Precision measurement method for small and very small displacements using the laser vibration meter

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Abstract – The paper presents a system which is capable to perform a measuring method for small and very small displacements (microns). The measurements were made using a laser vibration meter, are very precise and can be controlled with a PC. Through the static and dynamic analyze of the system, we noticed if the polarity of the current is changed, using the same current settings in the computer, the displacements of a loudspeaker's membrane are different. The displacement of the membrane is smaller for the advancement than for the receding. A copper line could be attached to the system, line which could suffer tensions or distortions, but could be displaced horizontally very precise.

I. Introduction

During the last years many high-precision numerical equipments for measuring the displacements have been developed [1] [2]. The laser vibration meter is a device which performs non-contact single-point or differential measurements, which visualize vibrations or microscopic cartography of a surface.

Laser vibration meters are used to measure precisely mechanical vibrations [3]. They are based on Doppler principle, measuring the laser ray dispersed back by a vibrating object, to determine the displacement and the speed of the vibration [4].

II. Theoretical considerations

Figure 1 presents the measurement of the dimension for a symmetrical position of the laser, δ=0.

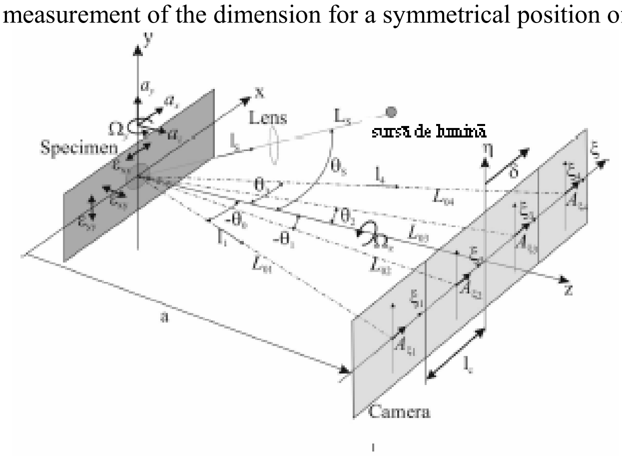


Fig.1. Measurement scheme with 4 virtual rooms

The mathematical approach and the signal processing algorithms are taken from [5] [6], resulting the equations needed for the implementation of the measurement method.

III. Measurement method for small and very small displacements

Experiments and measurements with a single loudspeaker have been carried on.

The following workbench has been realized:

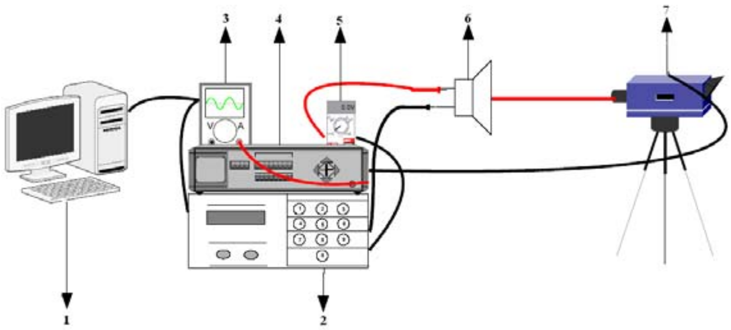


Fig.2. – Workbench components:
1. Computer for the automatic system control;
2. Power supply Agilent 6653A;
3. Oscilloscope Tektronix 1002 TDS;
4. Laser vibration meter;
5. Ammeter;
6. Loudspeaker;
7. Sensor-head of the laser vibration meter.

The power supply is connected together with the oscilloscope to the computer via the GPIB interface, thus the current and voltage could be set and the oscilloscope signal is visualized on the computer. The loudspeaker is connected to the power supply and the oscilloscope is connected to the signal output of the laser vibration meter.

The vibration meter is connected to the sensor-head of the vibration meter. This is positioned such as the laser ray come perpendicularly on the plane surface of the loudspeaker and to be reflected exactly to the sensor-head. In order to have a good reflection, the laser contact surface and the membrane with TiO_2.

To visualize the functioning of the system, a value for the output current and voltage is set. The loudspeaker's membrane moves and the head of the vibration meter feels it, then transmits to the vibration meter which will send the output signal to the channel 1 of the oscilloscope, which will transmits via GPIB he signal to the computer. In such manner we obtained a signal that shows the difference, in Volts, between the final position of the membrane after setting the current and its initial position.

The output quantity of the vibration meter is measured in V/mm, and to obtain the displacement in mm we have to multiply the order of the vibration meter with the voltage difference between the two positions of the membrane. Thus, we obtained the membrane's displacement in mm according to the real output current of the power supply.

First step is to set in Matlab the output voltage and current for the membrane's displacement. The voltage will stay at 8 V and the current will be variable, according to the displacement we want to obtain. The bigger the current, the bigger the displacement will be.

There are two Matlab programs, one to initialize, to set and to control the power supply, and the second one to read the values from the oscilloscope.

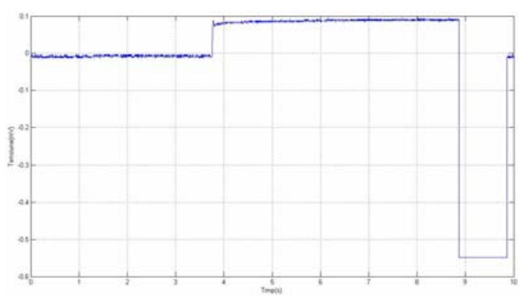


Fig.3. – Voltage-Time chart

We notice that the voltage value is not perfectly linear and perturbations occur because of:

1. acquisition conditions, steps, movements, air currents;

2. interferences with other electrical equipments;

3. a slightly move of the membrane, because the output voltage of the power supply is not constant;

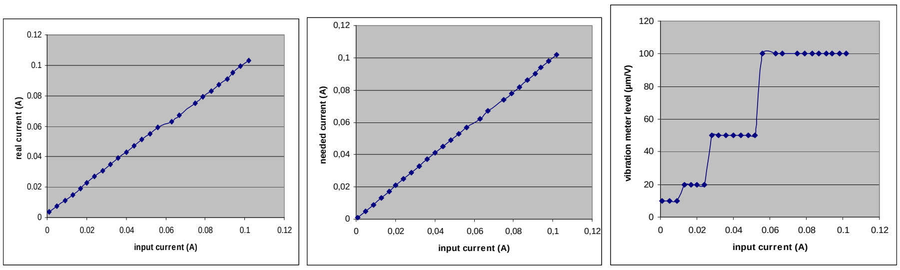
In order to calculate the voltage difference from the chart and implicitly the displacement of the membrane, we should calculate an average of the perturbations. We notice a barrier drop in the right-hand side of the graphic (-0.5 V), because of the stabilization of the system and until the data acquisition and measurements start. We eliminate this part and we use the data until second 8 from the time-axis.

The voltage difference D will be the difference between the D_f and D_i, where D_f is the average of the perturbations from the second 0 to second 3, and D_i is the average of the perturbations from the second 4 to second 8.

The order of the oscilloscope is set to 100V/division, and the vibration meter one's is 5µm/V. The voltage difference is 9,215 V, and the membrane's displacement is 9,215 x 5 = 46.077 µm. Thus, for a real output current of 0.00715 A, the membrane's displacement is 46.077 µm. The measurements are carried on until a current of approximately 0.1 A.

We notice that the used power supply has not a constant output current, therefore the set Matlab current is not always equal to the power supply's one.

Results of the measurements are presented in the following charts.



a) b) c)

Fig.4. – a) real current – input current chart

b) needed current – input current chart

c) vibration meter level – input current chart

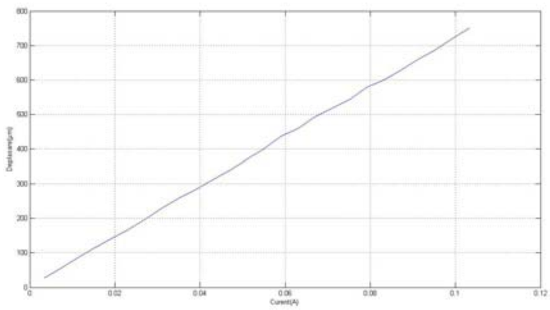


Fig.5. – Displacement-current chart

For the charts the 25 measured values of displacement and current, respectively, have been used. We notice that the membrane's displacement is linear, according to the current from the reeling of the coil.

In order to execute multiple measurements of very small displacements, we need a smaller output current and, implicitly, a smaller current in the membrane's coil reeling. Because the power supply has a minimum output current of 0.001A and because of the big difference between the consecutive output currents of the power supply, we connect a resistor in parallel with the loudspeaker. The purpose of this resistor is to lower the current from the loudspeaker and to obtain smaller displacements of the membrane.

IV. Conclusions

A system with a laser vibration meter, capable to perform small and very small displacement measurements is presented. These displacements are very precise and could be very well controlled by the computer. A copper line could be attached to the system, line which could suffer tensions or distortions, but could be displaced horizontally very precise.

Performing a series of static measurements and a dynamical analysis of the whole system, we notice that for the same current set from the computer, the displacements of the membrane are different, when the polarity is changed. The displacement of the membrane is smaller for the advancement than for the receding. This fact is due to the force of the membrane, which is smaller for the receding to its initial position.

In order that the membrane executes a displacement of 1.6 microns, we should have through the membrane's coil reeling of the loudspeaker a current of 0.25 mA.

V. References

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