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MEASURMENT OF VIBRATION FREQUENCY OF THE VIBRATING OBJECTS BY LASER

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ABSTRACT

When the rugged surface of a matter is illuminated with laser, the scattered beams from the surface of the object are interfered together and make laser speckle pattern. By analysing the variations of these patterns, useful information is obtained about the vibrational displacements of the surface. In this paper, a method based on laser speckle patterns used to measure the vibration frequency of the illuminated object from in a long distance. Detected frequency of the object is in a good agreement with the real frequency.

Keywords: Laser speckle, Surface vibration , Interference

Vibration is an oscillating motion around the equilibrium point. All objects that have mass and elasticity are capable of vibration, so most of the machines and various instruments are vibrating at different frequencies. Vibration can be found in the transportation, aerospace, industrial environments, etc.Vibration measurements in industrial machinery lead to early diagnosis and the control of vibration of machines. However, there are different ways to record and detect the movements of objects. For example, in industry, vibration sensors gain particular importance. Vibration sensors are the primary instruments needed for measuring vibration which sense vibration movement, and put it into an electrical signal proportional to the AC vibration. In other cases, it can be noted that the piezoelectric accelerometers have low sensitivity at low frequencies which can be noted as one of its major disadvantages.As another industrial applications for recording the vibrations, accelerometers can be mentioned. By use of an accelerometer, vibration signals can be analyzed and reviewed. It is evident that mentioned measuring instruments are mainly capable of measuring vibrations in contact with the vibrating object which causes limitations. In addition, suitable position of sensor connector and cable are the factors which should be considered in sensor use (Wali, 2012; Holler et al., 2007). One of the newest methods using laser optics to record the vibrations is able to measure body vibrations without any contact. Laser spackles are patterns which are caused by the interference of coherent laser beam that deal with the object with specific surface roughness and reflectivity. The interference of coherent waves which are not in phase leads to spot pattern.When a rough surface is illuminated by light with high coherence and the surface is vibrated under the effect of a certain frequency a slight deformation of the body is created and the spot pattern formed by the reflection of light Will change. Localized movements in the surface of the body cause localized changes in the pattern of spots and these changes are directly related to the changes, or to the vibration of the object. In fact, the size of the laser speckles depends on several parameters such as: Wavelength of the Laser, degree of coherence, used lenses; observation plane of laser speckles.Vibrations of objects can be either caused by sound sources or the object itself which vibrates as a vibrating source. In general, two modes of vibration of the objects can be investigated. First, the vibrations which are caused by sound sources for example the vibration of a paper which is exposed to the audio source like a loudspeaker. The second study is when the object is vibrating as a sound source which means that in the process of testing the vibrations of speaker are directly observed and recorded. In both cases there are different ways to measure vibrations. For example, the use of laser Doppler effect in measurement process with high speed camera for detecting oscillations of laser speckle patterns and processing the recorded signals in order to achieve the vibrational frequency of the object(Hague et al., 2007), the detection of vibrational frequencies of an object with small amplitude in long distance by a Yb^{3+} fiber laser, in which laser speckle is formed by the incidence of laser beam on vibrating object, and reflection from surface of the object. Received signal from the detector is amplified by a low noise audio preamplifier and is registered by typical sound card of computer (Veber et al., 2011), laser vibration detector detects almost

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invisible vibration. The base of device is formed by a laser pointer and a simple receiver circuit. This device is based on the detection of changes in the reflected laser beam intensity and received by a photo detector. Device performance is limited to a reflective surface such as a mirror or a glass window. There is no guarantee of the availability of these surfaces. Another limitation of this device is that the laser beam should be close and (but not exactly) parallel to the normal vector to the surface (Shih-Yu Sun, 2011), and pulsed laser vibrometer consists of a pulsed laser light, and an optical sensor. The object vibrations are measured by the changes of photon flow. The advantage of this method presented in this paper is the simplicity of its experimental setup, its speed and accuracy of obtaining the vibrational frequency of objects. In addition, in this method, there is no need for special laser source or high-speed cameras (ChenChiaWang, 2009).

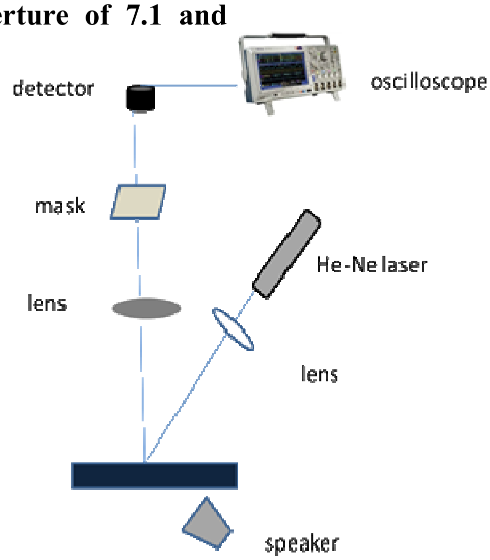
Experimental setup

In this experimental work, the object is illuminated with a Helium - Neon laser beam after passing through a x10 lens. Figure 1 shows the experimental setup. For object vibration, a speaker, which is controlled by a computer, is used. In the path of reflection beam, a lens with numerical aperture of 7.1 and foucal distance of 35mm is exposed to the laser speckle patterns befor the mask. It is necessary to use a suitable photodetector after the mask to detect the variation of the laser speckle patterns. It is also essential that the whole of the active region of the photodetector to be exposed to the laser speckle pattern.

We used a mask between the detector and the lens in order to measure simultaneously the vibrations of several speckle patterns. The size of mask is taken in a way that the size of the laser speckle patterns is comparable with the active region of the detector.

The vibrations of laser speckle patterns cause the change in photocurrent and as a result, the changes are recorded by the detector and the change is demonstrated as voltage-time on the oscilloscope.

In this experiment, power of used laser is 5 mW in which The used laser is stable, so the signal to noise ratio is high. Area of the mask is 11.85 * 11.85 mm^2 and size of holes is 0.4 mm(Fig.2)



Figur 1:*Experimental setup*

Figur 2: *The used mask*

Experimental result

Piezoelectric plate

Several methods exist for measuring the piezoelectric plate vibration. In experimental setup and in order to measure the vibrations, piezoelectric plate is used as a vibrating object. The piezoelectric plate is connected to a signal generator, and vibrate with arbitrary signals. The piezoelectric plate is exposed to a laser beam and the variation of related laser speckles are recorded. Moreover, the recorded signal by detector is very close to the main frequency of the object(Table.1).

Table 1: Deteced frequencies for piezoelectric

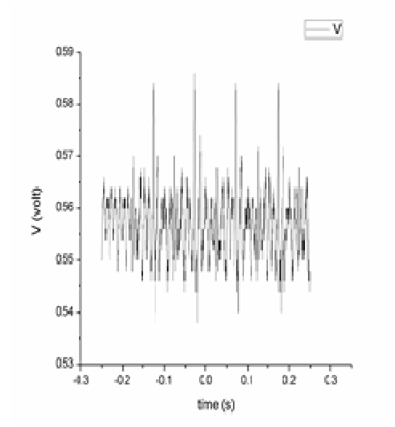
Real frequency	Detected frequency	Real frequency	Detected frequency
5Hz	4.9Hz	504Hz	500Hz
10Hz	9.52Hz	601Hz	549Hz
20Hz	20.40Hz	702Hz	729Hz
30Hz	31.25Hz	800Hz	769Hz
40HZ	41Hz	903Hz	929Hz
50Hz	52Hz	1000Hz	1000Hz
91Hz	90Hz	2000Hz	2000Hz
102Hz	100Hz	3000Hz	3115Hz
201Hz	200Hz	4000Hz	4032Hz
302Hz	303Hz	6000Hz	6038Hz
400Hz	403Hz	8000Hz	8130Hz

Paper and cellephone

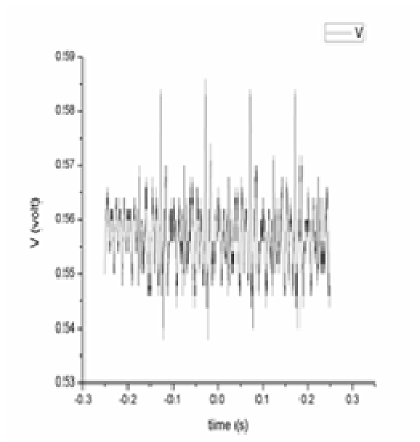
In order to study the effect of physical charactresits of vibrating objecs, the experiment is done for two different objects; paper and cellophane.The results are presented in Table 2. In the first column of the table, the frequencies played by speaker which cause the vibration of the object are presented. Second and third columns of the table are obtained frequencies from measurements.Obtained results are in good agreement with the applied frequencies to speaker. Two examples of recorded signals by oscilloscope are chosen and presented in Fig 3 and 4. Vibrating frequency of both objects are 10 Hz. It is worthwhile to note that the obtained vibrating frequency from calculations is very close to its real quantity.

Table 2:Detection frequency for paper and cellophane

Main frequency	Detect frequency for cellophane	Detect frequency for paper
500Hz	500 Hz	495 Hz
300Hz	290Hz	303 Hz
200Hz	200Hz	200 Hz
100Hz	989 Hz	99.9 Hz
70 Hz	69.9HZ	71.4 Hz
30 Hz	29.7HZ	30 Hz
10 Hz	10 Hz	10 Hz
5 Hz	4.9 Hz	5 Hz
2 Hz	1.9Hz	2 Hz



Figur 3:*Detected signal for cellophane*



Figur 4:*Detected signal for paper*

CONCLUTION

Due to the importance of vibration measurement in industry, determination of the frequency of objects is one the very important issues in the world which is always has been considered by the researchers. In this paper, we used a new method to measure the vibrations of objects. Very simple and low cost optical setup and the modest are important advantages of this method. Obtaining the frequency with high precision without the need for complex processing steps is possible.

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