

SAFETY IN THE RAILWAY INDUSTRY

Rafal Burdzik¹, Boguslaw Nowak², Jacek Rozmus³, Pawel Słowiński⁴, Jaroslaw Pankiewicz⁵

^{1,4} Silesian University of Technology, Faculty of Transport, Katowice Poland

^{2,3} DR-TECH Sp. z o.o., Imielin, Poland

⁵ Warsaw University of Technology, Faculty of Automotive and Construction Machinery Engineering, Warsaw, Poland

¹e-mail: rafal.burdzik@polsl.pl

Abstract: *Safety of the railway transport is extremely important issue, thus it has to be supported by numerous of terms. It is not only the legislation and organization or traffic control but also the proper quality of every devices in the railway infrastructure. The paper deals with safety in the rail industry. Companies and producers of railway equipment have to guarantee the best quality, maintenance and reliability. Safety is also a device directly responsible for protecting e.g. level crossings but also safety in terms of design and construction. . Supervision of products is fulfilled in Poland by e.g. the Office of Railway Transport managing the safety and regulation of rail traffic. The paper presents industry security in terms of product as safety in design and production, in construction, in exploitation. Despite such extensive, multisector and multifaceted organizational, legal and technical safety structures in rail transport it is advisable to conduct further research into the analysis of the possibilities for improved safety. Also authors have assumed that for the improving of railway crossing safety level the support system for the traffic detection can be developed. To increase of the complex crossing safety level the support system has to be independent from current usage control devices, as axle counter block. Thus the paper presents concept of application of vibration wave propagation employing as source if information on train or car detection.*

Key words: *railway safety, product safety, rail vibration.*

1. Introduction

The constantly changing social and legal environment has a direct effect on the entire rail industry, which in turn tries, despite obvious financial and organizational difficulties, to deal with the constant, progressive division of the railway structure and the steady progressive degradation of the infrastructure to keep up with the often-imposed rate of change.

Traffic of trains on the railway infrastructure are regulated through a signaling system and a well-defined set of rules. The European Railway Traffic Management System (ERTMS) is a major industrial project that aims at replacing the many different national train control and command systems in Europe with a standardised system (The Office of Railway Transport, 2016). As the foundations of ERTMS can be pointed methodology for security-informed safety and hazard analysis. One of the most important components of railway safety system is train detection systems. Especially when considering the recent development of high-speed railways. Currently the ETCS Level 1 and 2 provide

the train localization functionalities by using track circuits or axle counter systems. The signaling devices are usually triggered by sensors by trains approaching the crossing level and which are in the impact area of heads of the wheel sensors detecting movement in their area and movement direction of the rail vehicle. There are following warning devices installed at the crossings: light traffic control devices most frequently with a sound signal and one or two pairs of half barriers. For the reliability of such multi-elements system it is very important to ensure the best quality, functionality and efficiency operational of every each devices. Thus the paper deals with safety procedures in railway industry produce track and control devices.

Safety in the rail industry is not just about legal or regulatory safety. Security is also a device directly responsible for protecting e.g. level crossings but also safety in terms of design and construction. It is also of great importance to define certain habits in railway workers, as well as traffic participants such as passengers, drivers or pedestrians. Security related to railways means a number of issues

(Jacyna-Golda I. et al., 2014; Lewiński, A. et al., 2014; Sitarz M. et al., 2011; Kwasiborska A. et al, 2017; Zboiński K., 2015) of which only a few will be addressed in this paper.

One of the example of the legal description of safety requirements in correlate with crossing level categorization. The paper (Burdzik R. et al, 2016) presents study focused on the categories of railway crossings level and their functions in the traffic safety. It also present the mainly rail vehicles detection systems used in crossing level as the determinant to maintain safety functions.

This paper presents supplementary analysis in scope of the railway safety, due to previous articles of the authors (Burdzik R. et al, 2016; Burdzik R. et al, 2017). Thus the content of the series of the articles presents complex study on the railway safety in terms of legal law, railway rules and procedures, safety systems and devices. There are good fundamentals to extend research and study improvements to increase the safety level of railway transport.

2. Safety of the industry in legal and organizational terms

Every country has its own rail management structures, responsible for, among all, safety processes related to the movement of both internal and external trains affecting the environment (Mironiuk W., 2015). In Poland, rail safety is a responsibility of different branches, from energy, road and automation to the carriers themselves. An important function in this chain is also the producers of equipment and railway vehicles who are more and more responsible for the safety of their products throughout their lifecycle. Supervision of products is fulfilled in Poland by e.g. the Office of Railway Transport managing the safety and regulation of rail traffic. It verifies the managers of infrastructure in terms of maintenance and modernization of railways according to European and national standards, and also ensures that railways are operated by carriers guaranteeing adequate security levels (The Office of Railway Transport, 2016); Wielądek A., 2005; Council Directive, 2004).

Every Polish infrastructure manager and each carrier have their own range of instructions, recommendations and other documents that oblige them to maintain industry safety in the area for which they are responsible, e.g. in railway

automatics. The railway transport plays an important role in developing sustainable transport and it has to be considered as integrated system in terms of reliability and safety due to all components of the system (Siergiejczyk M. et al, 2016; Jacyna M. et al., 2014; Jacyna M. et al., 2015).

However, due to the fact that Poland belongs to the EU, community rail safety regulations are in force here, too. Within the frame of the common market in the EU, a decision was made to create a coherent system of European rail transport. The main goal of the aforementioned system was to remove barriers limiting the possibility of borderless traffic, as well as increasing transport safety. For this purpose, based on Regulation No 881/2004 of the European Parliament and of the Council of 29 April 2004, the European Union Agency for Railways (ERA) has been set up being one of the many bodies of the European Union and having legal personality. This agency has the capacity for legal action in any EU Member State within the boundaries of the law of a given country (Wielądek A., 2005).

Regulation 881/2004 referred to above is one of the four EU documents included in the so-called II railway package. The other 3 are:

- Directive 2004/49 /EC on rail safety, on the licensing of railway companies and on the allocation of railway infrastructure capacity and charging fees for the use of railway infrastructure and the granting of safety certificates;
- Directive 2004/50 EC on the interoperability of the trans-European high-speed rail system and on the interoperability of the trans-European conventional rail system
- Directive 2004/51/EC on the development of the Community's railways.

Due to internal domestic or inter-company regulations, as a result of the above-mentioned directives, the railway entities created in Poland from the division of PKP, responsible for the construction, service and maintenance of railway infrastructure, are obliged to develop and implement management systems guaranteeing their permanent and continuous safety review (Polish Railway Company, 2017; Polish Railway Company, 2016). But it has to be considered that the PKP SA Board of Directors cannot adopt resolutions concerning the functioning of the infrastructure manager.

A constant approach to continuous work on the safety of the industry requires a totally new approach

and huge work facing railway managers in Poland. The new Rail Transport Act resulting from Directive 2004/49 about railway safety, transformed in the course of adoption of the European Union (EU) directive 798/2016 in terms of railway safety (Dz. U. EU L138/102 of 26.5.2016), defines, for example, in art. 16, para. 1 the need for each Member State to establish a safety authority which may be e.g. the Ministry of Transport. This authority must be independent in organization, legal and decision-making terms from any railway company operating on the area of a given country's territory. Similarly, the investigative body in accordance with art. 21, para. 1 must be independent in organization, legal and decision-making terms and must be functionally independent of the security and railway regulators. Art. 8, para. 1 of this directive obliges the Member States to set up national safety regulations and ensure their publication and availability to all infrastructure managers, railway enterprises, applicants for safety certification and authorization in terms of safety in a language understandable by everyone affected by these rules. According to Art. 9, para. 1, the infrastructure managers and the railway companies are required to establish their own safety management systems in order to ensure that their rail system complies with the requirements of national safety regulations and safety requirements. According to Art. 10, para. 1, in order to access the infrastructure, all users must have certification in terms of safety and in art. 11, para. 1, in order to authorize for managing and operating the railway infrastructure, the infrastructure manager must obtain a safety authorization from the safety authority in the Member State in which it is registered (Council Directive, 2004).

3. Industry security in terms of product

Product safety can be divided into the following aspects:

- Safety in design and production,
- Safety in construction,
- Safety in exploitation but above all
- Safety in the product/article itself.

3.1. Safety in design and production

A safe design of products intended for each railway market requires design offices or manufacturers themselves to adopt appropriate procedures directly resulting from the requirements of infrastructure managers.

In October 2015, the PKP Management Board implemented a very important procedure of the SMS-PW-17 Security Management System "Adoption of elements of subsystems and technologies intended for use on railway lines managed by PKP PLK S.A."

Due to the above, a list of products was created, which in order to be used, require an Approval of Use for application on railway lines managed by PKP PLK S.A.

All products subject to the above-mentioned procedure exploited on railway lines managed by PKP PLK S.A., must hold a valid Approval of Use issued by the relevant PKP PLK S.A. Board Member.

The products not subject to the SMS-PW-17 procedure are allowed to exploitation in accordance with the principles contained in the "Manual of evaluation, qualification of contractors and material approvals in PKP PLK S.A.", being an annex to the Corporate Procurement Policy of PKP PLK S.A (Polish Railway Company, 2017).

Generally, the safety certification system for both rail carriers and railway infrastructure managers assumes that there is a constant exchange of information and remarks between the certification process and the supervisory process regarding the observed irregularities related to its functioning. This information, collected during the certification process constitutes a basic scope of activities related to supervision, while the observations collected during the audit process have a direct impact on the renewal process of certificates and security authorizations (Polish Railway Company, 2016).

The design process itself is governed by relevant laws such as e.g.:

- Construction Law (uniform text Journal of Laws of 2010, No. 243, item 1623, as amended.)
- Rail Transport Act (uniform text of Journal of Laws of 2007 No. 16, item 94, as amended.)
- appropriate regulations such as e.g.:
- dated 26.02.1996 in regards with technical conditions to be met by intersections of railway lines with public roads and their location (Journal of Laws of 1996, No. 33, item 144, as amended),
- dated 3.07.2003 in regards with detailed technical conditions for traffic signs and signals and traffic safety devices, as well as conditions of their placement on the road (Journal of Laws 2003, No. 220, item 2181),

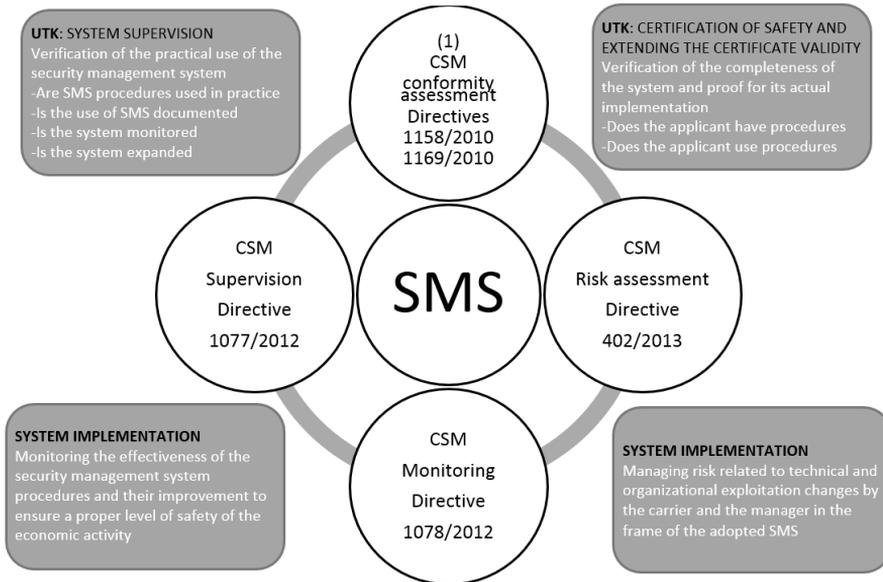


Fig. 1. Flow chart of certification and supervision processes (Polish Railway Company, 2016)

proper requirements of infrastructure managers and others such as e.g.:

- WTB-E10 Instruction - Technical guidelines for the construction of devices controlling railway traffic in the PKP company constituting an appendix to the Order No 43 of the PKP Management Board dated 09.09.1996, as amended,
- Safety requirements for rail traffic control devices - DG PKP KA No. KA2b-5400-01/98 dated 06.02.1998,
- Work of the Railway Institute No. 4430/10 of 2011 - Determination of permissible levels and disturbance parameters for rail traffic control devices.

and appropriate railway regulations such as e.g. Ie-1 (E-1) Instruction for Traffic Light or SMS-PW-17 procedures permitting elements of subsystems and technologies to be used on railway lines managed by PKP PLK S.A.

3.2. Security in buildings and startups

Similarly, as in design, all activities on railway areas must be organized according to relevant laws, standards, regulations or railway instructions.

The most important ones are, e.g., the Building Law Act (uniform text Journal of Laws of 2010, No. 243,

item 1623 as amended). The most important ones are Ie-6 (WOT-E12) Guidelines for the technical acceptance and commissioning of rail traffic control devices and the Ie-100a Conditions for safe installation and operation of rail traffic control devices managed by PKP PLK S.A.

3.3. Safety in exploitation

The maintenance of security in service and operation, i.e. throughout the entire life cycle of the product, that is from the time of its installation and commissioning, are also dependent on the compliance with the relevant rules.

The most important ones are the Ie-12 (E-24) Manual of maintenance, inspections and repair of current railway control devices, Ir-7 Manual of road and railroad crossings and transit of June 14, 2016 and Ie-100a - Conditions for safe installation and operation of railway traffic control devices on railway lines managed by PKP PLK SA.

3.4. Product/Article Safety.

Every product authorized for operation on the area of the PKP PLK network will undergo a series of tests and examination carried out in the production phase, related to its safe behavior in its life cycle. Some of the articles that are considered important

require a complex certification process as discussed above. As an example, we will use srk category A, B and C signaling devices. Despite the use of technically advanced technical solutions adopted in their design, production and subsequent development and exploitation of the highest standards of safety, these systems are not always able to prevent accidents. In the case of transits with active signaling of an approaching train, many accidents are related to non-compliance of the participants to the warnings signaled by the above-mentioned devices.

Unfortunately, statistics suggest that despite the decrease in the number of events, fig. 2 at rail crossings in the last 2 years has seen a significant increase in the number of victims of these accidents compared to the previous years.

4. Potential corrective measures in terms of improving safety

Despite such extensive, multisector and multifaceted organizational, legal and technical safety structures in rail transport, the increasing number of fatal accidents is alarming given the

positive trend in the overall decline in rail accidents. It is therefore advisable to conduct further research into the analysis of the possibilities for improved safety.

Activities that could improve safety at rail crossings and more precisely contribute to the decline in the number of victims:

- Separating traffic flows by rebuilding crossings into multi-level intersections.
- Reclassification of a crossing to another category, e.g. such whose safety rating is higher than of the existing one.
- Use of crossing warning dashboards on crossings equipped with automatic signaling.
- Continuously increasing the awareness of drivers about crossings such as a "Safe crossing" action, promoting compliance and proper behavior at intersections.
- Construction of new railway crossings
- Development and implementation of new, more reliable vehicle detection systems and information systems about approaching trains or a damaged car at the railroad crossing.

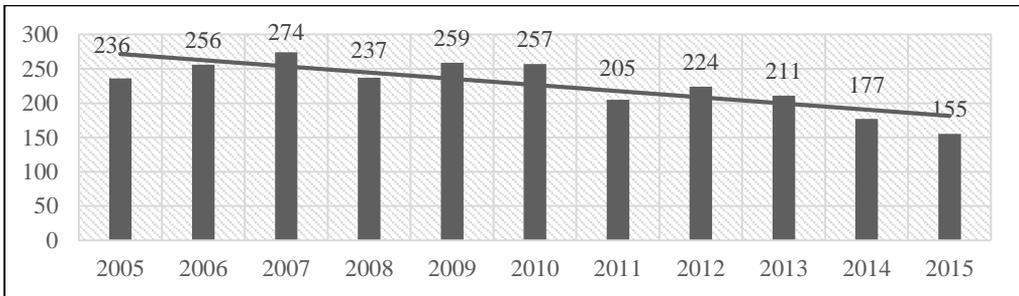


Fig. 2: Total number of accidents at rail and road crossings in 2005-2015 (Kot S., 2016)

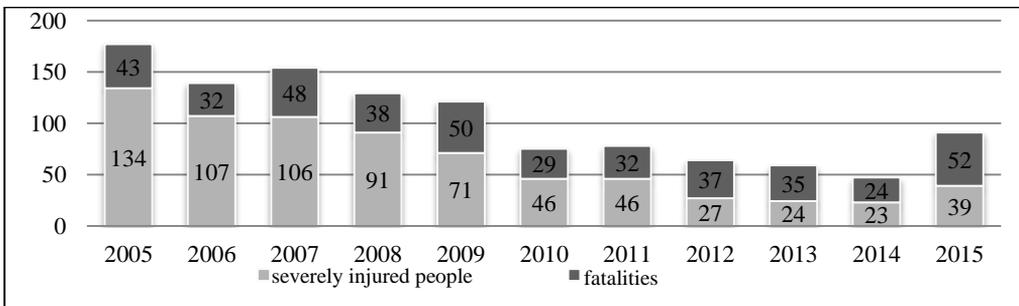


Fig. 3. Cumulative number of fatalities and severely injured persons at rail and road crossings (Kot S., 2016)

In regards with the last issue, an important concern in addition to the detection of an oncoming rail vehicle and the activation of signaling, is the detection of moving or non-moving objects at the very crossing and an early warning of the driver respectively. It is also very important to be able to identify a pedestrian as well as trace his movement in the area of a railway crossing. For now, it seems that the most appropriate technique for this type of security is the recording and interpretation of video or radar information, and the overall research and implementation of increased rail safety with the use of these systems is referred to as HRI - Highway-Railroad Intersection) (Mnii, 2008; John A., 2001). VPAS may be used as an example (Vehicle Proximity Alert System), which is mainly based on providing information to the cyclist about the approaching train (John A., 2001).

Another approach in this area was presented by the authors in the article (Burdzik R. et al, 2016). The concept of a safety system assisting at railway crossings was presented there as a module for detecting a rail vehicle using vibration signals.

5. Safety support system – case study

Authors have assumed that for the improving of railway crossing safety level the support system for the traffic detection can be developed. Some preliminary conception have been depicted in (Burdzik R. et al, 2016; Burdzik R. et al, 2017). To increase of the complex crossing safety level the support system has to be independent from current usage control devices, as axle counter block. It can be achieved by the operation parameters occurred

from different information source. Thus the investigation have been performed on application of vibration wave propagation employing as source if information. The emission of vibration includes the vehicle-track-soil interaction, the vehicle and track irregularities, and the dynamic axle loads. (Auersch L., 2010). The concept of prediction of railway-induced vibration were also presented in (Auersch L., 2014). The vertical interaction forces between the wheel and the rail are very sensitive both to irregularity of the track and train speeds.

Rail track is composed of two rails lying on sleepers joined by railpads. The rail provides the contact between the train wheel and the track. Vibrations from trains propagating from the rail to the ballast going through the sleepers, strains these same elements (Picoux B., 2005).

One of the major principles of wave propagation is the principle Huygens. The center particle stimulated to vibrate through the wave is the source of a new wave. Fundamental wave definition, considered as propagation of disorder ξ with velocity v by material , can be determined as formula:

$$\frac{\partial^2 \xi}{\partial t^2} = v^2 \left(\frac{\partial^2 \xi}{\partial x^2} \right) \tag{1}$$

For the case study on railway safety support system basing on the vibration propagation phenomena some preliminary investigations have been conducted.

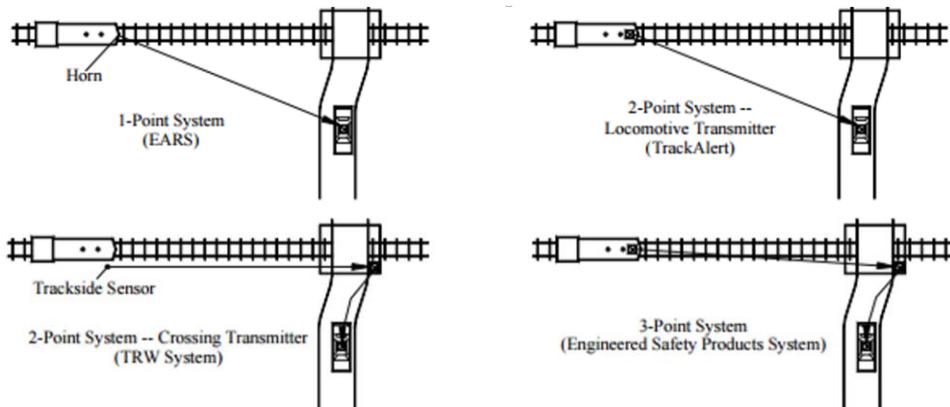


Fig. 4. Types of systems VPAS (John A., 2001)

The vibration sensor was connected into rail to register acceleration of the rail forced by the passing vehicle. During the experiment two scenarios were investigated. One as the car passage through the crossing level and the second as train simulator (two axle bogie) passage on the track. The vibration sensor was mounted next to the crossing level. The

waveforms of the acceleration of vibration for both cases have been depicted in Figure 5. For the illustration of the concept of data analysis the observation windows have been marked, where the amplitude of the signal is significantly higher (higher than reference value).

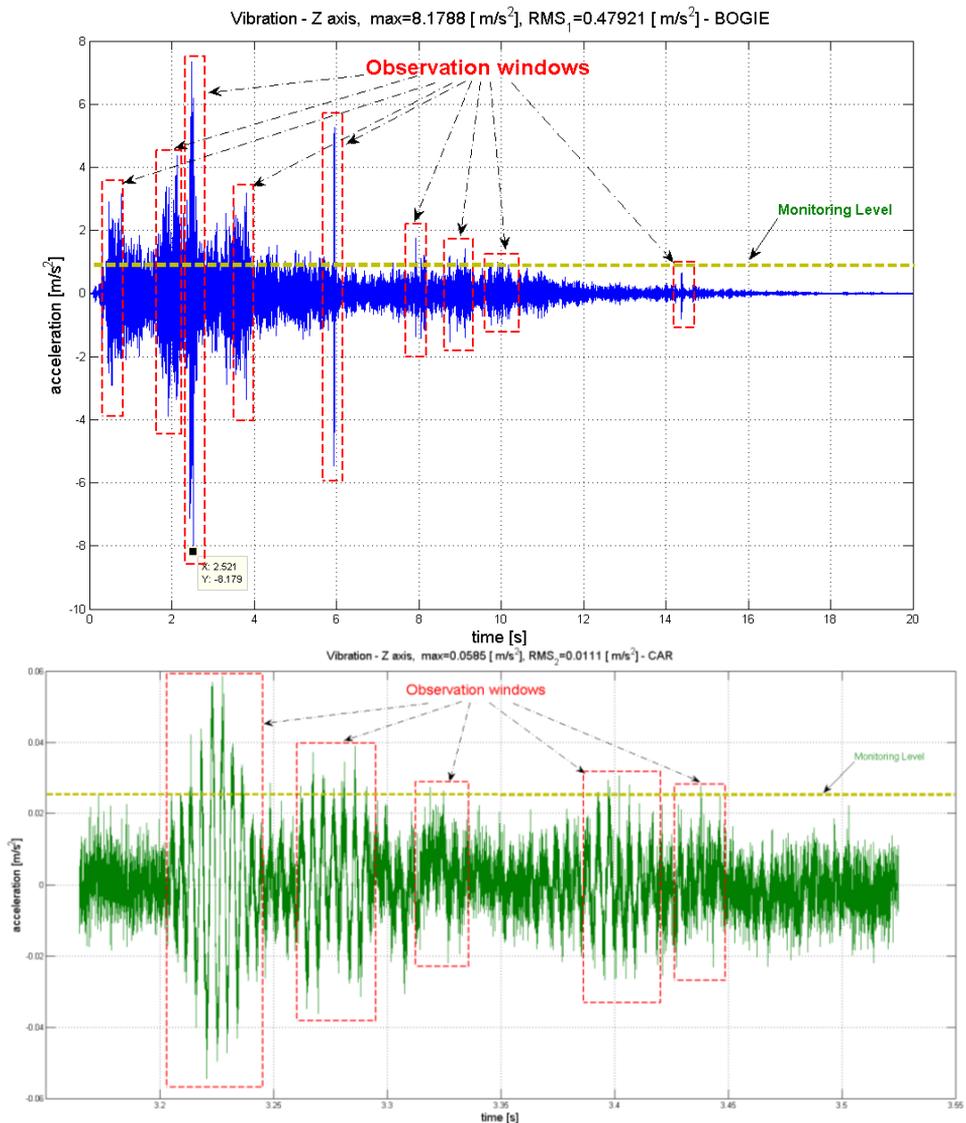


Fig. 5. Vertical acceleration of the rail - Traffic detection observation windows (upper – train passage, bottom – car passage)

A signal is represented in the domain of frequency by application of the discrete Fourier transform. In the sphere of signal processing, it is mainly used to transform the $f(t)$ function, being continuous in the domain of time, into the $F(\omega)$ function, continuous in the domain of frequency. The Fourier transform can be expressed as formula:

$$F(\omega) = \int_{-\infty}^{\infty} f(t) \cdot e^{-i2\pi\omega t} dt \quad (2)$$

The frequency distribution of vibration signal of passing car and train (bogie) have been depicted in Figure 6. Also it has been marked the observation windows, which are the defined frequency bands, where the energy of the signal is significantly higher.

Based on presented exemplary results it can be assumed that vibration signal of rail can be considered as source of information on vehicle traffic on the crossing level thus it can be implemented as support for the safety level.

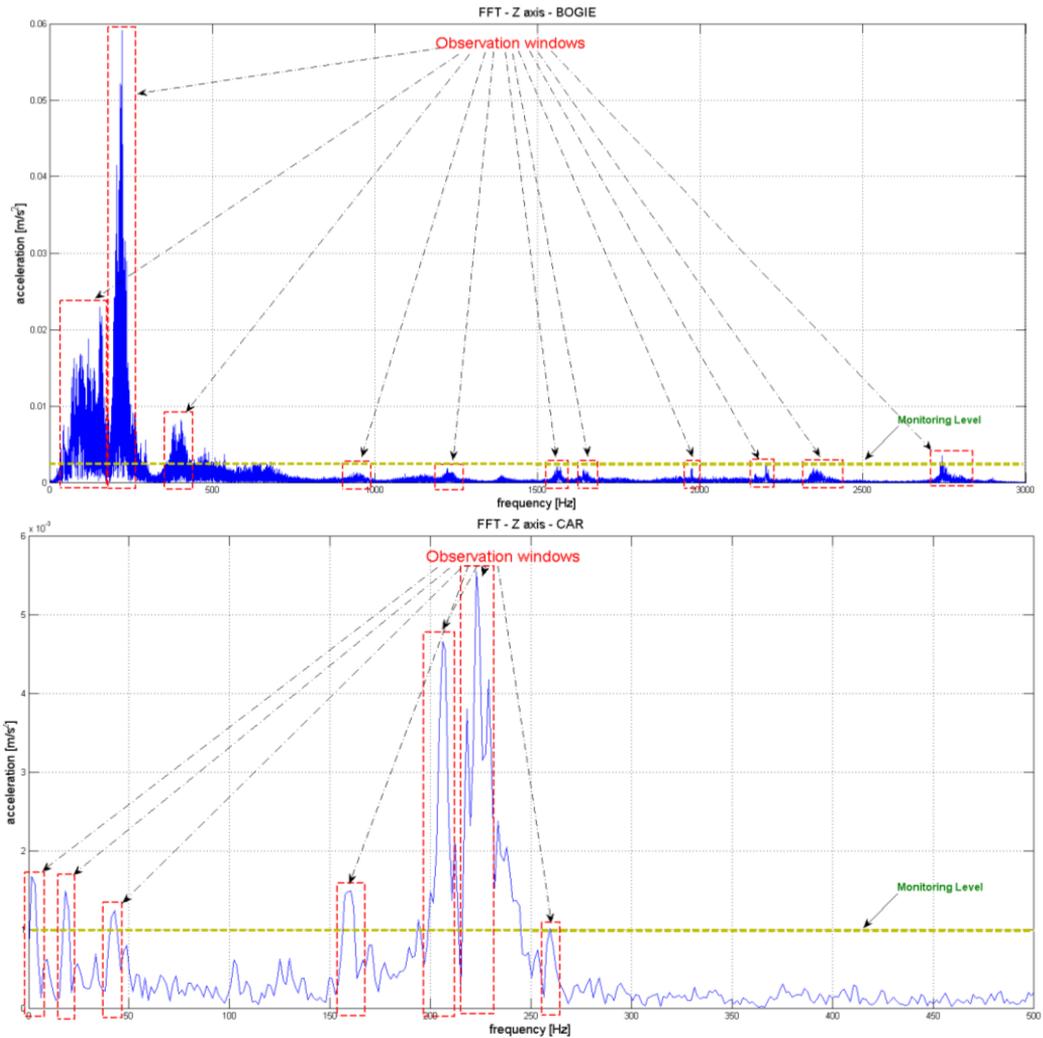


Fig. 6. Frequency distribution of vibration signal of passing train (upper) and car (bottom)

6. Conclusion

When speaking safety in the railway industry, it is not even possible to focus solely on the safety implemented in e.g. in or track-side control devices, especially when consider railway system as interoperable system (Pawlik M., 2016). The issue of security is an area binding almost all stakeholders in the industry and at the same time the participants of traffic affecting the railway infrastructure.

Among the problems that occur in the area of railway safety, there are those that result from rail transport technology and technique, the procedures and regulations used, but also from the inappropriate approach of employees to this issue, resulting from lack of necessary knowledge, mentality, habits, etc. In addition, the necessity to adopt safe habits in road users can make a significant contribution to improving railway traffic safety. The factors that determine safety in the area of rail crossings are:

- the way of informing road users of approaching a crossing
- the way to inform road users about traffic violation on the road
- the way to inform drivers of the state of the passage securing- closed/open traffic
- improvement of the reliable operation of train detection systems,
- organization of road traffic in the area of railway crossing,
- visibility in the area of the railway crossing,
- road surface on the crossing,
- behavior of road users passing through railway crossings,
- on crossings secured with devices handles by man
 - a way of informing them of the need to close crossing for traffic.

Results of the preliminary research presented in this paper show some potential of vibration signal as fundamental information source for the support of the safety system. At the same time, it should be underlined that the level of safety in rail transport is not limited to rail crossings but covers all transport and accompanying processes such as traffic safety, safety of getting in and out (loading and unloading), safety of stop and other stages of the transport process.

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