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VIBROISOLATION OF RAILWAY CROSSINGS WITH THE APPLICATION OF SHAPE-MEMORY ELEMENTS

Summary. This research presents existing problem of railway elements and motor – vehicle road elements at their intersections. The objects of simulation research were vehicles passing over a level crossing of automobile road and rail-transportation road. Objective of this research was to determine the vibration levels of structural elements of the crossing, to generate the loading curves for certain parts and to prepare a mathematical model that could be applied in further simulations. For this purpose a model of level crossing was built in the SolidWorks system. Subsequently, those simulations will produce relatively optimal level-crossing construction with the application of shape - memory elements, NiTi-type-materials.

WIBROIZOLACJA PRZEJAZDÓW KOLEJOWYCH Z WYKORZYSTANIEM ELEMENTÓW Z PAMIĘCIĄ KSZTAŁTU

Streszczenie. W pracy przedstawiono symulację oddziaływań dynamicznych pojazdów samochodowych w trakcie przejazdu przez wibroizolowany przejazd kolejowy z elementami elastomerowymi, wewnątrz których umieszczone są elementy z pamięcią kształtu typu NiTi. Symulację przeprowadzono dla samochodów osobowych o masie 1500 kg i samochodów ciężarowych o masie 15000 kg w zakresie prędkości 30 – 100 km/h i naciągu od 0 – 100 kN. Na rys.1 przedstawiono przejazd kolejowy składający się z płyt betonowych wewnętrznych 1 i zewnętrznych 2 podpartych elementach elastomerowych, w których umieszczone są druty typu NiTi z pamięcią kształtu 3. Celem tych symulacji jest określenie wpływu naciągu drutów z NiTi na własności systemu układu wibroizolacji przejazdów kolejowo samochodowych oraz możliwości regulacji parametrami wibroizolacji, jakimi są sztywność i tłumienie.

1. INTRODUCTION

The objects of simulation research were vehicles passing over a level crossing of automobile road and rail-transportation road, whose mathematical models were explained in section 3 of the paper [3]. Objective of this research was to determine the vibration levels of structural elements of the crossing, to generate the loading curves for certain parts and to prepare a mathematical model that could be applied in further simulations. Subsequently, those simulations will produce relatively optimal level-crossing construction. For this purpose a model of level crossing was built in the SolidWorks system. Its structure is presented in fig.1 and the outline is explained in fig. 2.

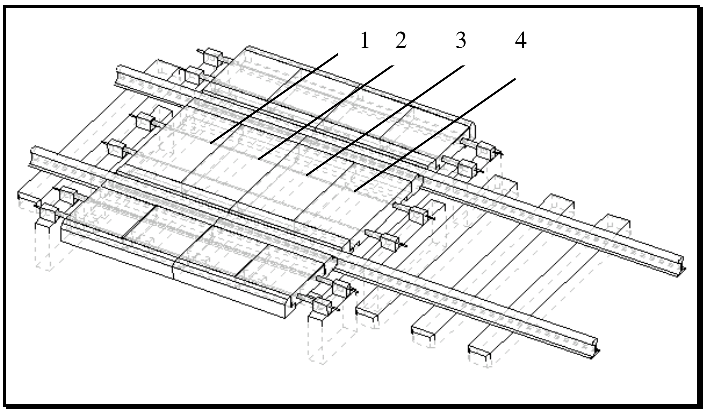

Fig. 1. Structure of vibroisolated railway crossing
Rys. 1. Schemat wibroizolowanego przejazdu kolejowego

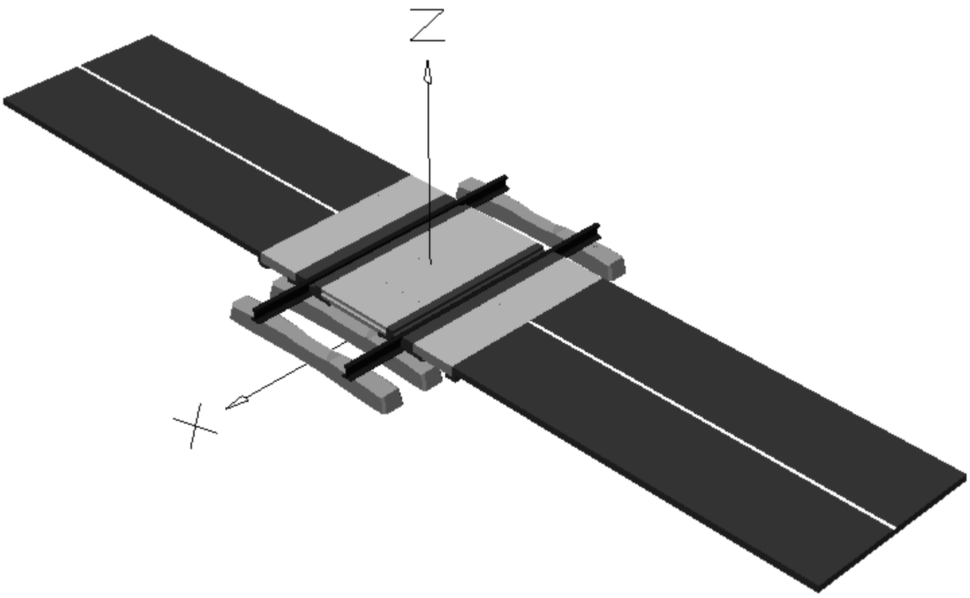

Fig. 2. Demonstration of vibroisolated railway crossing
Rys. 2. Modelowanie wibroizolowanego przejazdu kolejowego

After determining the moments of inertia of individual elements of the crossing, based on experimental research data and information obtained from earlier studies of related railway crossings and tramway crossings, we conceived a dynamic model of railway crossing in the MSC Visual Nastran 4D system. This model was applied for performing a series of simulations of operational loads of the assumed vibroisolation system as well as for specifying vibration levels of structural elements of the railway crossing (mainly inner slabs).

2. MODEL AND ENVIRONMENTAL CHARACTERISTICS

The simulation model of railway crossing was constructed by means of the software suite of MSC VisualNastran 4D. All the elements of the crossing were modeled as stiff bodies. This assumption was sufficient to carry out simulations, which concerned the mutual influences of individual components the of railway crossing, i.e. under-bed, rail and the crossing itself. In this model all the stiff bodies were joined by kinematic connections, whose elastic and damping parameters were determined in accordance with the real values that occur in those types of connections. Sliding of motor-vehicle wheels was also taken into consideration. Different scenarios were considered, e.g. ice, water skid. For simulation purposes a few vehicle models were constructed, such as a car of the weight of 1500 [kg] and a truck weighing 15000 [kg].

In each model the contact between a tyre and surface was simulated; fig. 3 and fig. 4.

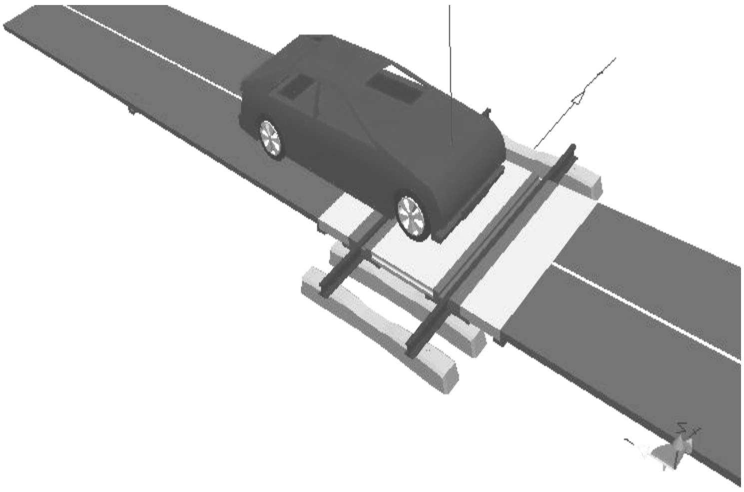

Fig. 3. Simulation of a car driving over the railway crossing in the MSC VisualNastran 4D system
Rys. 3. Modelowanie przejazdu samochodu osobowego przez przejazd kolejowy przy pomocy MSC VisualNastran 4D

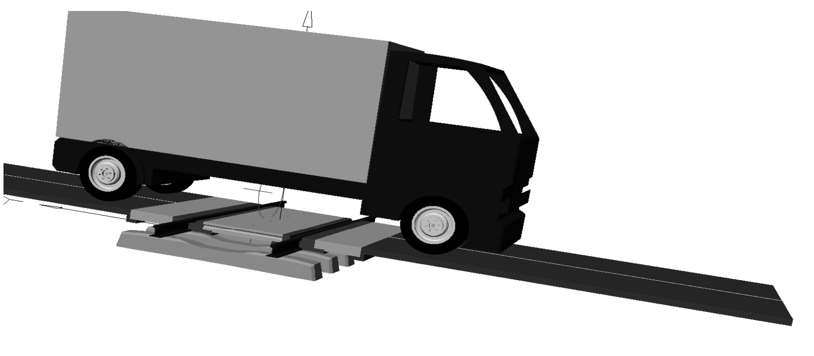

Fig. 4. Simulation of a truck passing over the railway crossing in the MSC VisualNastran 4D system
Rys. 4. Modelowanie przejazdu samochodu ciężarowego przez przejazd kolejowy przy pomocy MSC VisualNastran 4D

The model is parameterized, which enabled to carry out the different variant of dynamic simulations, as well as to create the database of component elements of the railway crossing. In the proposed solution of crossing construction strings are the main load-bearing elements. Those strings are mounted inside concrete slabs, through pre-manufactured channels. The NiTi strings are driven through straight-line openings and attached at both ends to retaining blocks with clench sleeves. As load-bearing elements they carry the tensile forces and transverse forces deriving from external loads on the crossing. String attachment both at passive and active side is done by means of conical jaws girding the string and thrusting into a pressing slab thus blocking the string (fig. 5). Pressing slab is fixed in a retaining block. There is a possibility to control the tensile force at the active side of a string, thereby to control the stiffness of the whole crossing.

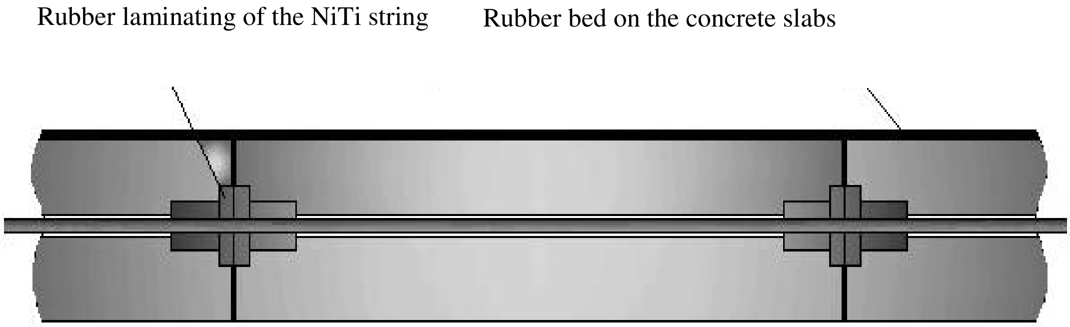

Fig. 5. Conception of driving the strings through concrete slabs – longitudinal section through a slab
Rys. 5. Koncepcja prowadzenia cięgna przez płyty betonowe – przekrój wzdłużny przez płyty

Strings that are placed inside channels hollowed in concrete slabs are held by rubber connectors at the joints of the slabs – as it is demonstrated in fig. 6. These connectors play the role of articulated joints between slabs and they transmit the external loadings onto a string.

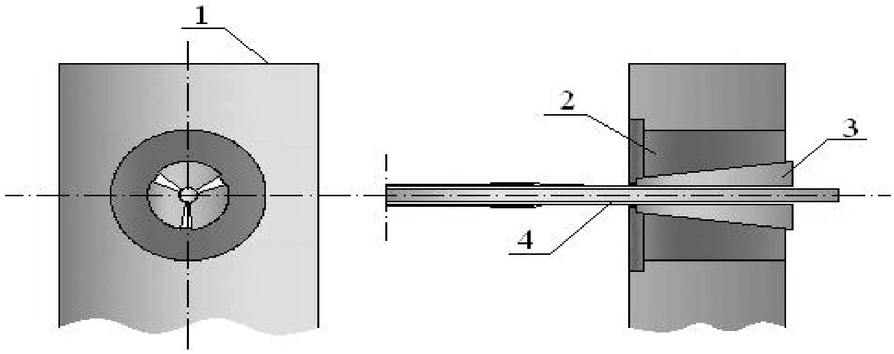

Fig. 6. Frictional attachment - string fastened into a retaining block: 1 – retaining block, 2 – pressing slab, 3 – conical jaws, 4 – NiTi string
Rys. 6. Zakotwiczenie tarciowe – sposób zamocowania cięgna w bloku oporowym: 1 – blok oporowy, 2 – płyta dociskowa, 3 – szczęki stożkowe, 4 – cięgno z NiTi

Rubber - concrete slabs are placed on vibroisolated and sound-isolated elements manufactured of rubber. They are also covered with elastomer anti-slide layer. The main element transferring the dynamic effects from rail transportation and automobile transportation are strings made of NiTi alloy. Their additional task is to protect the slabs from lateral displacement and to enhance the stability of the crossing. Concept of vibroisolation with the application of NiTi strings involves setting such tensile force in the string so as to provide a possibility of adjusting the vibroisolation parameters for the specific type of automobile vehicle. That would reduce dynamic and acoustic effects on natural environment and slabs' keyboarding. This solution features:

- possibility of simple control of tension in load-bearing element and the slabs' compressing force depending on the extent of loading of the railway crossing;
- possibility of simple control of tension in load-bearing element by changing the temperature of a NiTi string;
- effective components isolating the noise source (railway rail), by means of rubber layers of sound-isolating properties attached under the rails;
- concrete slabs propped up on rubber elements and strings with their position stabilized by means of strut screws or temperature;
- resilient-elastic connection of slabs - along the axis of track; between the slabs resilient-elastic elastomer elements were applied was and rubber connectors play the role of articulated joints between the slabs;

- capability of controlling the stiffness and suppression in vibroisolating elements, mainly elastomer components in which the NiTi strings are sunken;
- concrete slab covered in damping rubber layer of anti-slide texture.

3. SIMULATIONS OF DISPLACEMENTS OF SLAB CENTERS OF VIBROISOLATED RAILWAY CROSSING DURING THE PASSAGE OF A CAR OF MASS ABOUT 1500 KG AND A TRUCK OF MASS ABOUT 15.000 KG

The simulations of vibration displacements of vibroisolated internal slabs 1 - 4, (fig. 1) were conducted for the parameters enclosed in table 1.

Table 1

Parameters the simulations of vibrations displacement of vibroisolated slabs

Simulation No.	Vehicle type	Vehicle weight [kg]	Vehicle speed [km/h]	Damping coefficient of rubber element [Ns/m]	Tensile force of the string [kN]
1	car	1500	30	adjusted	0; 20; 40; 60; 80; 100
2	car	1500	50	adjusted	0; 20; 40; 60; 80; 100
3	car	1500	70	adjusted	0; 20; 40; 60; 80; 100
4	car	1500	100	adjusted	0; 20; 40; 60; 80; 100
5	truck	15000	30	adjusted	0; 20;40; 60; 80; 100
6	truck	15000	50	adjusted	0; 20; 40; 60; 80; 100
7	truck	15000	70	adjusted	0; 20; 40; 60; 80; 100
8	truck	15000	100	adjusted	100

Since truck speed is in principle limited to 70 km/h, the simulation was conducted with the NiTi string tension of 100 kN. Fig. 7, fig. 8, fig. 9, and fig. 10 below present the example results of calculations obtained by simulation of displacements of the crossing slab1 for a car and a truck with weight for plate 1, (fig. 1), at string tension of 20 and 60 kN, and driving speed of 50 km/h.

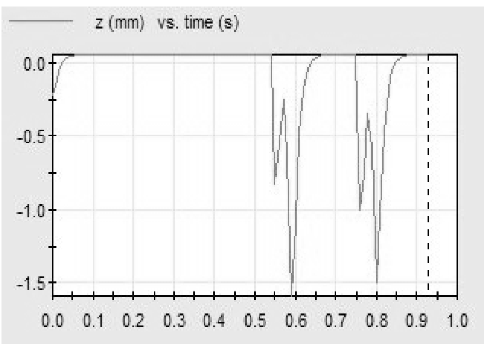

Fig. 7. Amplitude of displacements of slab1 tension force of 20 kN and the car speed - 50 km/h

Rys. 7. Amplituda przemieszczeń płyty 1 przy naciągu cięgna siłą 20 kN i prędkości samochodu – 50 km/h

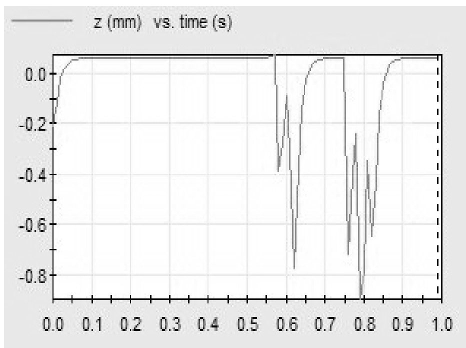

Fig. 8. Amplitude of displacements of slab1 with with tension force of 60 kN and the car speed - 50 km/h

Rys. 8. Amplituda przemieszczeń płyty 1 przy naciągu cięgna z siłą 60 kN i prędkości samochodu – 50 km/h

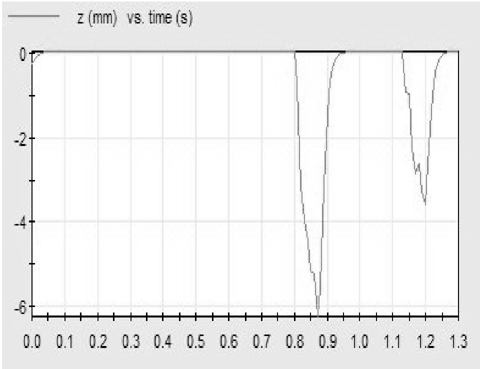

Fig. 9. Amplitude of displacements of slab1 with tension force of 20 kN and the truck speed - 50 km/h

Rys. 9. Amplituda przemieszczeń płyty 1 przy naciągu cięgna siłą 20 kN i prędkości samochodu ciężarowego – 50 km/h

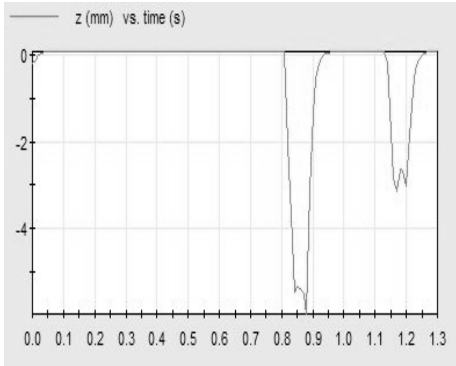

Fig. 10. Amplitude of displacements of slab1 with tension force of 60 kN and the truck speed - 50 km/h

Rys. 10. Amplituda przemieszczeń płyty 1 przy naciągu cięgna z siłą 60 kN i prędkości samochodu ciężarowego – 50 km/h

Analysis of these curves clearly proves that there is significant effect of the string tensile force on the value slab displacement in a vertical direction. It must be remembered that tension forces of strings made of shape-memory materials determine this value. Stiffness of those strings depends both on tensile force and temperature. Both of these parameters can be tested quite accurately. Simulations were carried out for different values of tension forces. Research pertaining to NiTi material properties is contained in literature item [2]. This allows for significant freedom of selection of vibroisolation parameters taking intelligent material into consideration.

In addition, simulation of displacement amplitude of central slab in the crossing was carried out for vibroisolated crossing and typical crossing, i.e. without vibroisolation. The simulation assumed driving of a car of 1500 kg mass at the speed of 50 km/h. The characteristic of this simulation is presented in fig. 11.

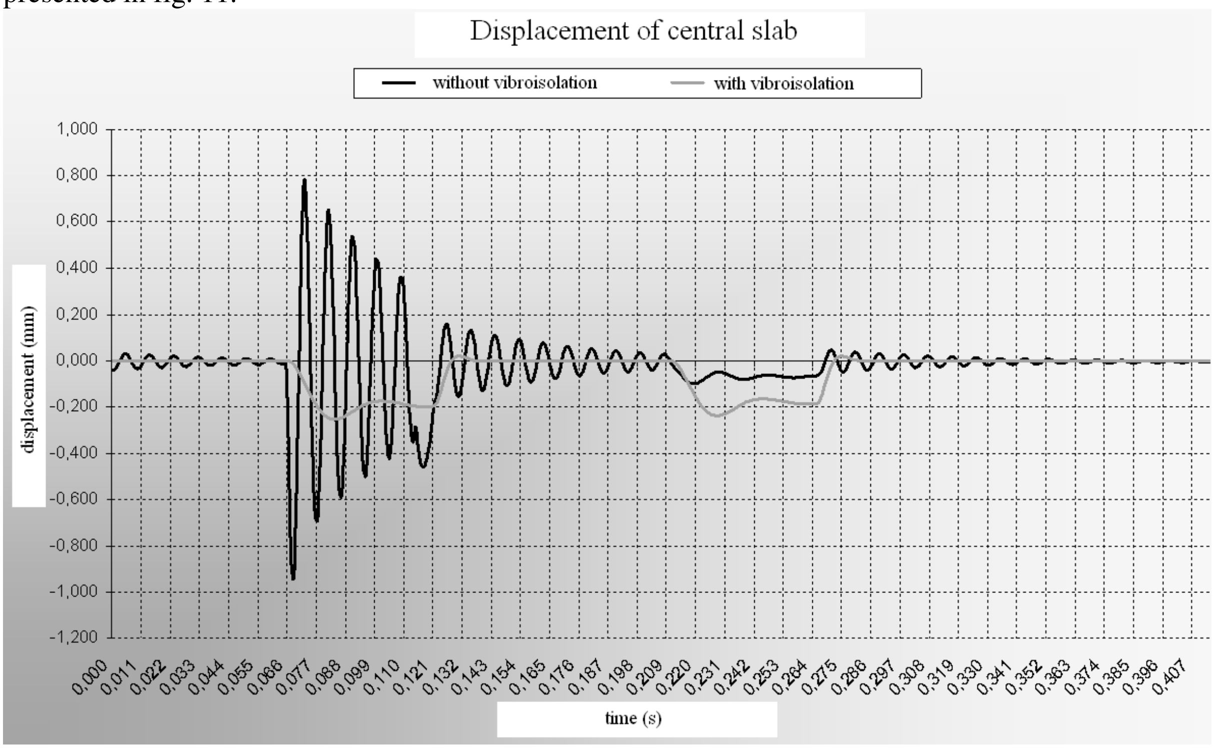

Fig. 11. Displacement of center slab in the crossing for vibroisolated crossing and typical crossing, without applying vibroisolation for a car of 1500 [kg] mass and at the speed of 50 [km/h]

Rys. 11. Przemieszczenie środkowej płyty betonowej przy przejeździe samochodu o masie 1500 [kg] po tradycyjnym przejeździe i przejeździe wibroizolowanym z prędkością 50 [km]

This drawing reveals a considerable difference of vibration amplitudes for the compared types of crossings, which proves the positive effect of applying the vibroisolation system in railway crossings. The crossing without vibroisolation is characteristic for the occurrence of great vibration amplitude of the center slab, which in consequence, after a long exploitation, causes the phenomenon of jumping up of the slab and its quicker technical degradation.

This phenomenon is clearly shown in amplitude-frequency characteristic (fig. 12) where difference of vibration amplitudes for both types of crossings rides is particularly apparent. This characteristic is a strong evidence for the effectiveness of the application of vibroisolation system.

4. SUMMARY AND CONCLUSIONS

Based on conducted simulations for vibroisolation systems of railway crossings the conclusions can be drawn, that ideas of solutions of railway crossings, introduced among other works in items [1] and [4,5], fulfill the assumed requirements and significantly reduces the transmission of dynamic effects from automobile vehicles to the surroundings.

To recapitulate, it could be stated that conducted simulation research enables to formulate the following conclusions that should be taken into consideration in designing vibroisolated railway crossing:

- value of damping coefficient of elastomer vibroisolating elements, as well as intelligent materials suggested to be included in the railway crossing structure, should be as high as possible, to limit the values of vertical displacements of rubber-and-concrete slabs (central and external ones), in order to reduce slab keyboarding. The value needs to be precisely adjusted not to lead to deterioration of vibroisolation (damping coefficient is selected through simulations),
- mass of automobile vehicles significantly affects the dynamic loads on the crossing; whereas vehicle speed has smaller effect on these loads,

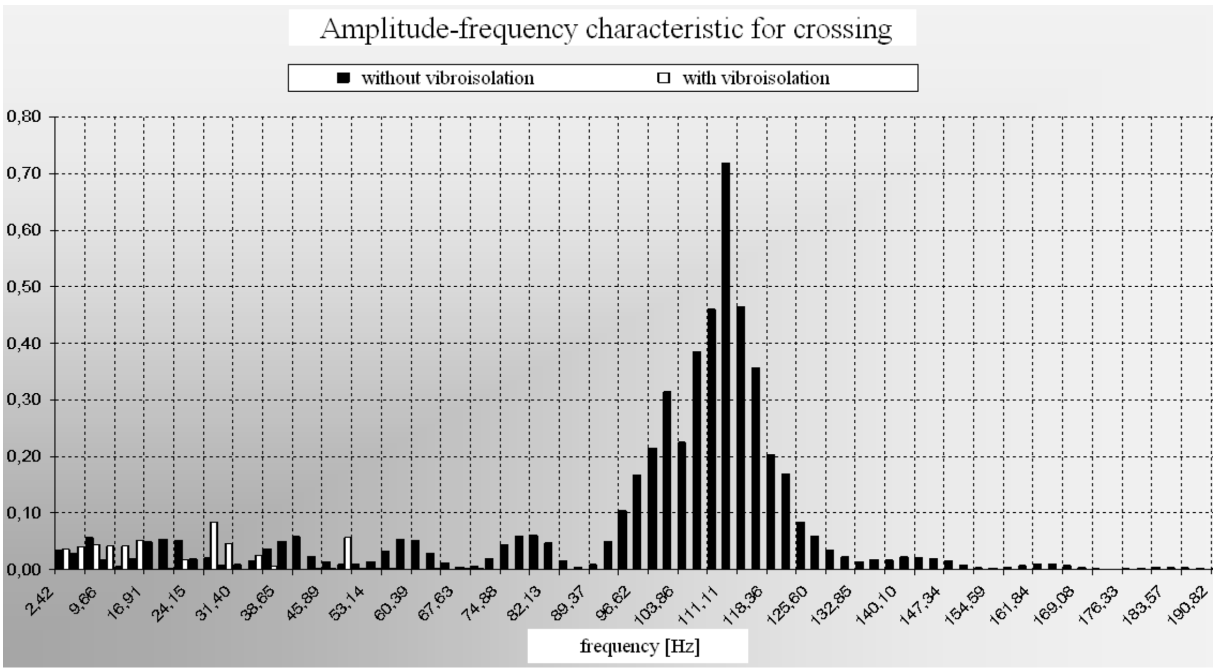

Fig. 12. Amplitude - frequency characteristic for crossing with the application of vibroisolation and without it
Rys. 12. Charakterystyka amplitudowo częstotliwościowa przejazdu z zastosowaną wibroizolacją oraz bez niej

- possibility of keyboarding is eliminated,
- the application of strings made of intelligent, NiTi alloy type, material as additional vibroisolating and load-bearing element enables to adjust the vibroisolation parameters in a discreet manner or through the application of automated systems to control the tension force in strings depending from the type of automobile passing over the railway crossing.

Compared to other technological solutions of railway crossings, the solution suggested above features much simplified assembly and the possibility to control damping and resilience parameters in real-time, which allows for better fulfillment of vibroisolation requirement. This requirement is fundamental in reducing dynamic influence on the surroundings.

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