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Operational Vibration Analysis of Railway Transport Complex

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BIOGRAPHICAL NOTES

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KEY WORDS

Transport complex, container, vibration analysis

ABSTRACT

Packages for transporting radioactive materials have to meet requirement of normal and accident transport conditions. On the basis of methodology of experimental verification packages for transport of radioactive materials elaborated by authors were realized extensive tests of containers. In the paper is described modal and vibration analysis of transport complex during its transportation.

1. Introduction

Transport containers serve for manipulation and transport with spent nuclear fuel from reactors of nuclear power stations. During the certification of packages (containers) for transporting radioactive materials is necessary to provide analyses that they

meet requirements of Regulations of Nuclear Regulatory Authority of the Slovak Republic - UJD SR No.57/2006 Z.z. for normal and failure conditions of transport [1]. On the workplace of authors was recently realized safety verification of containers by analytical and numerical methods [2]. Because of fact that above-mentioned verification recommends for the assessment of container safety experimental methods, the authors had elaborated methodology for such a test of nuclear waste packages [3, 4]. One part of extensive experimental analysis [5, 6] was a modal analysis and analysis of vibration of real transport complex during its moving.

According to Supplement No. 1 of Regulation No. 57/2006, Part II., the consignment have to withstand any accelerations, vibrations, or resonances that can arise under conditions presumable during normal transport without decreasing of tightness of closure mechanisms in different parts of package or without violation of its integrity. From this reason has been accomplished modal analysis and analysis of vibration of system container – wagon, during its movement with prescribed velocity, starting, breaking as well as movement through twists and locations, where mechanical vibration of system could occur [7]. Container (Fig. 1) is positioned during the transport on special railway wagon (Fig. 2). For the transport on the carrying wagon are on the body of container welded 4 supporting (carrying) surfaces. The container is fixed to wagon by fitted bolts and 2 though holes on every supporting surface. Selected transport conditions and technical parameters of transport complex are max. velocity of loaded coach 100 km/h, weight of container 68 t, weight of wagon 35 t, max. loading capacity of wagon 85 t.



Fig. 1: Container for transport of spent nuclear fuel.



Fig. 2: Transport complex with container.

2. Causes of transport complex vibration

There are several sources of vibration in road and railway transport complexes [8 - 10]. The most important sources of excited vibrations that can occur during movement of transport complex are:

■ Interaction of steel wheels of undercarriage of wagon during their rolling on rails

Vibration is caused by bumpiness (corrugation) of contact surface on rail heads (Fig. 3), or by roughness of contact surface resulting from damaged wheels.

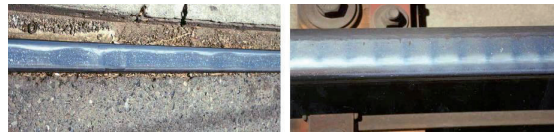


Fig. 3: Bumpiness of contact surface on rail head.

■ Impacts of wheels

The impacts of wheels occur during run through the rail joints as result of gaps between rails or due to their non-coaxially. The same effect arises during run through rail switches (Fig. 4). In case of wheel damage (Fig. 5), where the flat surfaces on the wheel occur, the periodic impact influences results to excited vibration.

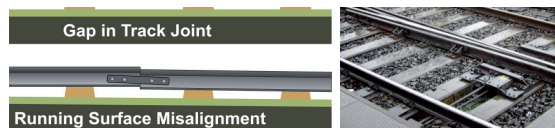


Fig. 4: Discontinuity of railway track.

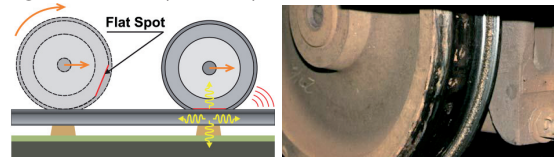


Fig. 5: Damage of wagon wheel.

■ Immediate character of run

The excitation shakes can occur also during starting, breaking and running through bends, which is accompanied by noticeable sound effect.

3. Causes of transport complex vibration

Modal analysis of mechanical systems can be realized by analytical, numerical or experimental methods of mechanics [7, 11, 12].

Modal analysis of carrying part of wagon bridge was realized for two positions of three-axis acceleration sensor Brüel & Kjær 4506B. Sensor S1 was positioned on a lid of container (Fig. 6a) and sensor S2 on a frame of undercarriage above pan of wagon bearing (Fig. 6b). Locations of sensors allow gaining information about transmission of vibration excitation during movement of complex at the second stage of measurement (see section 4).

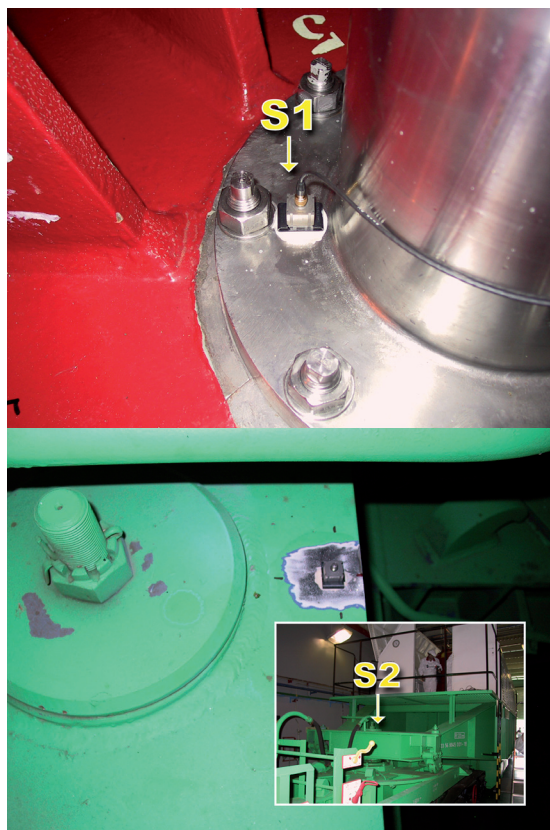


Fig. 6: a) Location of sensor S1 on lid of container, b) location of sensor S2 on the frame of undercarriage over bearing shell of wagon.

Table 1: Eigenfrequencies of transport complex.

Frequency [Hz]	4.33	13.99	35.37	44.37	74.15	81.37	98.54	120.2	435.9	696.7
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The locations of hammer impact were chosen in such a way that the longitudinal and transversal symmetry of wagon has been exploited. There were chosen 9 locations for excitation by impact hammer. The locations were the same for both sensors (S1 and S2). Acceleration sensors S1 and S2 had axis x in vertical direction, axis y was oriented perpendicular to axis of wagon and axis z was identical with wagon's axis. For excitation was used impact hammer Brüel & Kjær model 8210. For the measurement and its evaluation has been used platform Pulse produced by company Brüel & Kjær.

Functions of frequency transfer measured for individual positions of excitation were processed in program Pulse Reflex. Software algorithms using function CMIF (Complex Mode Indicator Function) has been used for estimation of eigenshapes and eigenfrequencies. The eigenfrequencies determined by this procedure on the basis of analysis of stability diagrams are given in Table 1. It have to be mentioned that results of modal parameter measurement in which sensor S2 was used, are identical with those gained by sensor S1.

4. Operational vibration analysis of transport complex

Measurement of operational vibration of transport complex during its movement was realized on railway road of length approximately 3600 m. The road was divided to 5 sections (see Table 2) with considerably different characteristics of driving. In section No. 1 were recorded vibrations during starting of complex and during its movement through railway switches of railway station. Section No. 2 is characterized by driving through right bend. Section No. 3 is a straight road on the beginning of which is a railway bridge above road communication. Section No. 4 is left bended. In the section 5 that can be considered as straight road, the complex was stopped, accelerated and halting at the end of section. Maximum velocity of complex during measurement was 40 km/h, which corresponds to value received from operator.

For the measurement of vibration deflections were used three-component acceleration sensors Bruel&Kjaer 4506B, applied in locations S1 and S2. The sensors were connected to measurement system Bruel&Kjaer PULSE 3560 that records time-de-

pendent charts of acceleration deflections to the hard disc of notebook. Measurement apparatus was supplied from portable electro-generator. In order to receive more precise analysis, time-dependent charts at individual sections were further divided into smaller time intervals. As the aim was to assess massiveness of vibration, the acceleration charts were transformed by function of frequency weighting $1/j\omega$, while the received frequency spectrum of maximum velocities for given sections were filtered to frequency range from 2 Hz to 1 kHz, in accordance with Standard STN ISO 10816-1. Frequency spectra of maximum velocity amplitudes and its maximal effective values determined from signals S1 and S2 are for each section given in Fig. 7 - 12. Appropriate choice of frequency range allows reading frequen-

cies at the highest amplitudes of velocity.

Table 2: Lengths and short description of road sections.

Section number	Section length	Description of section
1	800 m	Movement from station – typically crossing several railway switches.
2	400 m	Right twist.
3	600 m	Relatively straight road.
4	150 m	Left twist.
5	1650 m	Relatively straight road.

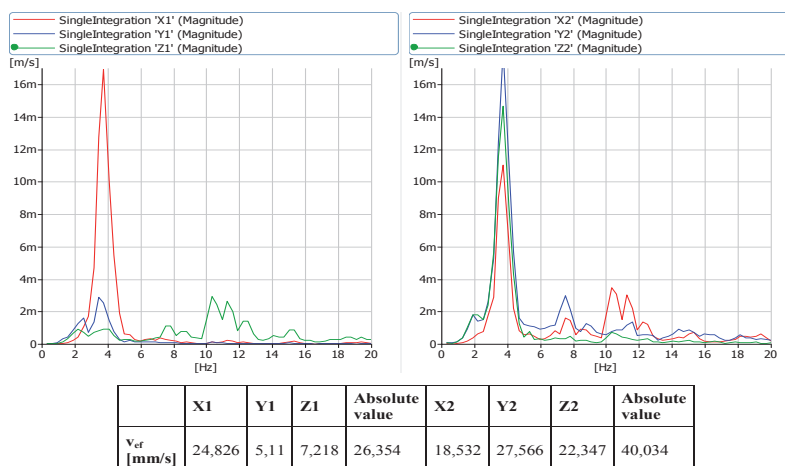


Fig. 7: Frequency spectra of maximum velocities and its effective values: Section no. 1 - acceleration through railway switches.

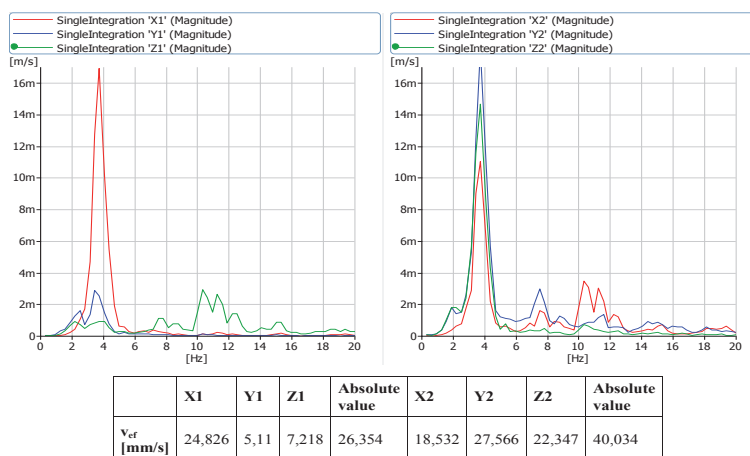


Fig. 8: Frequency spectra of maximum velocities and its effective values: Section No. 2 – right twist.

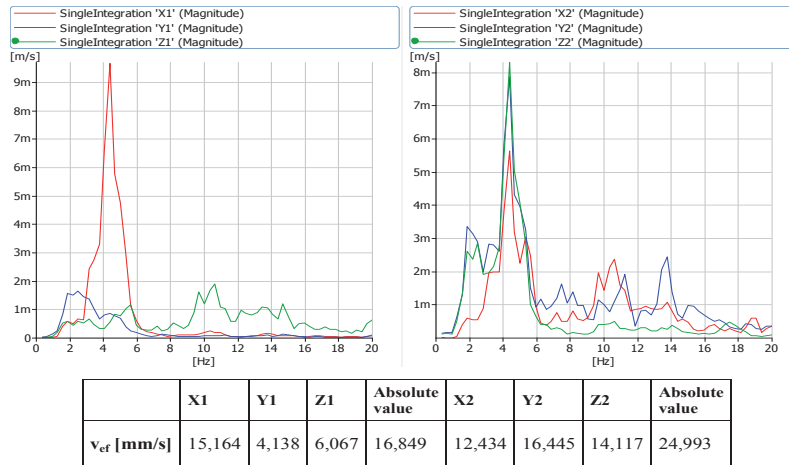


Fig. 9: Frequency spectra of maximum velocities and its effective values: Section No. 3 – straight.

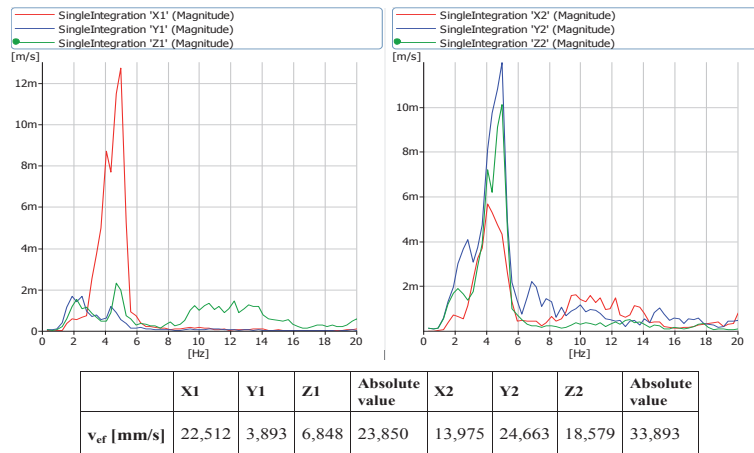


Fig. 10: Frequency spectra of maximum velocities and its effective values: Section No. 4 – left twist.

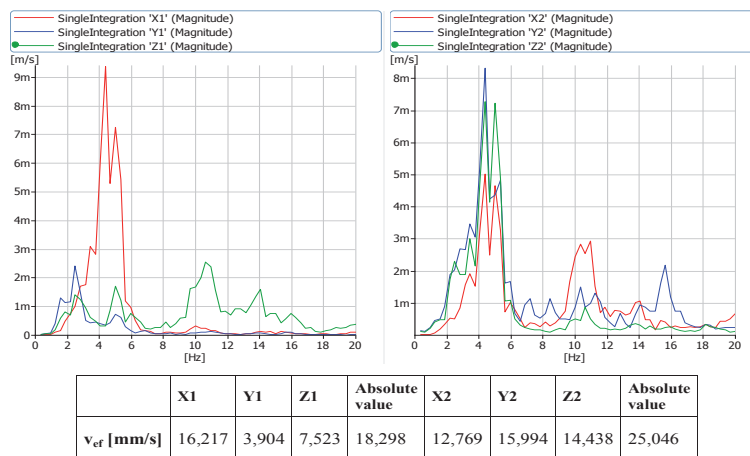


Fig. 11: Frequency spectra of maximum velocities and its effective values: Section No. 5 – movement.

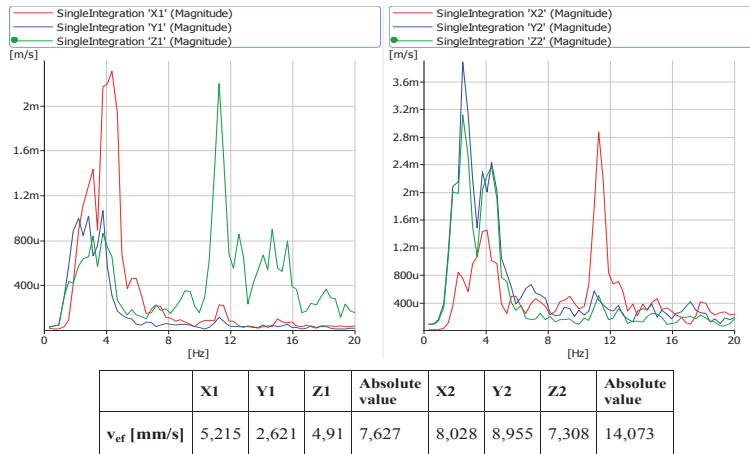


Fig. 12: Frequency spectra of maximum velocities and its effective values: Section No. 5 – deceleration on straight road.

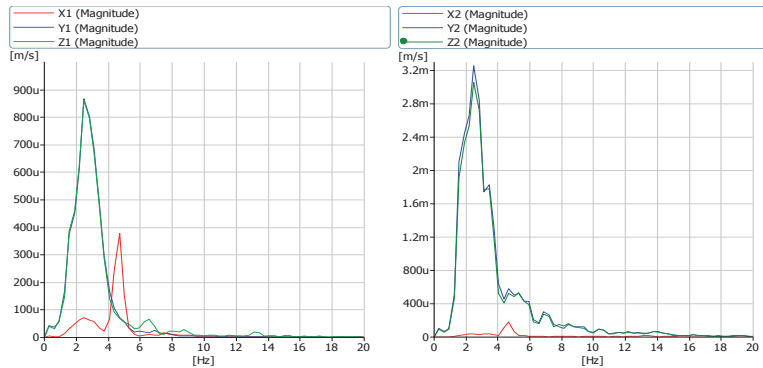


Fig. 13: Frequency spectrum of maximum amplitudes of complex vibration velocity during standstill of wagon measured by sensors S1 and S2.

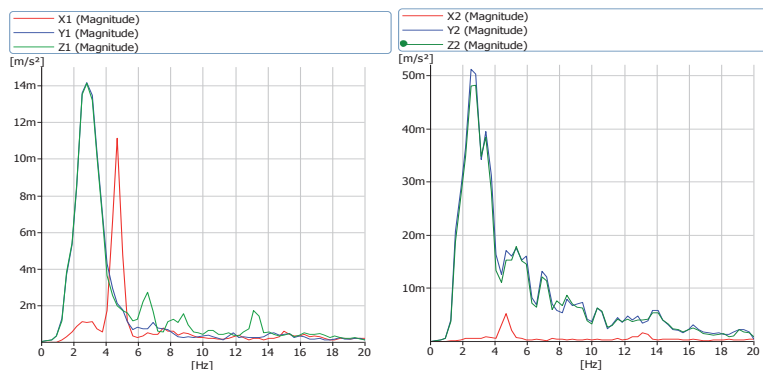


Fig. 14: Frequency spectrum of maximum amplitudes of complex vibration acceleration during standstill of wagon measured by sensors S1 and S2.

From operational vibration analysis of transport complex accomplished during its moving results that maximum effective vibration velocity was

40 mm/s. This velocity was reached during acceleration through railway switches at the first section of road.

In order to determine excitation effect of locomotive motor to vibration of transport complex as well as for elimination of influence of voltage generator, measurement of frequency spectrum of maximum vibration velocities of unmoving transport complex with working motor of locomotive and voltage generator has been accomplished. In Fig. 13 and Fig. 14 are depicted frequency spectra of maximum velocities and accelerations of vibration in locations of sensors S1 and S2 in directions x, y, z.

From graphs in Fig.13 and Fig.14 results that the biggest amplitudes of velocities are in frequency range 2.5 to 2.8 Hz. These amplitudes can be registered also on charts of vibration velocities of transport complex during its movement.

5. Conclusions

From the results of operational vibration analysis of transport complex can be concluded that vibration velocity magnitudes mainly depend on the type of railway road and of transport conditions. The biggest amplitudes of vibration velocity during movement were reached at the range frequency 3.8 - 5.0 Hz which correspond to eigenfrequency 4.342 Hz. Maximum allowable velocity 100 km/h of transport complex can be, on the basis of modal and vibration analysis, considered to be suitable for transport. At the same time it is recommended to over cross the velocity 42-43 km/h as fast as possible, because the excitation of system at this velocity is near frequency 4.3 Hz. The other eigenfrequencies that result from analysis are not important for the technique of transport and accordingly no attention is given to them. According to Standard STN ISO 10816-6 „Mechanical vibration of machines on non-rotating parts“, Addendum A, Table A.1 and for level of vibration massiveness 28, for machines with classification numbers 5, 6 and 7, such an equipment is suitable for long time operation.

It has to be mentioned that during assessment of vibration massiveness, it was considered that absolute value of effective velocity is result of vector addition of effective velocity components in direction of axes x, y, z. Maximum value of such velocity was 40 mm/s. The machines with diesel motors with power crossing 100 kW and classified at level 6 and 7 can work under this velocity without limits.

6. Acknowledgement

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