need to cover the skin surface with a white material on which will form the light fringes.
4. The Moiré projection method needs a sophisticated lot of apparatus and special devices that means the application of this method must to be justified.

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