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VIBRATION DIAGNOSTICS IN THE ASSESSMENT OF THE VEHICLES BODYWORK TECHNICAL STATE PROCEDURE

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Abstract: *An integral part of every vehicle, the car body plays an important role in aspects such as safety, aerodynamics, aesthetics and comfort. Studies of the dynamic properties of mechanical structures using modal analysis methods are now very widespread. The essence of this analysis is to obtain information about the object in the form of the so-called modal model, which consists of modes of natural vibrations, natural frequencies and damping coefficients, mass and dynamic stiffness. The paper presents the possibilities of implementing vibration diagnostics in the assessment of the vehicle structure technical state with modal analysis.*

Keywords: Modal analysis, vehicle bodywork, vibration diagnostics, technical state.

1. Introduction

Modern vehicles in new condition provide only a certain guarantee of proper behavior in extreme road conditions. Of course, each vehicle is subject to natural degradation processes over the time of its operation, which cause individual mechanisms and systems to lose their full technical efficiency and a significant part of the vehicle's structure to wear out. An equally important factor influencing the strength of the structure is the advancing corrosion process. In addition, all kinds of accident damage and the manner and quality of post-accident repairs also affect the technical condition. Current methods of diagnosing the load-bearing structure of vehicles are to a large extent based only on the organoleptic assessment of its condition, which is burdened with a large error in the assessment of its strength, durability, and thus the level of safety, both for the driver and other road users. Thanks to proper technical service, as well as the implemented systems for monitoring the technical state allowing for early detection of potential damage, it is possible to maintain or even extend the good technical state of the structure. Maintenance consists of a set of technological activities necessary to maintain the vehicle's mechanisms in a state of maximum technical readiness throughout its entire life (Żółtowski et al., 2015). Technological activities in the extensive maintenance process are supported by measurement methods supporting the assessment of the current vehicle technical state.

A local change in stiffness occurring in a mechanical structure is in many cases caused by damage. This situation has a direct impact on the form of the modal parameters of the modal model.

The assessment of stiffness changes on the basis of the modal model can be made in such a situation on the basis of the knowledge of the correlation between the model of the structure without damage and the model created on the real object after some time of exploitation (Kałaczyński et al., 2018)

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2. Methods

Applying the modal analysis method in the assessment of the selected vehicle body elements state practice, the system under test must meet the relevant conditions and assumptions (Żółtowski et al., 2015):

- the system is linear and its dynamics can be described using a linear system of ordinary or partial differential equations. From the assumption of linearity of the system, we can formulate the principle of superposition of the system;
- the system satisfies Maxwell's principle of reciprocity; as a result of this condition, we obtain symmetrical matrices of masses, stiffness, damping and frequency characteristics;
- the damping in the system is small or proportional to the mass or elasticity;
- the system is observable and it is possible to measure all the characteristics that are necessary to know the model.

The analysis of body dynamics is possible either on the basis of a structural model (e.g. FEM) or through appropriate tests on a real object. For the purposes of this study, a comparison of the applied experimental modal analysis for two elements of the structure of the car body, shown in Fig. 1, is presented.

a)

b)

Fig. 1: a) An undamaged part of the vehicle body structure,
b) damaged part of the vehicle body structure.

Assuming that the conditions have been met, the next stage of the research is to analyze the structure by stimulating it to vibrate by impulse excitation. This kind of excitation can be inflicted with a modal hammer or a vibration inductor. Fig. 2 shows the attachment of the response sensor and how to force the structure with a modal hammer. Arrangement of the measuring points show in Fig. 3.

Fig. 2: Modal analysis experiment example.

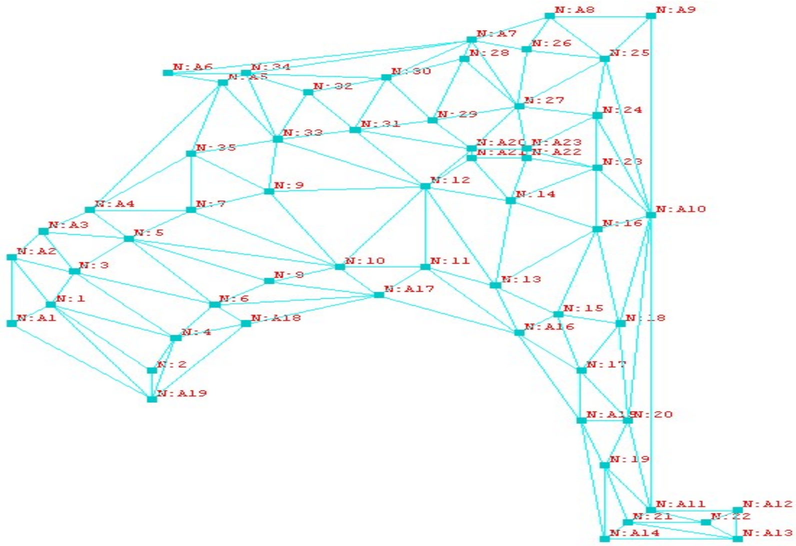

Fig. 3: Arrangement of measuring points on the test object.

The vibrational forms of the structure under study take different forms depending on the frequency of excitation. Each of the natural resonant frequencies corresponds to a specific form of vibration, often also called vibration modes. Selected mods are shown in Figs. 4 and 5.

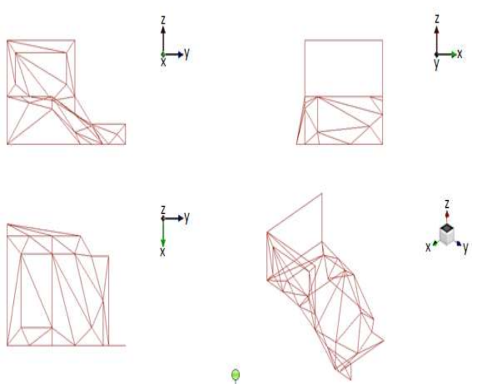

Fig. 4: Modeled geometry of the actual mode undamaged object.

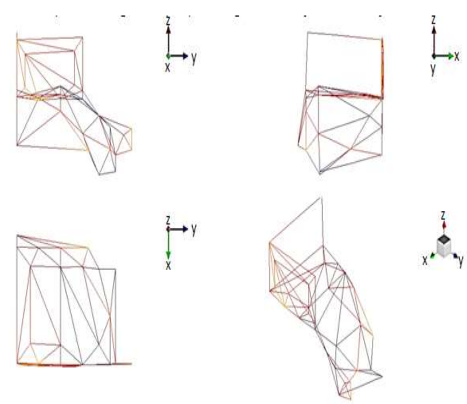

Fig. 5: Visualization of the selected mode of the body element as a response to the extortion inflicted.

One of the basic models of mechanical structures used for diagnostic purposes are finite element models. The results obtained from the simulation of the tuned model are compared with the model obtained from the measurement on a real object. If the correlation between the results of the model without damage and the results of the model derived from the experiment is close to unity, then the mechanical structure is not defective. A low or decreasing correlation value between the models indicates a specific type of damage or a progressive degradation of the mechanical structure (Łukasiewicz et al., 2014).

This type of structural diagnosis is based on the study of changes in the elements of the stiffness or elasticity matrix. The stiffness and elasticity matrices are closely related to the parameters of the modal model by the following relationships (Olatunbosun et al., 2010):

$$K = M\left(\sum_{i=1}^{n} \omega_i^2 \Psi_i \Psi_i^T\right) M, \tag{1}$$

$$S = \sum_{i=1}^{n} \frac{1}{\omega_i^2} \Psi_i \Psi_i^T, \tag{2}$$

where: n – Number of degrees of freedom, M – mass matrix, K – stiffness matrix, S – elastic matrix, ω_i – eigenfrequency, Ψ_i – vector of natural vibration modes.

As a result of the experiment, individual parameters of the modal model were obtained, which are summarized in Tab. 1.

	Natural frequency of vibrations [Hz]	Damping factor [%]	Order of the modal model
Undamaged element	146.010	0.81	23
	241.241	3.53	37
	357.726	3.77	27
	563.986	1.99	39
	613.041	1.71	26
	867.667	2.12	40
Damaged element	257.297	2.53	42
	426.802	1.97	34
	443.474	1.97	42
	759.213	2.26	37
	835.186	1.61	28
	913.352	1.34	24

Tab. 1: Summary of the obtained modal model parameters.

3. Conclusions

The problem of vehicle body parts degradation on Polish roads is still of importance. This is influenced not only by difficult climatic conditions, but also by the tendencies of vehicle users, who are largely interested in cars after more than ten years of operation, as well as post-accident cars, in which repair processes affect the dynamic properties of the repaired car components. In this type of vehicle group, the degradation of the body occurs to a large extent as a result of corrosion processes. This raises another problem with the assessment of the corrosion degree, which is still based only on organoleptic methods. Analyzing the available literature, it can be seen that several solutions to this problem have been developed, while the proposed methods are still very complicated and difficult to implement during the mandatory simple technical inspection.

An attempt to apply modal analysis methods for this purpose may shed a completely new light on the existing problem, and even become a viable solution that can also be applied to more common use.

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