UDK 534-8:616-006:616-72

MEASUREMENT OF VIBRATION PARAMETERS OF THE WAVEGUIDE FOR MEDICAL TREATMENT

Palevicius A.[1], *Bubulis A.* [1], *Minchenya V.* [2]

[1]Kaunas University of Technology, Kaunas, Lithuania
[2]Belarusian National Technical University, Minsk, Belarus

Methods allowing investigation of vibrations of the stainless steel waveguide by combining non-contact techniques with the state-of-the-art multiphysics software are developed. The vibrations of the waveguide, used in nowadays surgery are examined by the aids of the holographic interferometry technique, vibrometer based on Doppler shift of backscattered laser light and the virtual model of the waveguide is created by the Comsol Multiphysics software. (E-mail: algimantas.bubulis@ktu.lt)

Key Words: waveguide, non-contact techniques, virtual model.

Introduction

Long ago mankind is familiar with the vibrations phenomenon, from the vibrations caused by earth-quakes to the vibrating musical instruments. And all the time we try to investigate measure, evaluate and even control vibrations of the bodies. But the real interest in measuring and controlling vibrations arose with the complex industrial machinery. Step by step the need for accurate measurement and analysis of mechanical vibration has grown. The non-destructive method of holographic interferometry is found to be the one of the most suitable techniques for measuring vibrations of the micro order.

The aim of this article is to provide methods that allow investigating the vibrations of the stainless steel waveguide by combining non-contact techniques with the state-of-the-art multiphysics software. The vibrations of the stainless steel waveguide, used in nowadays surgery, are examined by the aids of the holographic interferometry technique, vibrometer based on Doppler shift of backscattered laser light and the virtual model of the waveguide is created by the Comsol Multiphysics software.

The measurement of vibrations

Over the last 15 or 20 years a whole new technology of vibration measurement has been developed which is suitable for investigating modern highly stressed, high speed machinery.

In practice it is very difficult to avoid vibration. It usually occurs because of the dynamic effects of manufacturing tolerances, clearances, rolling and rubbing contact between machine parts and out-of-balance forces in rotating and reciprocating members. Often, small insignificant vibrations can excite the resonant frequencies of some other structural parts and be amplified into major vibration and noise sources.

Sometimes though, mechanical vibration performs a useful job. For example, the vibrating waveguide is used in modern treatments for vascular occlusive disease. The working principle of this waveguide is based on the delivery of ultrasonic energy along the length of a small diameter wire, similar in size to an interventional guide wire. The ultrasonic energy creates cavitational streaming that is designed to rapidly dissolve thrombus, and quickly restores blood flow without adversely damaging surrounding structures [1, 2, 4].

A fundamental requirement in all vibration work, whether it is in the design of machines which utilize its energies or in the creation and maintenance of smoothly running mechanical products, is the ability to obtain an accurate description of the vibration by measurement and analysis.

The procedure of vibration measurement and analysis can be demonstrated by the simple scheme, presented in figure 1.

In the vibration measurement scheme, the motion (or dynamic force) of the vibrating body is recorded by the non-contact measuring instruments, such as holographic interferometers, or vibrometers based on Doppler shift of backscattered laser light. The output from the signal conversion instrument can be displayed on a display unit for visual inspection, recorded by a recording unit or stored in a computer for later use. The data can be analyzed to determine the desired vibration characteristics of the structure.

Experimental investigation of vibrations of the waveguide

The experimental investigation of vibrations of the waveguide was held in the Mechatronics Center in Kaunas University of Technology.

The investigation using vibrometer based on Doppler shift of back scattered laser light is demonstrated in figure 2.

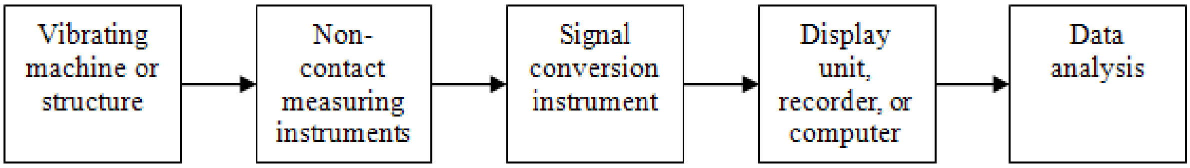


Figure 1 – Vibration measurement scheme [3]

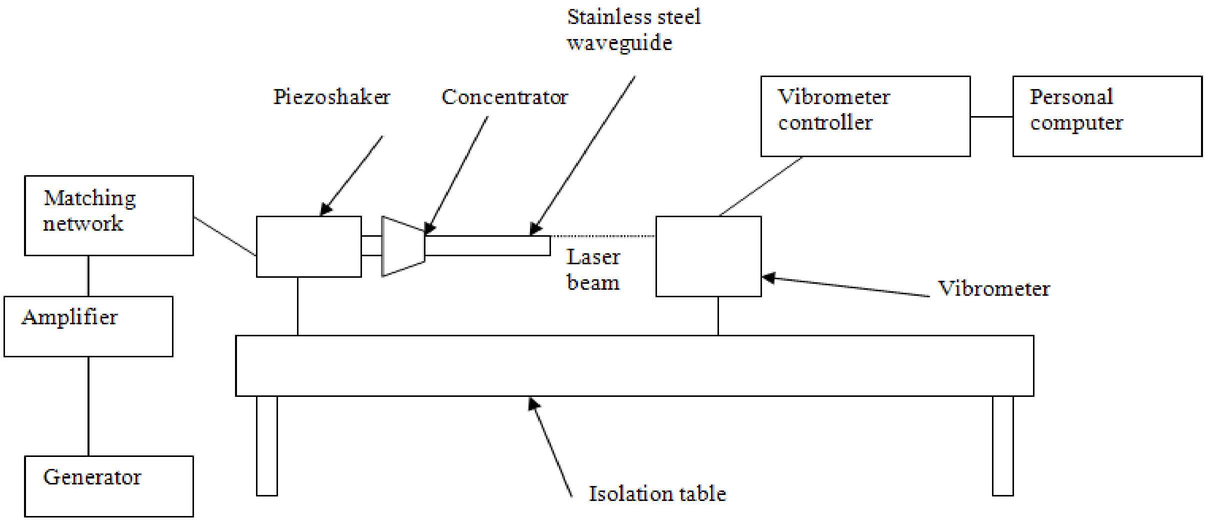


Figure 2 – The scheme for the measurement of vibrations of waveguide by vibrometer

Piezoshaker is fixed in the holders. The concentrator is attached to the piezoshaker head in order to amplify and concentrate the vibrations transmitted to the waveguide. The waveguide is attached to the concentrator. Piezoshaker and vibrometer are assembled on the isolation table, in order to avoid external vibrations, which can influence the final results of the experiment.

The vibrations of the waveguide are analyzed in the most characteristic point. This point is at the conical end, where the whole mass of the waveguide is concentrated, thus the vibrations are the most intensive.

The investigation of the waveguide using holographic interferometry is performed according to the scheme, presented in figure 3.

By holographic interferometry technique, the vibrations of the waveguide are investigated using the aluminum plate, attached to the end of the waveguide in order to get a good area of bearing, which results into clear holographic interferograms. The plate is fixed by its end in the holder and contacted to the end of the waveguide. The vibrations of the waveguide head are transferred to the aluminum plate and the plate is investigated by the method of holographic interferometry. By this method it is not possible to investigate the waveguide without fixing its end.

The results of the experimental investigation

The example of obtained results after the experimental investigation of the waveguide by the aids of vibrometer, based on Doppler shift of backscattered laser light are presented in figure 4.

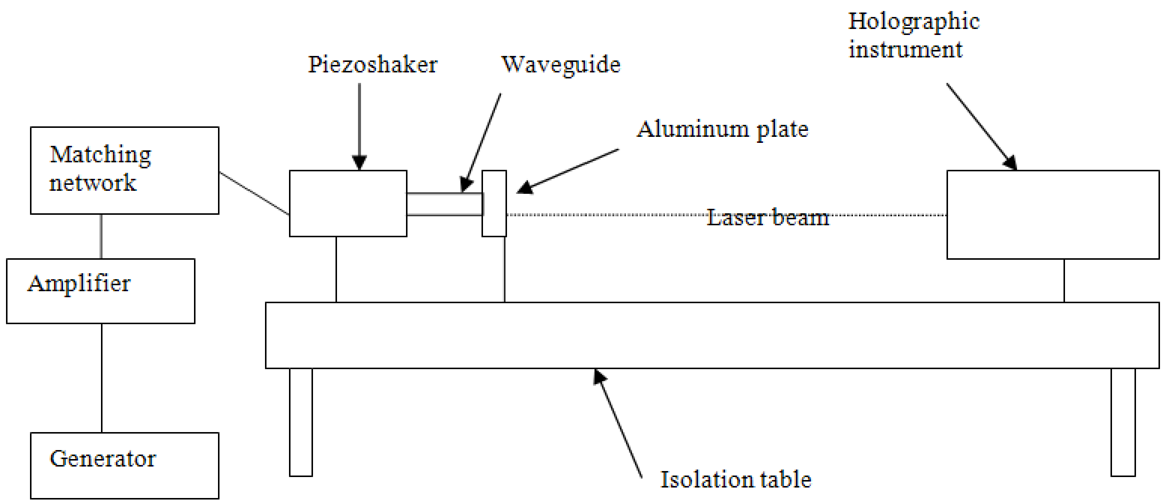
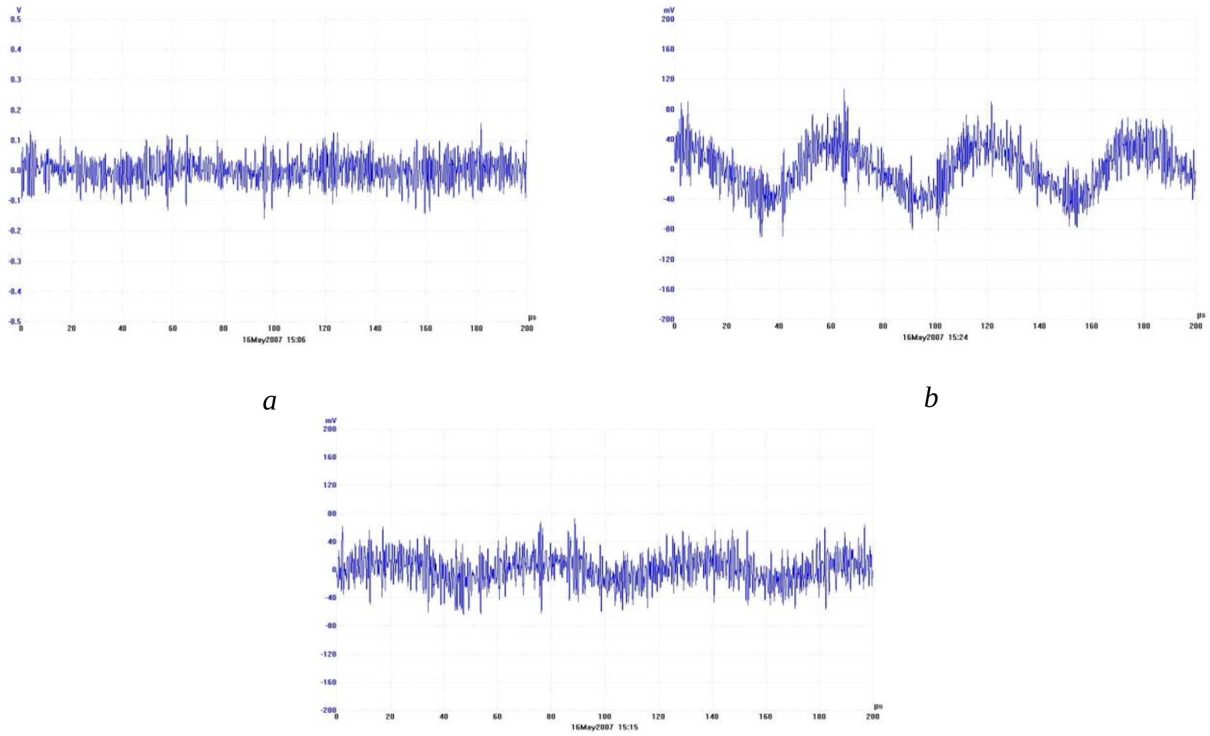


Figure 3 – The scheme for the measurement of vibrations of waveguide by holographic interferometry



a *b* *c*

Figure 4 – Results of the same frequency (17 kHz), but different amplitudes: *a* – 100 mV; *b* – 400 mV; *c* – 600 mV

It is possible to calculate the amplitude of vibrations according to the obtained results. The equation for calculations of amplitudes of vibrations is:

$$V = A\omega = A \cdot 2\pi \cdot f, \qquad (1)$$

where V is the voltage, A is the amplitude of vibrations, f is the frequency of vibrations. Transforming formula (1), one can obtain:

$$A = \frac{V}{2\pi \cdot f} = \frac{U_V \cdot K}{2\pi \cdot f}, \qquad (2)$$

where U_V is the voltage peak, K is the coefficient, defined by the vibrometer instrument.

The example of the results obtained by the holographic interferometry instrument are presented in figures 5 and 6.

a *b* *c*

Figure 5 – The holographic interferograms of the same amplitude (100 mV), but different frequencies: *a* – 12 kHz; *b* – 17 kHz; *c* – 19 kHz

a *b* *c*

Figure 6 – The holographic interferograms of the same frequency (17 kHz), but different amplitudes: *a* – 150 mV; *b* – 300 mV; *c* – 600 mV

After the analysis of the obtained results, it can be stated that, the vibrations of the waveguide depends upon the:

- the frequency of the signal;
- the amplitude of the signal.

According to the obtained holographic interferograms, it is possible to calculate the amplitudes of vibrations, following the certain procedures [1]. But also there is software that enables to get the results performed by the computer.

Virtual design of the waveguide

The virtual model of the vibrating waveguide can be created by the state-of-the-art multiphysics software. Comsol Multiphysics is a powerful interactive environment for modeling and solving all kinds of scientific and engineering problems based on partial differential equations (PDEs). When solving PDEs, this software uses the proven finite element method. This virtual modeling technique allows designing object of investigation and simulating the conditions of investigation, without performing the real experiment. After the simulation it is possible to get numerical and graphical evaluation of the designed object.

Conclusion

In this article the non-contact techniques such holographic interferometry and vibration measurement based on Doppler shift of backscattered laser light were presented and described. These techniques were applied for the measurement of vibrations of waveguide, used in modern surgery for treatments of vascular occlusive disease. The virtual design of the object of investigation, described in this article, can be used not only as independent investigation, but also as a supplementary method for the experimental techniques.

References

1. *Cloud, G. L.* Optical methods of engineering analysis / G. L. Cloud. – Cambridge : Cambridge University Press, 1998.
2. *Palevičius, A.* Wave mechanical systems: (theory, holographic interferometry). Electronic resource / A. Palevičius, M. Ra-gulskis, R. Palevičius. – Kaunas : Caritas, 1998.
3. *Rinkevičius, A.* The investigation of piezotransducers vibrations by the method of holographic interferometry / A. Rinkevičius – Kaunas : KTU, 2006.
4. Omniwave Technique. From *Omnisonics* [online]. 2007 [sited 2007-05-30]. – Mode of access : http://www.omnisonics.com.

Палевичус А., Бубулис А., Минченя В.

Измерение параметров колебаний волновода для медицинской терапии

Разработаны методы, позволяющие исследовать колебания волновода из нержавеющей стали путем комбинации бесконтактных методов с современным мультифизическим программным обеспечением. Колебания волновода, используемого в современной хирургии, исследуются с помощью метода голографической интерферометрии, виброметра, основанного на доплеровском смещении рассеянного лазерного излучения, и виртуальной модели волновода, созданной с помощью программы Comsol Multiphysics. (E-mail: algimantas.bubulis@ktu.lt)

Ключевые слова: волновод, бесконтактные методы, виртуальная модель.

Поступила в редакцию 05.08.2011.