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EXPERIMENTAL MODAL ANALYSIS IMPLEMENTATION IN THE ASSESSMENT OF THE LARGE-SIZE OBJECTS DYNAMIC STATE

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Abstract: *The paper presents the possibility of using the experimental modal analysis in the assessment of the structure of a large-size object dynamic state. An example of a large-size structure was the Hybrid Multimedia Mobile Stage (HMSM). The aim of the research procedure was to determine changes in the dynamic state of the Hybrid Multimedia Mobile Stage undercarriage at individual phases of its production. The measurement method used for this purpose was the experimental modal analysis, which is characterized by an impulse method of forcing vibrations. The scope of the research process included taking field measurements of the research object in order to determine the dynamic state at several stages of the production of the mobile stage.*

Keywords: Modal analysis, Mobile stage construction, Dynamic state.

1. Introduction

The growing requirements of the market economy and environmental protection in terms "quality" of newly constructed or modernized facilities force the constructors of large-size structural structures (WSK) to introduce new diagnostic methods and measures, supervising the evolution of changes in their state and facilitating the making of operational decisions (Muślewski et al., 2015). New trends in modular construction, increasing operational susceptibility (maintainability, diagnosable, repairable) force a new approach in research on the evolution of their state changes (Żółtowski et al., 2013). It is possible to assess the state of technical systems (at the prototype stage), the quality of newly manufactured technical systems (at the production stage) and to monitor the evolution of state changes (at the exploitation time) using the methods of technical diagnostics (Kałaczyński et al, 2018). It provides information on the current, past and future status in well-designed systems for recognizing and monitoring changes in the status of supervised technical systems. The specificity, unification and typification of structural modules requires the implementation of a specific diagnostic task by designing dedicated diagnostic systems (Strzelecki P. et al, 2019). This triggers many new construction, technological and operational problems, which were undertaken as part of the research procedure carried out in order to improve the practice of using large-size structural structures based on the achievements of science. (Kozłowski et al., 2015). Hybrid Multimedia Mobile Stage, due to its properties and scope of use, corresponds to the wide horizon of the use of diagnostic tools in the assessment of the dynamic state. One of them is modal analysis. Hybrid Multimedia Mobile Stage (HMSM) at various phases of its production is subject to the need to verify various dynamic states based on a modern measurement technique and research methodology including the possibility of distinguishing and identifying states. (Łukasiewicz et al, 2014). The used measurement method for this purpose was an experimental modal analysis, which is characterized by an impulse method of forcing vibrations.

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2. Methods

The research object is a steel frame of the mobile stage made of I-sections and C-sections. The frame of the semi-trailer is made of general purpose structural steel S355 J2H.

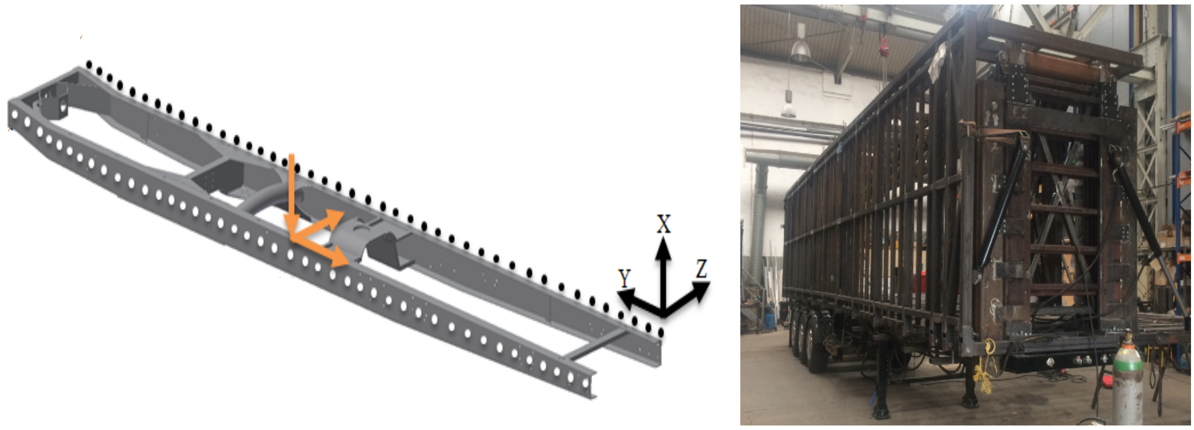

Fig. 1: Research object and the scheme of mobile stage trailer measuring frame

The frame of the semi-trailer is situated on a hardened surface. All wheels were inflated with air at the level of 0.4 MPa. The measurement was carried out at the temperature of 19ºC and air humidity at the level of 48%. For the purposes of the experiment, the research facility provided the appropriate level of operating fluids. Method for measuring the stage support frame structure together with the obtained spectral transition matrix FR matrix. A very important aspect in the case of this research object was the appropriate selection of the number of measuring points, the distribution of which is shown in Figure 1 in the form of black and white dots. The research object, characterized by such high geometric complexity and non-linear properties of structural dynamics, requires the selection of a sufficiently large measurement points number and the appropriate, observable frequency band, so as to reflect the exact dynamic state on the basis of the huge amount of data obtained in this way. Due to this fact, 64 measurement points were adopted, in which the response of the structure to the impulse input excitation was recorded. The load-bearing structure input was applied in three directions (X, Y, Z), at two measurement points, one on each side of the support frame, exactly in the middle of its length. The extortion points fell at 16 and 48 of the measurement points. The adopted excitation points and the number of vibration signal reception points of the examined structure allowed to obtain six full spectral columns of the FRF transition function. As a result, 36,864 spectral FRF functions were obtained, on the basis of which a modal model of the trailer's supporting frame was created.

The momentum in this case caused that the time-consumption of the conducted modal experiment increased much more. The vehicle chassis response was recorded in three directions (X, Y, Z) at all 64 measurement points. The tested structure was analyzed in the low frequency range up to 1024 Hz. The vibration signal received by means of a three-axis piezoelectric sensor was sampled at a frequency of 2048 Hz. The measurement methodology also in this case began with meeting the assumptions of the modal analysis. An initial measurement was carried out at two extreme points of the load-bearing frame research object, then the situation was reversed and another measurement was carried out. The graphs of spectral transition functions obtained in this way were put together for the purpose of comparison. They are shown in Figure 2. Unfortunately, the degree of geometric complexity of the research object with numerous attached subassemblies has a very strong influence on the obtained measurement result. Numerous fasteners, additional components, introduce numerous disturbances to the vibration signal obtained. As a result, the research object in this form isn`t as linear as modal research requires.

The modular structure of the measuring system included:

- LMS SCADAS Recorder multichannel signal analyzer,

- modal PCB hammer T086C03,

- piezoelectric vibration sensor PCB T352C33,

- LMS Test.Xpress software.

It is clearly visible in the comparison of FRF diagrams presented in Figure 3, where only 61.45% compliance was achieved.

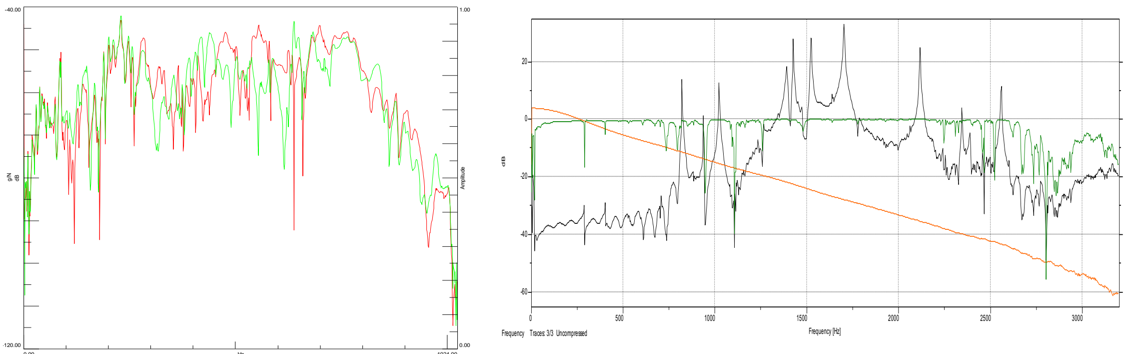

Fig. 2. Comparison of spectral transfer functions of FRF from the performed test

The process of verifying the designated poles doesn`t end at the stage of the stabilization diagram. In order to complete the process of selecting the designated poles, the AutoMAC tool is used, which allows you to verify that the designated poles don`t sometimes represent the same dynamic state. In the AutoMAC diagram, it is visible in the form of red fields tending to the value of 100. The poles, which ultimately are suitable for describing the dynamic state of the test object, are characterized by a very low value, usually not exceeding 10. The values corresponding to the designated poles are presented in Table 1.

Tab. 1: Percentage value of the convergence between selected modes of natural vibrations

trailer frame		Mode 2	Mode 3
		80,088	359,221
Mode 2	80,088	**100**	2.454
Mode 3	359,221	2.454	**100**

The selected projection of the selected mode of free vibrations of the trailer frame is presented in Figure 3.

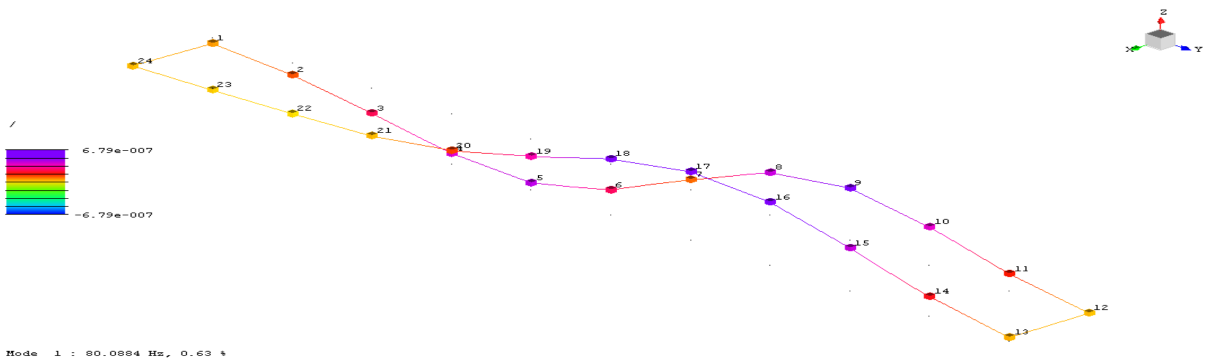

Fig. 3. The first form of natural vibrations - 80.0884 Hz, 0.63% (isometric projection - lower extreme deflection). natural vibrations

The characteristics analysis on individual stabilization diagrams showed that the main parameter having the greatest share in the dynamic state change in the mobile stage -trailer frame. These changes had the mass originating from the successively assembled components of the mobile stage. These changes also had an impact on the determined natural frequencies, with the greatest change taking place in the last third phase of the production of the mobile stage when all its most important structural elements were installed, such as: stage platform, stage roof, columns lifting the roof structure, etc.

In the first and the second production stage of the mobile stage, a much smaller number of possible poles describing the dynamic state of the second stage of mobile stage production was noticed. The mass index causes that the base of individual frequencies peaks natural vibrations is narrower, sometimes even leading to a significant reduction of its vibration amplitude. Each of the presented stabilization diagrams has features common to the others, but there is no doubt that the change in the dynamic state is clearly noticeable on each of them. The greatest change can be observed in the third stabilization diagram - 3rd phase of the production of the mobile stage, where the dynamic state of the trailer's frame was concentrated on higher natural frequencies compared to the previous stabilization diagrams.

On the constructional point, this effect is of course desirable, and in the case of the production of this mobile stage it occurred not naturally as well. The modes of natural vibrations are such a special determinant of dynamic state changes in frame of the mobile stage trailer. The summary of the first modes of free vibrations for different phases of the production of the mobile stage is shown in Fig. 4.

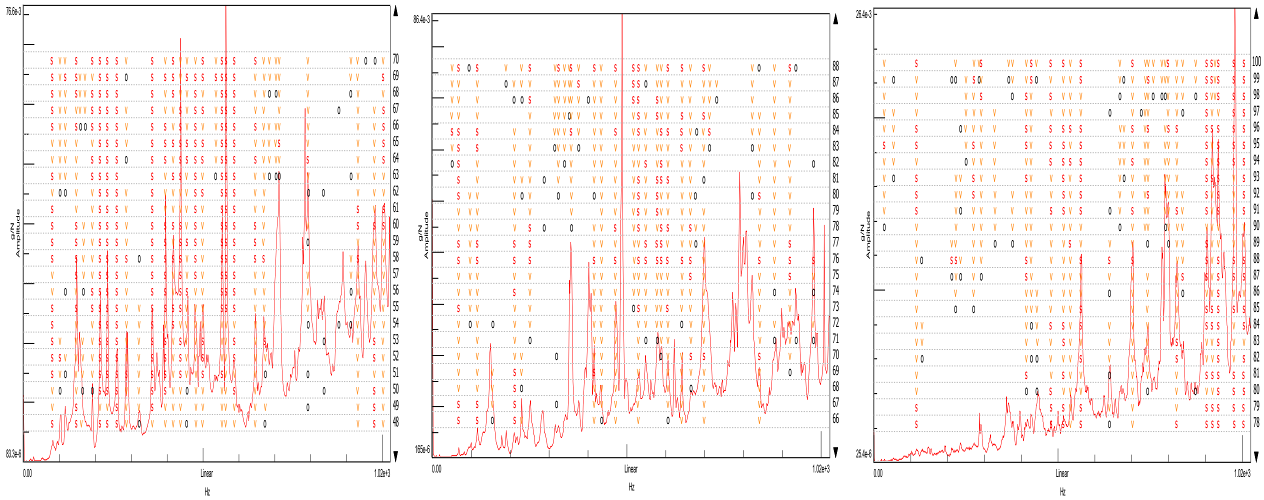

Fig 4. Stabilization diagrams created at individual phases of the production of the mobile (phase I, phase II, phase III)

The paper presents selected research results and selected fragments of the adopted research procedure. Full documentation of the research process is available from the authors of this study.

3. Conclusions

The model modal model was created especially for analysis the modal parameters of the technical object, which was a reference point for subsequent studies carried out at individual phases of the mobile stage production. Comparing individual modal models made it possibility to assessment of change in the frame dynamic state of. The obtained results of the implemented research procedure confirm the identification and differentiation of the dynamic states of the Hybrid Multimedia Mobile Stage, such as an example of a large-size structure. The use of the experimental property of modal analysis indicates its applicability.

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