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NONDESTRUCTIVE EVALUATION OF AUTOMOBILE TIRES BY ELECTRONIC SPECKLE PATTERN INTERFEROMETRY

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ABSTRACT
Electronic speckle pattern interferometry (ESPI) was used for the evaluation of mechanical properties of automobile tires. The tire on wheel disc was fixed on the holder and its vibration was generated by loudspeaker. Vibrational field of the whole tire was visualized by ESPI and recorded into PC. Natural frequencies of various vibrational modes were measured and results were compared with those obtained by Doppler's vibrometer.
Keywords: tire vibration, natural frequencies, ESPI, nondestructive testing

1. INTRODUCTION
The automotive tire is one of the pivot elements of the car. It should satisfy a number of functional requirements. It must work reliably in a large region of dynamic conditions – from static loadings to high frequency exciting of mechanical vibrations. The pneumatic tire today is a highly sophisticated engineering structure, which viscoelastic, anisotropic and nonhomogeneous properties all of its components have to be taken into account.
Several material models and various numerical methods are used for the construction and design of tire. Sophisticated software products and high power computers help constructors to perform new prototypes of tires [1]. Nevertheless, not all properties of prototype coincide with projected ones. Very effective tool to test the effectivity and applicability of design procedure is to compare computed properties of tire with the experimentally measured ones.
In practical terms, many vibration measurements of single components of the industrial mechanisms are required either for testing purposes or as a tool to determine the mechanical properties of a mechanism. For complete identification of the tire vibration mode it is inevitable not only to specify the natural frequency of the tire but also to define the oscillating amplitude distribution on the surface of it. That means to define the complete vibrational field of the tire.
The tire vibration during road car exploitation is a very complicated process. Therefore the reducible experiment was carried out, in which the tire was steady in the massive holder and all the perimeter of it was free. We have chosen the holographic method, as the most reliable and sensitive method available for non-contact inspection of vibration characteristics of pneumatic tires. Holographic interferometry is one of the most frequently applied optical method in non-destructive testing, inspection, metrology and imaging of very small shape deviation of the objects investigated [2, 3]. The method analogous to holographic interferometry based on the properties of laser speckles and digital processing of image is known as electronic speckle pattern interferometry (ESPI) [3, 4]. ESPI includes three basic techniques: time-average method, double exposure technique and real-time visualisation method.

The object of this paper is to give results of measurements of natural vibrational modes of tire investigated and its natural frequencies by electronic speckle pattern interferometry.

2. METHOD

Holographic interferometry is a method based on the interference of two optical wave fields – first one is scattered by object in primary state, the second one by object in load state [2,4]. Naturally, these fields cannot really exist in the same time. Hence, at least one of them is reconstructed by holographic way. The interference patterns allow computing the shape deviation of object in every point. Therefore, the interferogram stores the full information about the out of plane deviation of the object surface. Electronic speckle pattern interferometry uses the CCD camera instead of hologram. Unfortunately, camera records only the light intensity in a given pixel, not the phase. However, the laser speckle structure can be used for the purposes of recording . The interference pattern of vibrating tire surface is acquired and processed in a PC by electronic subtraction of both the original image speckle field and the image speckle field after deformation of rubber tire surface caused by vibrations. Due to its nature when two speckle fields are interfering one with another, the contrast of such a speckle correlation pattern is relatively poor, that is why it needs an improvement by image processing methods. Nevertheless, the visualisation of modal structure is clear and gives us the imagination about mechanical tire vibration particularly at higher order modes.

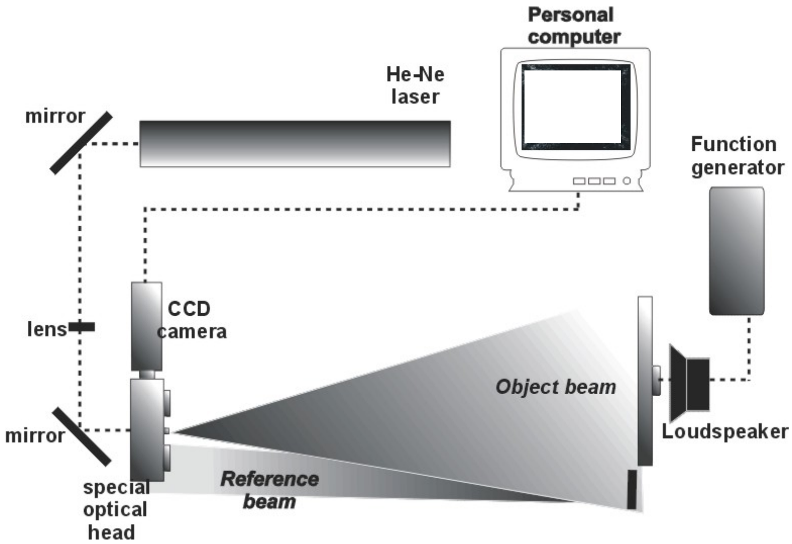

Figure 1. The block scheme of the experimental setup.

The electronic speckle pattern interferometry tire testing system, adjusted in our laboratory, consists of He-Ne 50 mW output power laser, optical elements, special optical head, CCD-camera, personal computer with framegrabber Kapa Lab Plus PCI and image processing software Impor 4 Pro [5, 6]. The equipment for tire clamping and exciting of vibration consists of steady holder, powerful loudspeaker and continually tuned harmonic generator with amplifier. A block scheme of the experimental setup is shown in Figure 1.

The ESPI method allows to obtain picture of whole vibration field of tire tested. As soon as the resonant frequency is reached, the clear interference patterns appear on the screen.

Besides, the measurements of vibrational state in given point of tire was performed by contact method (Bruel-Kjaer piezoelectric accelerometer) as well as noncontact method (Laser Doppler vibrometer). Several attempts were necessary to find the position in which amplitude was maximal (antinode).

3. RESULTS

The four samples of tire MATADOR -MAXILLA MPS 320 195 R14 C were measured. Three axial vibrational modes and seven radial ones was find by point method as well as two axial vibrational modes and six radial ones by ESPI method. All the sample had very close natural frequencies which indicate very high stability of production. Both metods give practically the same values of natural frequencies (difference ±1 Hz). The average values of natural frequencies are in the table 1. Some of the results obtained by ESPI method are shown on the Figs. 2 – 7.

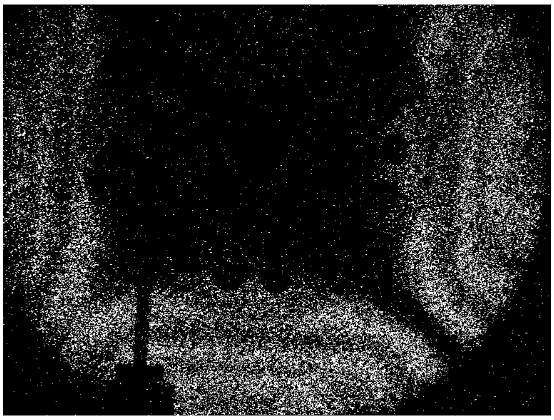

Figure 2. Axial mode, 2-nd order. Frequency 90 Hz.

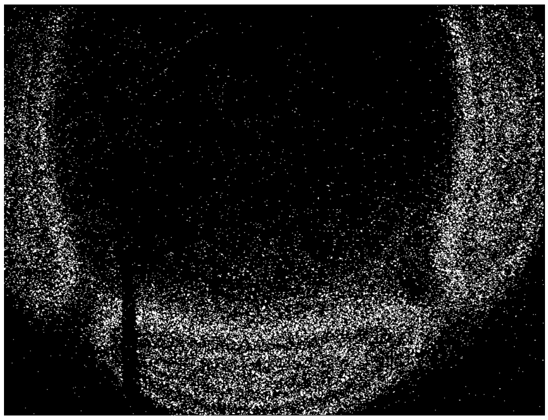

Figure 3. Radial mode, 2-nd order. Frequency 112 Hz.

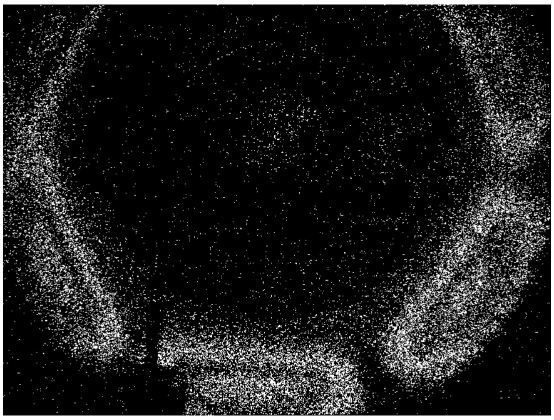

Figure 4. Axial mode, 3-rd order. Frequency 152 Hz.

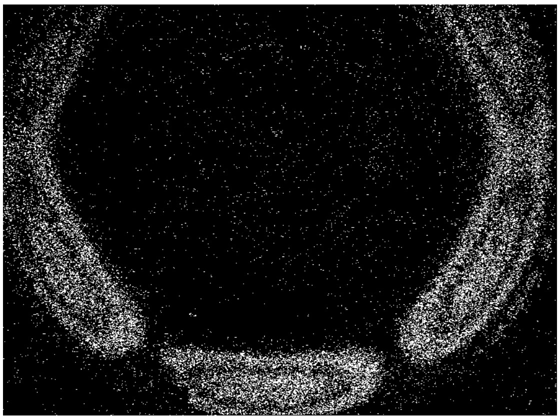

Figure 5. Radial mode, 3-rd order. Frequency 133 Hz.

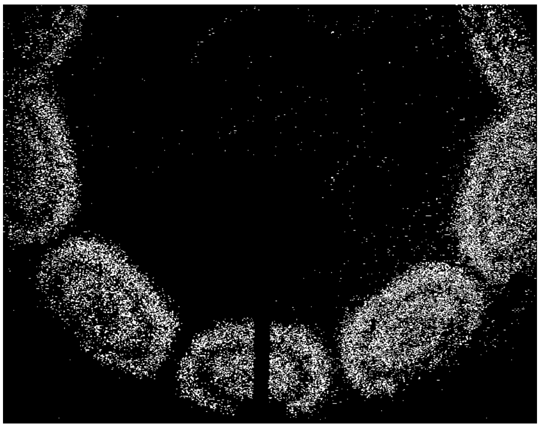

Figure 6. Radial mode, 5-th order. Frequency 174 Hz.

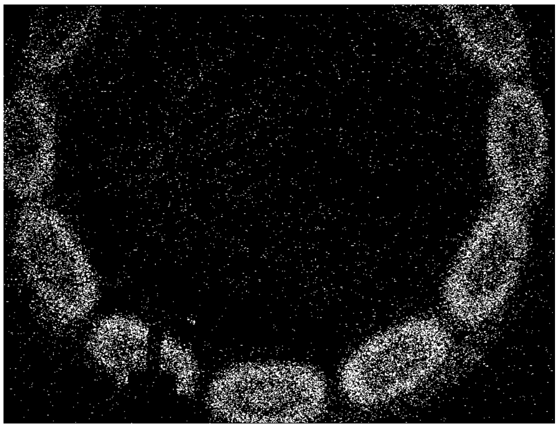

Figure 7. Radial mode, 6-th order. Frequency 194 Hz.

Table 1. Natural frequencies of automotive tire MATADOR -MAXILLA

Vibrational mode	Point method f, Hz	ESPI Method f, Hz	Amount of nodes
Axial 1-st order	61,75	–	2
Axial 2-nd order	90,5	90	4
Axial 3-rd order	153	151,75	6
Radial 1-st order	86,25	–	2
Radial 2-nd order	112,5	112	4
Radial 3-rd order	132,5	133,25	6
Radial 4-st order	155,5	154,5	8
Radial 5-st order	173	174	10
Radial 6-st order	194,5	194	12
Radial 7-st order	225,25	225	14

4. ACKNOWLEDGMENTS

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