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A CONCEPT OF THE MECHATRONIC SYSTEM DESIGNED FOR FREIGHT CARS MANAGEMENT

Abstract: Paper presents assumptions of the mechatronic system designed for freight cars management during their exploitation. The system is based on the idea to use piezoelectric transducers for measuring dynamical response and inferred on its basis about the status of the wagon. Non-classical transducers such as Macro Fiber Composite or Polyvinylidene Fluoride piezoelectric foils are proposed to be used in the system as sensors. Those elements should be glued on surfaces of the freight car's elements and connected to the wireless transmitting system. The type 1415 A3 freight car is considered in this work.

1. Introduction

Nowadays railway transport is very important for the development of the modern economy. Many research works concerning with problems occurring in this way of transport and its development are being carried out all the time [1,3,7,9-11]. The main goals of those works are usually to develop the infrastructure that is used for transport of goods and people, make it more cost-effective, safe and less burdensome for the environment. Presented work is also a part of the research project that aim is to modernize freight cars during their renovation. It is continuation of the research works connected with modernization of freight cars [3,11]. The project is carried out by the consortium that consists of the scientific entity – the Institute of Engineering Processes Automation and Integrated Manufacturing Systems from the Silesian University of Technology and enterprises – DB Schenker and Germaz. The aim of this research project is to modernize the analysed wagon during its renovation using new composite materials. Effects that are to be achieved by the modernization are:

- better corrosion protection of the wagon elements,
- easier unloading of the wagon in winter conditions (no freezing of the cargo to the sides and floor of the wagon),
- reduction of the weight of the wagon while its load increases,
- easier management of freight cars during exploitation.

In this work main assumptions of the mechatronic system designed to fulfil the last proposed goal are presented. The idea of the system is to make possibility to infer about the status of the wagon on the basis of its vibration generated during driving. What is more the system should be self-powered. Energy of vibrations will be also used for generate electric voltage using direct piezoelectric phenomena.

Applications growth of piezoelectric transducers is parallel to the process of piezoelectric materials development. New, more efficient transducers are searched all the time. Direct and reverse piezoelectric phenomena are very often used in new, innovative mechatronic systems. It is mostly caused because there is easy to transform mechanical energy into electrical energy and vice versa using piezoelectric transducers. It causes that they can be used both as sensors or actuators in mechatronic systems. Analysis and synthesis of the mechanical and mechatronic systems were presented in [2,4-6,8].

2. Object of considerations – the freight car type 1415 A3 and its models

As the object of considerations the freight car type 1415 A3 was selected. It is the 4-axle open wagon series EAOS and produced by BREC Belgium. It is one of the most popular types of wagons designed to unload with the use of tipplers. After consultations with employees of enterprise specialized in repairing of freight cars it can be noticed that the main problems during exploitation of this type of wagons are:

- corrosion of plating of the wagon's plating,
- mechanical damage of the wagon's plating - usually as a result of the improper unloading (using buckets and excavators instead of tipplers).

At the same time the type 1415 A3 wagon has a high strength of the supporting box (top girder, lateral reinforcing strip etc.). The considered type of freight wagon and its typical damages are presented in Fig. 1.

Fig.1. The considered freight wagon and damage of the body shell

As the first step of the whole research project CAD models of a few selected freight wagons were created using Siemens NX 8.5 software. Precision of the created models was verified by checking its mass after defining material properties of wagon components and juxtaposing it with the mass of the real wagon. After verification the models were used in strength analysis using the Finite Element Method in NX software. The CAD model is presented in Fig. 2. The created 3D model is very detailed and obtained discrepancy is 5,34% of the real wagon mass. The difference is the result that the model does not include the braking system (pipes and pneumatic cylinders, brake pads etc.) After its verification the model was used in strength analysis using the Finite Element Method in NX software. Obtained results will be presented in others author's publications.

Fig.2. The CAD model of the considered type of freight car

In order to verify assumptions of the designed mechatronic system based on analysis of the dynamical response of the freight car a physical laboratory model of the supporting structure of the considered 1415 A3 freight wagon was built in scale. It is presented in Fig. 3. There are a lot of simplifications in the created model juxtaposed with the real object. The purpose is that the laboratory model was created only for initial verification of the possibility to measure the dynamical response of the wagon using piezoelectric films. In the future works measurements on the real object will be carried out.

Fig.3. The simplified laboratory model of the supporting structure

In Fig. 3 a pendulum that was used for vibration excitation is also presented.

3. Measurements and results

In carried out tests the piezoelectric PVDF film was used as a sensor and pendulum was used for vibration excitation. The PVDF film was glued on the frame of the laboratory model in the position of the second measuring point (see Fig. 4). Measuring points were chosen on the basis of the modal analysis carried out using CAx software and virtual model of the system. In carried out tests a model LDT1-028K of PVDF piezoelectric foil was used [12]. It is presented in Fig. 5.

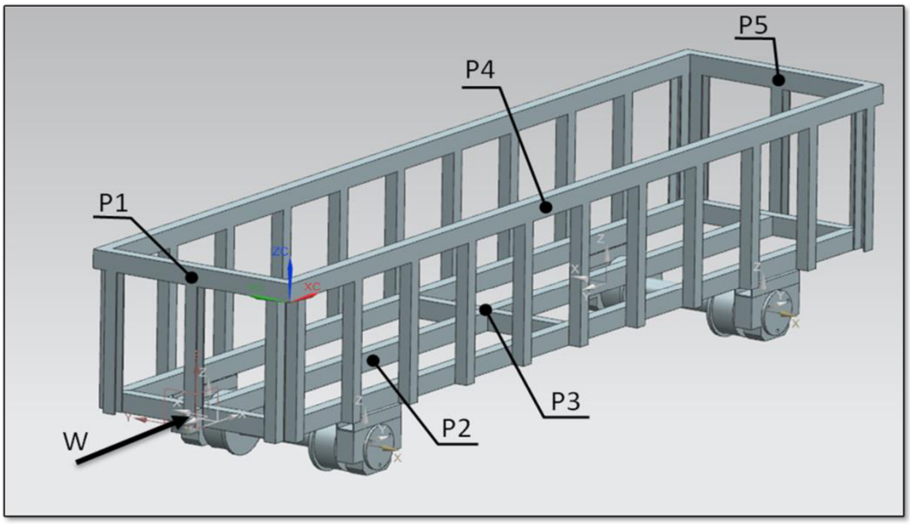


Fig.4. The CAD model of the laboratory stand with measuring points

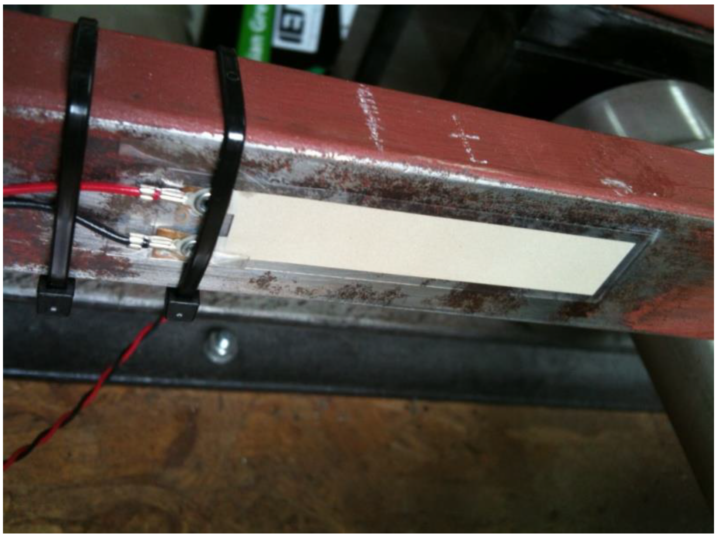
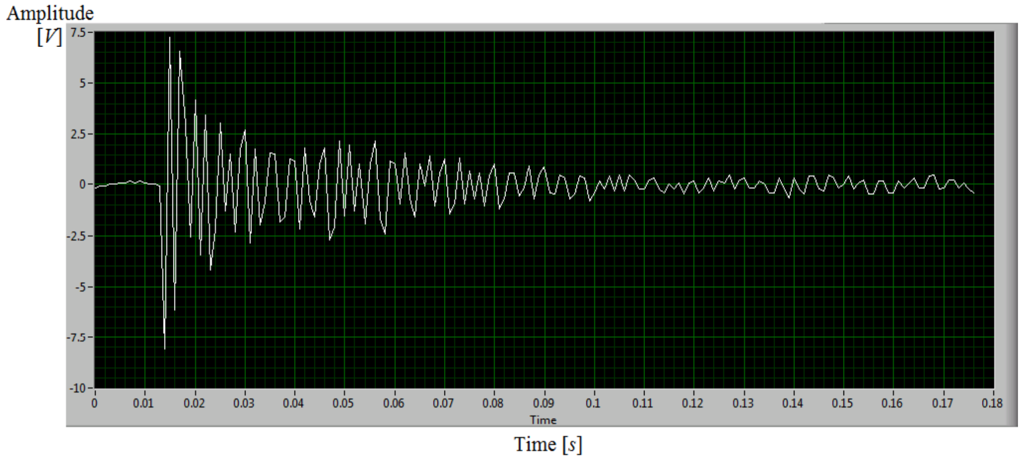


Fig.5. The CAD model of the laboratory stand with measuring points

PVDF piezoelectric film, and more particularly the sensor LDT, which was used in this study consists of three layers: polyester laminate, a piezoelectric film and a protective coating. The PVDF piezoelectric film elements produce more than 10 mill volts per micro strain and about 60 dB higher than the voltage output of a foil strain gage. Their capacitance is proportional to the area and inversely proportional to the thickness of the element. Such kinds

of sensors are the simplest form of piezoelectric film sensors that can be used for example as dynamic strain gauges and contact microphones for vibration or impact detection. They can be readily adhered to a surface with double-sided tape or epoxy [12].
During measurements two states of the freight car were analysed. Dynamical responses of the model without and with load were measured. In Fig. 5 results of the measurements conducted using PVDF piezoelectric foil glued in the position of the P2 measuring point are presented. It can be observed that this time maximum values of the voltage signal generated by the PVDF foil are very similar for both measurements – with and without load but it can be easily noticed that the time to damp vibrations is shorter for the system with load.

a)



b)

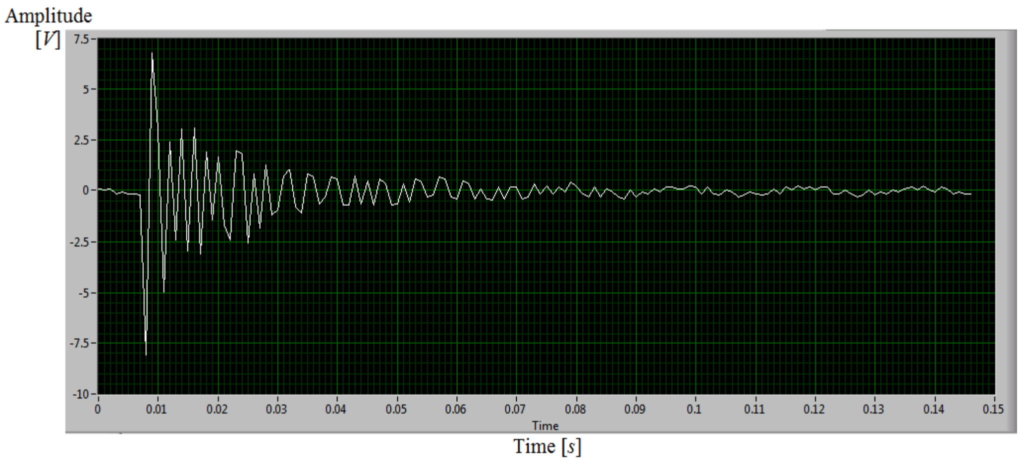


Fig.6. Results of measurements without (a) and with load (b)

Results of carried out tests were very repeatable so it can be assumed that proposed method of dynamical response measurements can be treated as very precise and successfully used in designed mechatronic system. During the future tests the analysis of the model dynamical response while driving will be carried out. Finally tests on the real object will be conducted in order to verify results obtained on the laboratory model.

4. Conclusion

The main aim of presented work was to verify if it is possible to measure dynamical response of the considered object using piezoelectric foils. The carried out tests proved that there is a possibility to create a mechatronic system that can be integrated with the freight car and used for its management during exploitation (collecting data about its location, condition, load etc.). Such system can be based on piezoelectric foils application. The system that is intended to be created will allow monitoring of the freight car dynamic parameters during its normal exploitation and inferred on its basis about the status of the wagon. It should be noticed that those results and proposed thesis must be verified by tests on the real objects during their normal exploitation.

References

1. Berghuvud A.: Freight car curving performance in braked conditions, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, (2002), pp. 23-29.
2. Białas K.: Mechanical and electrical elements in reduction of vibrations, Journal of Vibroengineering, Vol. 14, Issue 1 (2012), pp. 123-128.
3. Baier A., Zolkiewski S.: Initial research of epoxy and polyester warp laminates testing on abrasive wear used in car sheathing, Eksploatacja i Niezawodnosc – Maintenance and reliability, Vol. 15, Issue 1 (2013), pp. 37–43.
4. Buchacz A., Gałęziowski D.: Synthesis as a designing of mechatronic vibrating mixed systems, Journal of Vibroengineering, Vol. 14, Issue 2 (2012), pp. 553 -559.
5. Buchacz A., Płaczek M., Wróbel A.: Control of characteristics of mechatronic systems using piezoelectric materials, Journal of Theoretical and Applied Mechanics, Vol. 51 (2013), pp. 225-234.
6. Buchacz A., Płaczek M., Wróbel A.: Modelling of passive vibration damping using piezoelectric transducers – the mathematical model, Eksploatacja i Niezawodnosc – Maintenance and reliability, Vol. 16, Issue 2 (2014), pp. 301–306.
7. Connolly D. P., Kouroussis G., Giannopoulos A., Verlinden O., Woodward P. K., Forde M. C.: Assessment of railway vibrations using an efficient scoping model, Soil Dynamics and Earthquake Engineering, Vol. 58 (2014), pp. 37-47.
8. Dymarek A., Dzitkowski T: Method of active synthesis of discrete fixed mechanical systems, Journal of Vibroengineering, Vol. 14, Issue 2 (2012), pp. 458-463.
9. Kovalev R., Lysikov N., Mikheev G., Pogorelov D., Simonov V., Yazykov V., Zakharov S., Zharov I., Goryacheva I., Soshenkov S., Torskaya E.: Freight car models and their computer-aided dynamic analysis, Multibody System Dynamics, Vol. 22, Issue 4 (2009), pp. 399-423.
10. Zhai W. M.: Modelling and experiment of railway ballast vibrations, Journal of Sound and Vibration, Vol. 270, Issues 4–5 (2004), pp. 673–683.
11. Zolkiewski S.: Testing composite materials connected in bolt joints. Journal of Vibroengineering, Vol. 13, Issue 4 (2011), pp.817-822.
12. http://www.imagesco.com/catalog/sensors/film.html (Access 15.10.2014).