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MARCIN NOWAK, MARCIN WIKŁACZ*

NUMERICAL MODELING OF THE DYNAMIC IMPACT OF TRANSPORT STRETCHERS ON PATIENTS IN A MOVING AMBULANCE

MODELOWANIE NUMERYCZNE ODDZIAŁYWANIA DYNAMICZNEGO NOSZY TRANSPORTOWYCH NA PACJENTA W PORUSZAJĄCEJ SIĘ KARETCE

Abstract

The paper presents numerical simulation of an ambulance transport system which consists of three elements: the stretcher, the frame which holds the stretcher and a part of the ambulance. The model was designed with the use of SolidWorks 2013 software. The numerical analysis was done with the use of ANSYS Workbench 13 software. During the first stage the natural frequencies and the forms of vibrations of the model were determined. During the second stage the dynamic excitations on the transport system were simulated.

Keywords: *vibrations in the ambulance, natural frequencies medical stretcher*

Streszczenie

Artykuł przedstawia symulacje numeryczną systemu transportowego karetki, w skład którego wchodzą trzy elementy: nosze pacjenta, rama utrzymująca nosze wraz z pacjentem oraz fragment karetki. Model zaprojektowany został w programie SolidWorks 2013, a analiza numeryczna w programie ANSYS Workbench 13. Podczas pierwszego etapu wyznaczono częstotliwości oraz formy drgań własnych modelu. Następnie zasymulowano wymuszenia dynamiczne na system transportowy.

Słowa kluczowe: *drgania w karetce, drgania własne noszy karetki*

* M.Sc. Eng. Marcin Nowak, M.Sc. Eng. Marcin Wikłacz, Institute of Applied Mechanics, Faculty of Mechanics, Cracow University of Technology.

1. Introduction

This article deals with problems concerning the transportation of medical patients by ambulance – it is a problem which has thus far been largely unanalysed. Whilst transporting patients, ambulances will typically travel at relatively high speeds in order to ensure that the time taken to transfer the patient to hospital is kept to a minimum. During the journey, the patient is exposed to the constant vibrations resulting from the movement of the vehicle. These vibrations potentially have serious negative consequences for the patient with regard to an increase in the severity of medical complaints and the deterioration of the patient's health. It should be remembered that with regard to chassis construction, ambulances do not differ in any way from vehicles used for transporting other cargos. With this in mind, it is important to determine the impact that these vibrations have on the patient's wellbeing, and the role which the vibration isolating system can play in improving the patient's comfort.

The primary method of determining the type of vibrations affecting the patient during the transportation is to conduct the test with the use of accelerometer in the ambulance while the vehicle is in motion. Such tests were carried out in the Silesian Center for Heart Diseases in Zabrze and their results will be published in a separate article.

As the modelling of the entire vehicle with all the equipment and the complete crew on board would be extremely complicated, it has been decided to limit the project to constructing a transport system consisting of a stretcher, a steel frame holding the stretcher and some parts of the vehicle. According to the authors of the article, those three elements have the greatest vibration impact on the patient.

The numerical simulation carried out in ANSYS Workbench 13 software determines the natural frequency and the form of vibrations of the transport system. The simulation of the elements' behaviour during the dynamic excitations was carried out with the use of the data received during the measurement of the vibrations in a vehicle moving on the asphalt road.

2. Description of the transport system

As it was noted in the introduction, due to the complexity of the structure of the ambulance, only the so-called transport system was constructed. The transport system simulates the vibrations which have the greatest impact on the transported patient.

The system consists of three elements. The first is a fragment of the ambulance floor to which the force causing the vibrations was applied. This part has the role of substituting the whole chassis of the ambulance. The second element is a steel platform directly bolted to the floor of the vehicle (Fig. 1). It is used to adjust the angle of the patient's position, which helps inserting and removing the stretcher. The maximum angle is 10°. The platform also allows to avoid movement of the stretcher in the ambulance.

The third element of the transport system is the stretcher, located directly on the platform (Fig. 2). It is made mainly from aluminium. Once it is placed in the ambulance, the whole weight is transferred to the four wheels of the stretcher. There is a mattress placed on the stretcher which ensures the patient's comfort.



Fig. 1. Platform in the ambulance

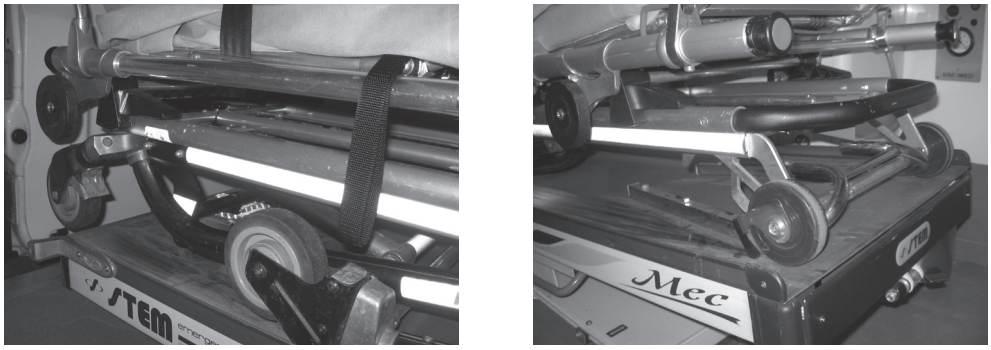


Fig. 2. Transport stretcher

3. Models of the transport system

3.1. Detailed model of the transport system

The model used for analysis has been designed in the Solid Works 2013 software. The authors of the article wanted to reproduce as accurately as possible the relationship between the stretcher and the vehicle. As a result a detailed and realistic model was designed (Fig. 3).

Unfortunately, with such a meticulous designing, a large number of bonds and elements was formed, which hindered considerably the measurement of the natural vibrations of the system. Initially the executive model of a similar stretcher was obtained. The model was simplified and adapted to the accurate parameters of the object. Two additional elements, which are part of the same system, were designed. The first is a mattress which is placed on the stretcher. The second element is a solid plinth which is supposed to represent the stretcher's attachment system in the ambulance and the vehicle itself. All the elements were combined together and transferred to the Ansys Workbench 13 software in order to carry out numerical simulations. After reading the model, it was found out that the number of contacts that the program had read is very large (about 2000), and that some contacts were erroneously adopted. As a result the study could not be continued. Nevertheless, very good parameters of the mesh were obtained (Tab. 1). Considering the significant complication that the detailed model entails, a simplified model was created and used to simulate the vibrations.



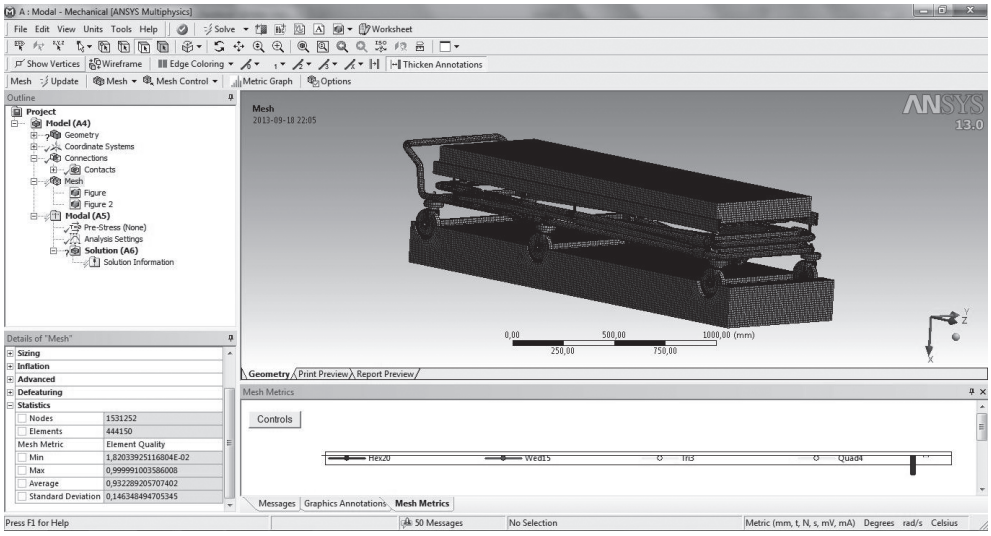


Fig. 3. Detailed model of the transport system

Table 1

Mesh data in detailed model

Bonds	1531252
Elements	444150
Average quality of the item	0,932289

3.2. Simplified model of the transport system

With the support of technical documents and a collection of pictures made by a hospital employee, a simplified model of the stretcher was designed. In terms of the geometry the new model was a good representation of the real object. The elements required for the study were recombined. The result was positive, the number of contacts significantly decreased.

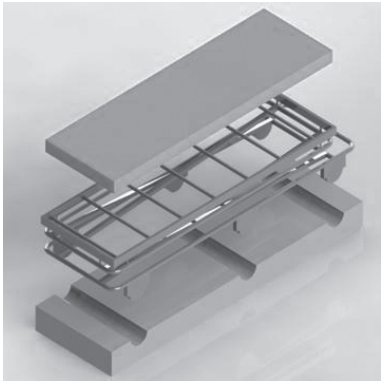


Fig. 4. Simplified model of the transport system

The first two elements of the transport system (the floor fragment and the platform) were represented as one element. One of the reasons for this was the simplification of the model, which in result enabled further analysis. Moreover, it did not affect greatly the results of the study, as the materials of both constructions are very similar, and the combination of these two elements is very rigid. It was assumed that the constructing material would be the structural steel. The final element of the transport system is an aluminium stretcher with a mattress. For the mattress the most similar material available in the program – polyethylene was used (Fig. 4). Selected parameters of the respective structures are shown below (Tab. 2).

Table 2

Selected parameters of simplified model

Parameter	Base	Stretcher	Mattress
Bonds	3495	5889	1722
Elements	2492	16510	1040
Average quality of the item	0.94875	0.59240	0.99935
Material	Steel	Aluminum	Polyethylene
Weight	2300	85	100

4. Determination of the frequencies of natural vibrations

For the simulation all the elements were fixed on all the side walls of the platform, the element located at the bottom of the whole system. The method can be justified by the system clamping the stretcher in the ambulance. It allows to apply the driven force from the lower surface of the model (Fig. 5).

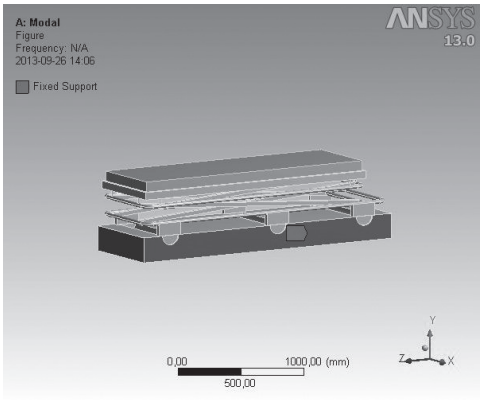


Fig. 5. Fixing of the transport system

Ansys software allows for a modal analysis. After determining the form as value 6, the distribution of the transport system elements' strains for the particular frequencies was obtained (4.56 Hz, 6.5 Hz, 27 Hz, 27.2 Hz, 59 Hz, and 62.7 Hz). The greatest deformations of the mattress can be observed with the low-frequency vibrations (5 Hz). With the increasing frequency the stretcher is becoming more deformed, whereas the deformation of the mattress is minimal (Fig. 6).

4.1. Dynamic excitations on the transport system

The second phase of the simulation was to apply the driven force and to read the values for the top surface of the model. The driven force was applied on the lower surface of the model, on the element substituting the ambulance. The value of the force was set on 10000 [N]. The force had only one directional component exerted along axis Y, adopted at the beginning of the modelling of the coordinate system. The method of fixing for this simulation remained the same as for the study of the natural vibrations frequencies. The result of the simulation is the amplitude-frequency diagram, created for the top surface of the model. The top surface is the upper part of the mattress, where the patient is resting during transport (Fig. 7).

5. Conclusions

The study gives an interesting insight into the behaviour of the relation between ambulance, stretcher, and mattress. Very little research was conducted regarding the impact of transport on the patient's health. The results of this study can be used in many fields, from the designing of the vibration reduction systems for ambulances to medical diagnostics. Further research on the topic is planned to be undertaken. Also the digital model has to be improved in order to achieve the most optimal combination of the model complexity with the quality of numerical calculations. Moreover, it is recommended to carry out laboratory tests and measurements in ambulances.

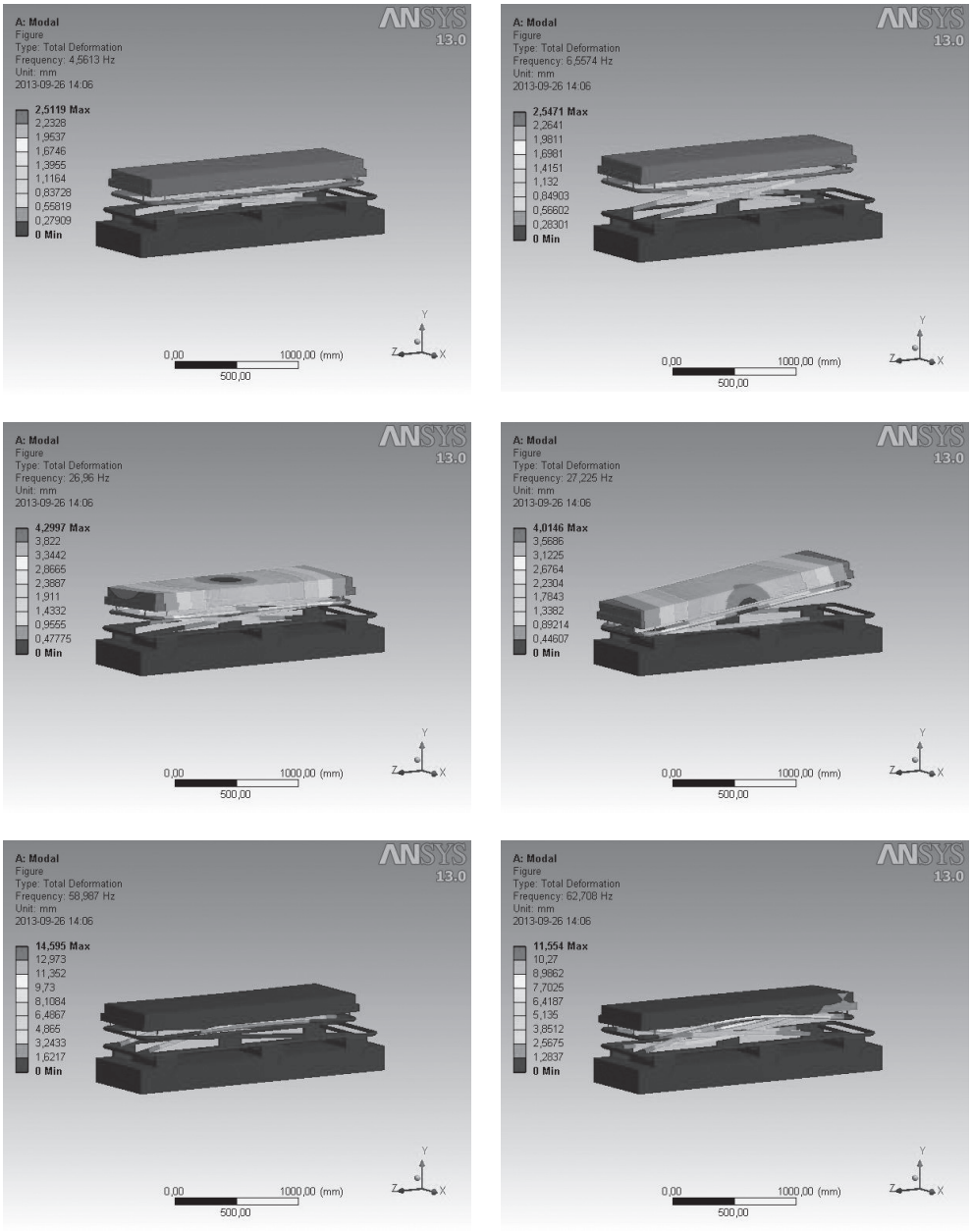
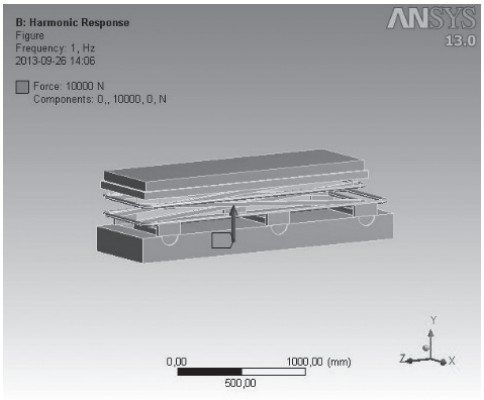


Fig. 6. Degree of elements' deformation depending on the vibrations' frequency



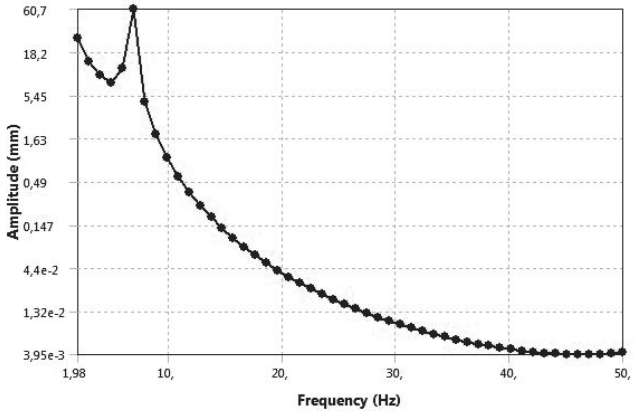


Fig. 7. Dynamic excitations on the transport system

References

[1] Concern: Ferno Group Companies, *Manual Instruction Patient Transport System – Mondial*, United States.

[2] Concern: Stem Emergency System, *Technikal Manual: Hydropneumatic Stretcher Support*, Italy.

[3] Sherwood H.B., Donze A., Giebe J., *Mechanical Vibration in Ambulance Transport*, Journal of Obstetric Gynecologic & Neonatal Nursing, Vol. 23(6), 1994, 457-463.