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Experimental Vibration Analysis of Railcar for Spent Nuclear Fuel Transportation

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Abstract Safe operation of technical and technological equipments is necessary for preventing undesirable and dangerous states. The questions of lifetime and reliability of mechanical systems are solved very often in this context in practice. Particularly high demands are placed on safety of equipments that can operate only on the basis of special permissions. Transport containers for transportation of used nuclear fuel cassettes belong to this group of devices. On the basis of operator's order, complex methodology of type tests of transport container including its means of transport was elaborated. Described methodology includes analysis of vibration of transport complex during its movement.

Keywords: *vibration analysis, railcar, transportation, spent nuclear fuel, container*

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1. Introduction

Transport containers Figure 1 serve for manipulation and transport of spent fuel from nuclear reactors. The projected lifetime of containers is 30 years. In order to get certificate of ÚJD SR (Nuclear Regulatory Authority of the Slovak Republic) for using these containers, it was necessary to map and document their actual technical state. In order to fulfill all demands of regulations, series of experimental measurements and tests were performed for determination of their residual lifespan [1,2,3].

Figure 1. Transport container for spent nuclear fuel

According to Supplement No. 1 of Regulation No. 57/2006, Part II., the consignment have to withstand any accelerations, vibrations, or resonances that can arose under conditions presumable during normal transport without decreasing of tightness of closure mechanisms in different parts of package or without violation of its integrity. Especially, nuts, bolts, pins, and other safety equipments has to be design in such a way that self-releasing cannot occur during their using, even in case of their multiple using. From this reason has been accomplished modal analysis and analysis of vibration of system container – railcar, during its movement with prescribed velocity, starting, breaking as well as movement through curves and locations, where mechanical vibration of system could occur [4,5,6].

Transport complex consists of special carrying railcar and transport container. Moving system of railcar Figure 2 is composed of four pairs of two-axle rotable undercarriages. Lower undercarriage is a railcar bridge manufactured as welded structure. It consists of main longitudinal and transversal rotating pans, carriers of couplings and heads. Above lower undercarriage is positioned working platform for positioning of container and its sheathing, which consists of basic plate and protective extensions. These extensionsare closed during the transport and protect container against unauthorized encroachment and influence of weather.

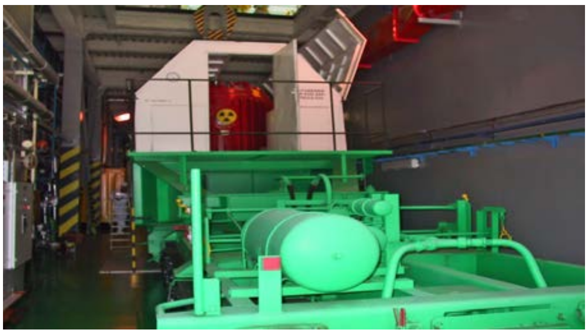

Figure 2. Transport railcar

For the transport on the carrying railcar are on the body of container welded 4 supporting (carrying) surfaces.The container is fixed to railcar by fitted bolts and two through holes on every supporting surface. Transport conditions and technical parameters of transport railcar are given in Table 1.

Table 1. Railcar technical parameters and transport conditions

max. velocity of loaded truck	100 km/h
max. velocity of unloaded truck	100 km/h
mass of container	68 t
mass of railcar	35 t
max. loading capacity of railcar	834 kN
mass of transport complex	120 t
max. loading of one axle	47 kN
whole length including bumpers	19 410 mm
min. radius of railway	75 m
ambient temperature during transport	-40°C to +38°C

2. Analysis of Railcar Vibration during Transport

2.1. Causes of Railcar Vibration

There exist several sources of vibration produced during transport [7,8,9]. The first one is an interaction of steel wheels of undercarriage of railcar during their rolling on rails. In this case, vibration is caused by bumpiness (corrugation) of contact surface on rail heads, or by roughness of contact surface resulting from damaged wheels.

Figure 3. Discontinuity of railway track

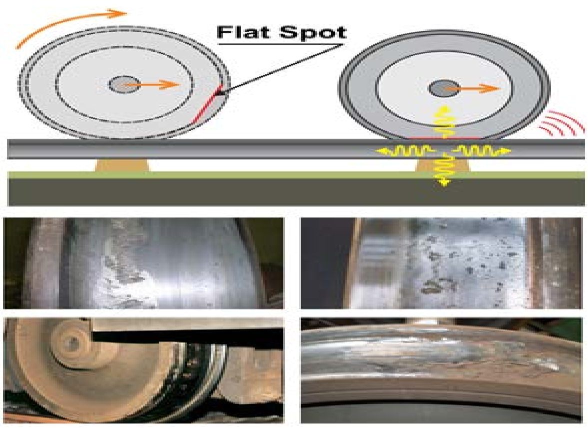

Figure 4. Damage of railcar wheel

The next source is the impact of wheel that occurs 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 Figure 3. In case of wheel damage Figure 4, where the flat surfaces on the wheel occur, the periodic impact influences results to excited vibration.

Immediate character of run can also cause vibration. The excitation shakes can occur also during starting, breaking and running through bends, which is accompanied by noticeable sound effect.

2.2. Experimental Measurement

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 Figure 5 and 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.

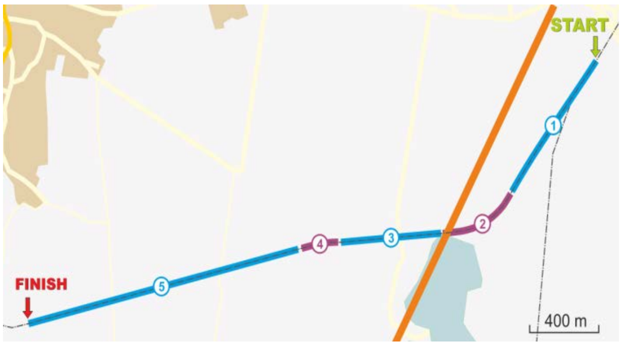

Figure 5. Map of the railroad used for operational vibration measurement

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

For the measurement of vibration deflections were used three-axial acceleration sensors Bruel&Kjaer 4506B, applied in locations S1 and S2. Sensor S1 was positioned on a lid of container Figure 6a and sensor S2 on a frame of undercarriage above pan of wagon bearing Figure 6b. Acceleration sensors S1 and S2 had axis x in vertical direction, axis y was oriented perpendicular to axis of railcar and axis z was identical with railcar's axis.

The sensors were connected to measurement system Bruel&Kjaer PULSE 3560 that records time-dependent charts of acceleration deflections to the hard disc of notebook. Measurement apparatus was supplied from portable electro-generator.

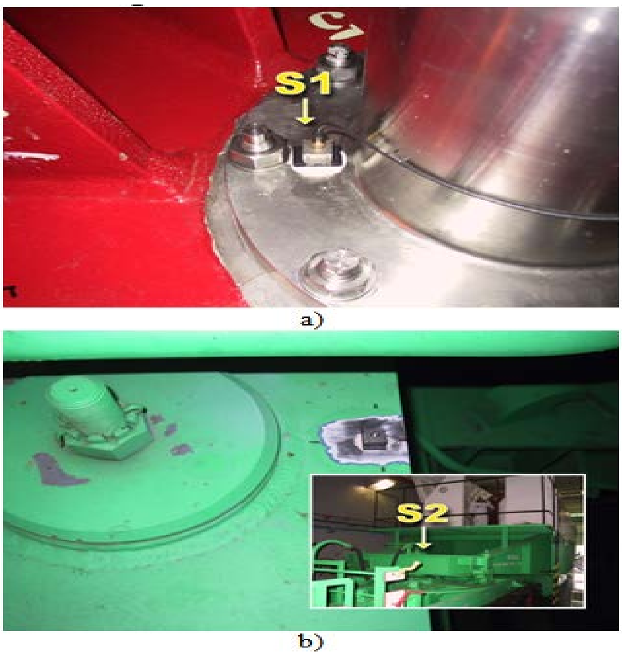

Figure 6. a) Location of sensor S1 on lid of container, b) location of sensor S2 on the frame of undercarriage over bearing shell of wagon

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/jω, while the received frequency spectrum of maximum velocities for given sections were filtered to frequency range from 2 Hz to 1kHz, in accordance with Standard STN ISO 10816-1 [10]. For every such spectrum effective velocity has been computed according to relation:

$$v_{eff} = \sqrt{v_1^2 + v_2^2 + \ldots + v_n^2}. \quad (1)$$

Frequency spectra of maximum velocity amplitudes determined from signals S1 and S2 are for each section given in Figure 7, Figure 8, Figure 9, Figure 10, Figure 11. Appropriate choice of frequency range allows reading frequencies at the highest amplitudes of velocity. Maximal values of effective vibration velocities are summarized in Table 3.

Table 3. Maximal values of effective vibration velocities reachedonindividual section of the railroad

Section No.	Effective values of vibration velocity (mm/s)							
	Sensor S1				Sensor S2			
	X1	Y1	Z1	Mag	X2	Y2	Z2	Mag
1	24,83	5,11	7,22	26,35	18,53	27,57	22,35	40,03
2	14,51	1,84	8,86	17,09	14,17	16,04	13,39	25,25
3	15,16	4,14	6,07	16,85	12,43	16,45	14,12	24,99
4	22,51	3,89	6,85	23,85	13,98	24,66	18,58	33,89
5	16,22	3,90	7,52	18,30	12,77	15,99	14,44	25,05

From vibration analysis of transport railcar accomplished during its moving results that maximum effective vibration velocity was 40 mm/s. This velocity was reached during accelerated movement over railway switches at the first section of road.

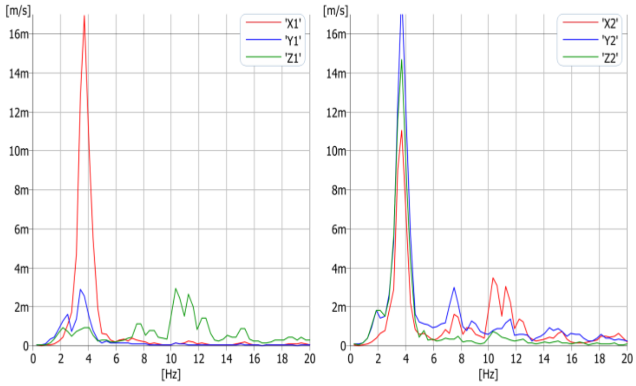

Figure 7. Section No. 1 - acceleration through railway switches

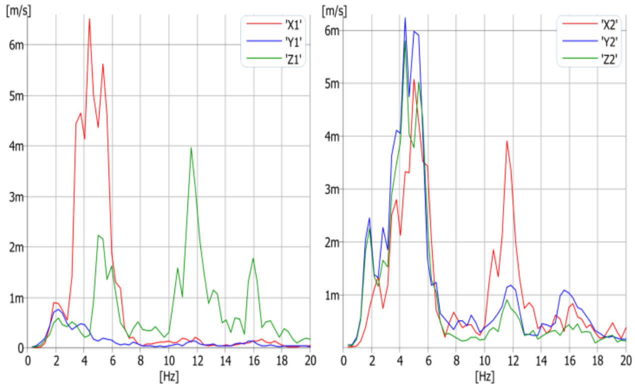

Figure 8. Section No. 2 - right twist

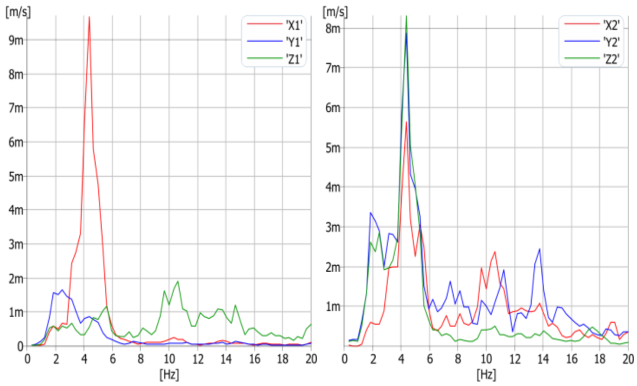

Figure 9. Section No. 3 - straight road

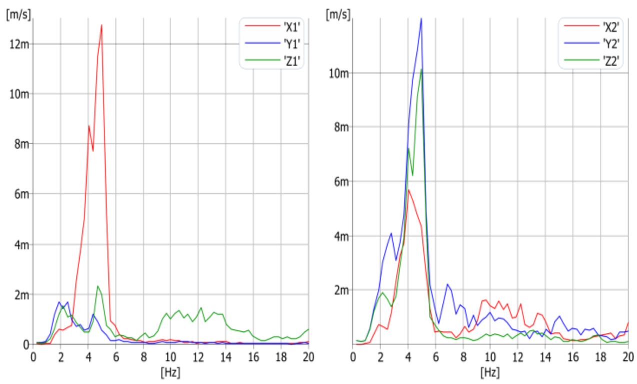

Figure 10. Section No. 4 - left twist

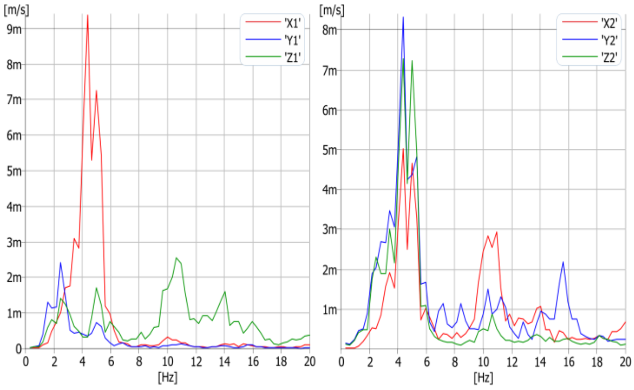

Figure 11. Section No. 5 - movement on straight road

In order to determine excitation effect of locomotive motor to vibration of transport complex, measurement of frequency spectrum of maximum vibration velocities of non-moving railcar with working motor of locomotive has been accomplished. In Figure 12 are depicted frequency spectra of maximum velocities and accelerations of vibration in locations of sensors S1 and S2 in directions *x*, *y*, *z*.

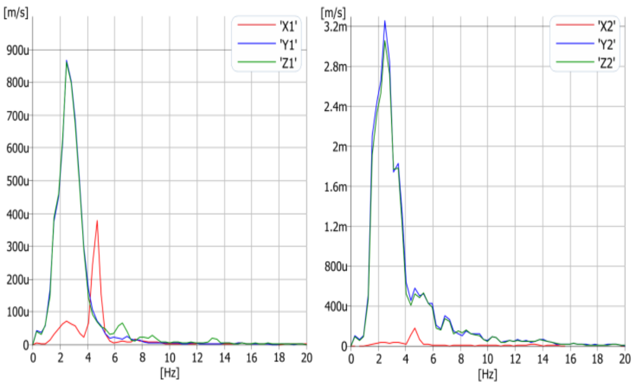

Figure 12. Frequency spectrum of maximum vibration velocities of non-moving railcar measured by sensors S1 and S2

3. Conclusion

From the results of operational vibration analysis of transport railcar can be concluded that vibration velocity magnitudes mainly depend on the type of railroad and of transport conditions. According to Standard STN ISO 10816-6 [11], Addendum A, Table A. 1 and for level of vibration massiveness 28, for machines with classification numbers 5, 6 and 7, the analyzed railcar 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. Maximum allowable velocity 100 km/h of transport complex can be considered as suitable for transport. 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 in the frequency range 3.5 ÷ 5.0 Hz, when the maximal effective value of velocity vibration occurs.

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References

[1] Trebuňa F. et al., "Methodology of standard measurements and tests including verification of residual lifetime of transport containers", Technical University of Košice, 2011.

[2] Trebuňa F., Šimčák F.,*Odolnosť prvkov mechanických sústav*, Technical University of Košice, 2004, 980 pages.

[3] Trebuňa F., Šimčák F., *Príručka experimentálnej mechaniky*. Technická univerzita v Košiciach, Košice, 2007, 1525 pages.

[4] Trebuňa F. et al.,"The verification of transport container's residual lifetime", Measurement report, Technical University of Košice, 2011.

[5] Trebuňa F. et al., "Standard measurements and tests of transport container", Final report, Technical University of Košice, 2011.

[6] Bocciolone M., Caprioli A., Cigada A., Collina A. "A measurement system for quick rail inspection and effective track maintenance strategy",*Mechanical Systems and Signal Processing*, Volume 21, Issue 3, April 2007, 1242-1254.

[7] Thompson D.*Railway noise and vibration: mechanisms, modelling and means*, Elsevier, 2009.

[8] Towers D. A., *Rail transit noise and vibration*, Harris Miller Miller & Hanson Inc., 2008.

[9] Žiaran S.*Znižovanie kmitania a hluku v priemysle*, STU Bratislava, 2006.

[10] STN ISO 10816-1 "Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 1: General guidelines." SÚTN, Bratislava, 1999.

[11] STN ISO 10816-6 "Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 6: Reciprocating machines with power ratings above 100 kW", SÚTN, Bratislava, 1999.