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Conformity Assessment of a Modernised Locomotive Bogie and Body Connection – Type Tests and Results

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Abstract

Referring to the lecture held on 16th Mini-Conference on Vehicle System Dynamics, Identification and Anomalies, Budapest, 5-7 November 2018, the accredited Notified Body started the conformity assessment process of the modernized bogie-locomotive body connection of MÁV-START Class V63 electric locomotives running with Ganz-MÁVAG UFC-type bogies, in 2017. Since the planned modification of the locomotives was delayed, the Conformity Assessment Body could perform the necessary riding quality and noise test in the summer of 2020 instead of September 2018. The study presents the modification carried out on the locomotives, the test procedures, and the test results. The aim and the novelty of the research was to apply the latest developments of the test procedures on a modified, existing rolling stock. The conformity for the new requirement makes challenges for the development of testing even if theoretically a well-known test method is applied. The article gives an example for the application of a classic test method combined with of the new possibilities, that makes unnecessary the use of additional railway test cars.

Keywords

rolling stock conformity assessment, riding quality tests, noise tests

1 Introduction

The Class V63 electric locomotives of 3676 kW (5000 HP) power and nearly 120 tons adhesive weight were designed for heavy freight train service, at beginning of the 1970s. Having finished the type tests, the production of the locomotives started with the null series, in 1980. 56 units of Class V63, Co'Co' (Co-Co) electric locomotives were built in Budapest until 1988. The first seven locomotives were equipped with UFC-type bogies. Although the structure of the UFC-type bogies met the expectations in terms of running technic and traction, however the relatively large number of the elements caused some difficulties in the maintenance work and wheel load adjustment. The rest of the Class were put into service with new bogies built under KRUPP licence. Although Ganz-MÁVAG UFC-type bogies had been successfully tested for 160 km/h speed on No. M63,002 diesel-electric locomotive earlier, the V63 fleet was licensed for 120 km/h, making possible to run with heavy express trains. Upgrading of Budapest – Hegyeshalom line and the procurement of MÁV high speed passenger coach stock made necessary to increase the speed of the existing express locomotives. 10 units of the Class V63 were involved in this project and the licensed speed of the locomotives was increased up to 160 km/h, creating the new MÁV Class V63,1.

2 Modernisation of UFC-type bogie-locomotive connection

Changing technical requirements over the decades, primarily the working conditions of locomotive crews, have necessitated changes, first to the locomotive bogie connection.

The UFC-type bogies' body connection on the locomotives is of the so-called pendulum suspension type. The suspension beams, which are "U" shaped steel castings located on either side of the bogie, are connected to the brackets formed on the side of the bogie frame with longitudinal pins. The transverse clearance of the suspension beam is 40 mm. The lower, horizontal part of the suspension beam is hollow and lined with sliding plates inside. The sliding plates flank the radius link-motion body, in which a spherical shell is mounted. A spherical

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component was bolted to the bottom of the bracket extending from the underframe, which is connected to the radius link of the suspension beam (Fig. 1). The hollow of the suspension beam is filled with oil. It is protected from the weather by bellows sewn from cowhide.

The advantage of the design is that it does not transfer minor lateral track defects to the locomotive body and allows the easy adjustment of the curve through the radius link also. However, the design has several disadvantages. Its sliding wear parts require maintenance, the leather accordion can be easily damaged, and rainwater, surrounding dust, brake dust can enter the hollow causing increased wear.

The mechanical metal structure transmits body noise on the bogie to the locomotive body without damping.

The pendulum suspension of the locomotive body met the requirements thanks to the high-quality structural materials, it was not considered a simple structure.

With its 3676 kW (5000 HP) power and nearly 120 tons of adhesive weight, the locomotive is excellent for heavy freight train service and contributes a considerable amount to the revenue of MÁV-START (Fig. 2).

All of these forced the owner to upgrade the locomotives' bogie-body connection. The owner commissioned the designers to plan a similar conversion to the Class V46 and V43 electric locomotives, and the bogie suspension should be implemented with the installation of a laminated rubber spring.

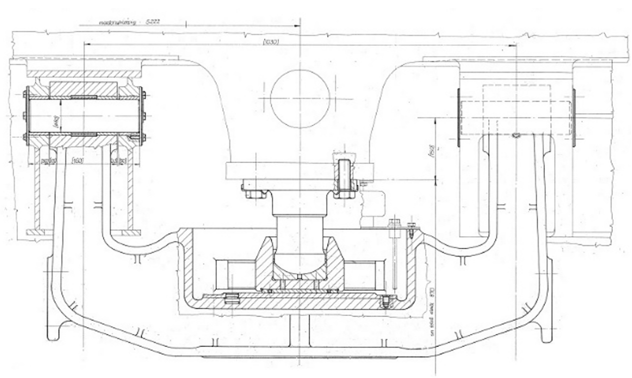

Fig. 1 The original locomotive bogie-body connection

Fig. 2 The converted electric locomotive No. V63,004
(Photo: Zoltán Lukács)

The Suspension Beams along with their components as well as the ball pin had to be removed for the conversion. In the place of the cast steel suspension beam, a new welded pendulum beam was designed to connect to the old part. Its horizontal top surface is suitable to accommodate two laminated rubber springs. The rubber springs are identical to those applied on Class V46 and V43 locomotives. The pendulum beam is rigidly attached to the bogie frame with bolted parts, so any horizontal movement is absorbed by the laminated rubber springs. The brackets extending from the underframe have been extended with additional pieces to rest on the laminated rubber springs (Fig. 3). Four transverse dampers per bogie were fitted between the bogies and the underframe.

To determine the effectiveness of the conversion, it is necessary to examine the extent to which the vehicle's riding quality and running safety parameters have been changed as the result of the conversion.

The modification of the locomotives must be certified since this kind of activity concerns the Technical Specifications for Interoperability relating to the Rolling Stock Subsystem – LOC&PAS TSI No. 1302/2014/EU (European Commission, 2014a) and Noise TSI No. 1304/2014/EU (European Commission, 2014b). The requirement in the case of old rolling stock modernization is that these parameters should show an improvement, including the reduction of drivers' cab noise levels.

The certification for the conversion of the locomotives' bogie-body connection and the measurement of the noise level tested in the driver's cab had to be carried out in accordance with the Module combination SB+SD, determined by the 2010/713/EU: Commission Decision

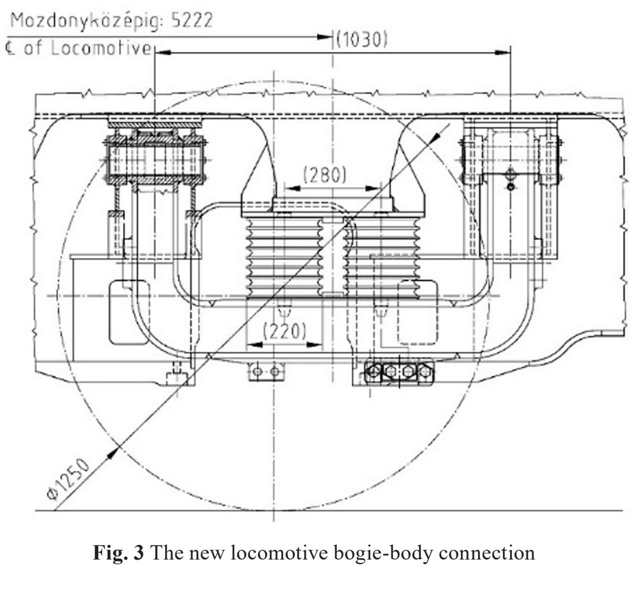

Fig. 3 The new locomotive bogie-body connection

of 9 November 2010 (European Commission, 2010) on modules for the procedures for assessment of conformity, suitability for use and EC verification to be used in the technical specifications for interoperability adopted under Directive 2008/57/EC of the European Parliament and of the Council (European Parliament, Council of the European Union, 2008).

The concept of the conformity assessment process was published in the Proceedings of the 16th Mini Conference on Vehicle System Dynamics, Identification and Anomalies (VSDIA 2018) (Malatinszky, 2019:pp.187–192).

3 Tests and test equipment

During the tests, the LUXACT Neo 1D sensor, developed and manufactured by SMG Technologie GmbH, was used for both cases, registering the speed at running technical and noise measurements. Unlike the traditional mechanical, optical, radar and GPS-based sensors, LUXACT is fundamentally based on two measurement principles, optical and inertial, taking advantage of both. The high-quality, innovative, wide-aperture optical system allows for a clear signal even in harsh environments.

The precise inertial system improves the optical signal if it is damaged. The sensor's brain is a high-performance DSP (digital signal processor) and FPGA (Field-programmable gate array) combined with a 24-bit ADC (analogue-to-digital converter). This intelligent system performs complex online calculations that integrate LUXACT optical and inertial technologies and enjoy the benefits of both. The collaboration of sensors provides a real-world response to rapid speed changes, low-noise speed measurements, and measurements in a zero-speed environment. Triaxial B&K 4524-B and 4535-B piezoelectric acceleration sensors were mounted on the vehicle body and bogie for the running technical tests. Only the *y* and *z* directions were evaluated (Figs. 4 and 5).

The measurement data of running technical tests were collected and processed using HBM Hottinger Baldwin Messtechnik GmbH Quantum X 840 B digital measurement data acquisition and processing instrument, HBM Catman software (Hottinger Brüel & Kjaer GMBH (HBK), 2019) (Fig. 6).

The interior noise level of the cab was measured with a Svantek 979 Integrating Noise Level Meter (Fig. 7).

The compliance with technical requirements of the LOC&PAS TSI is deemed established when a basic parameter is improved in the direction of the TSI defined

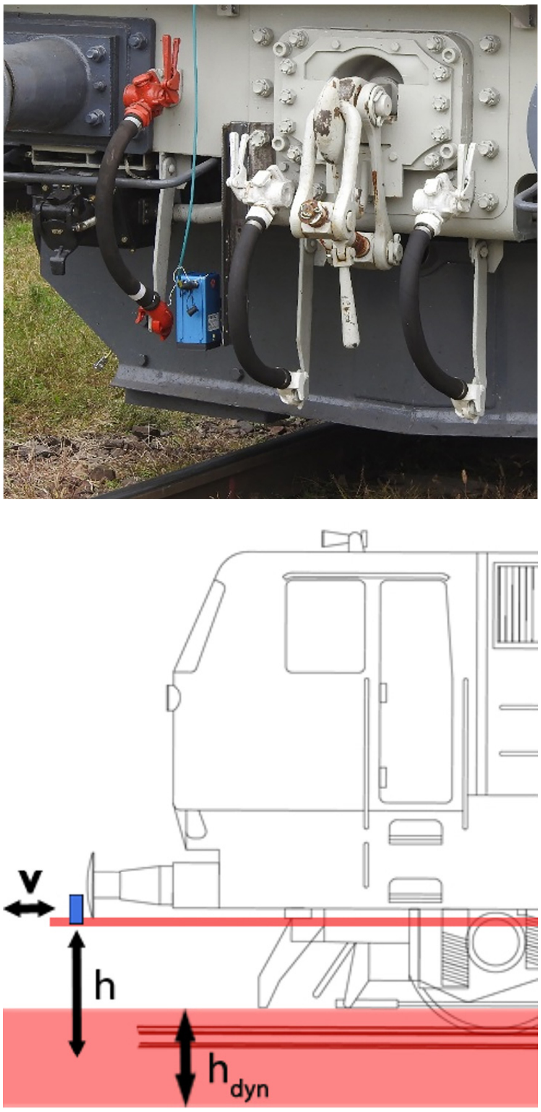

Fig. 4 The LUXACT on the headstock of the locomotive (Photo: Zoltán Lukács)

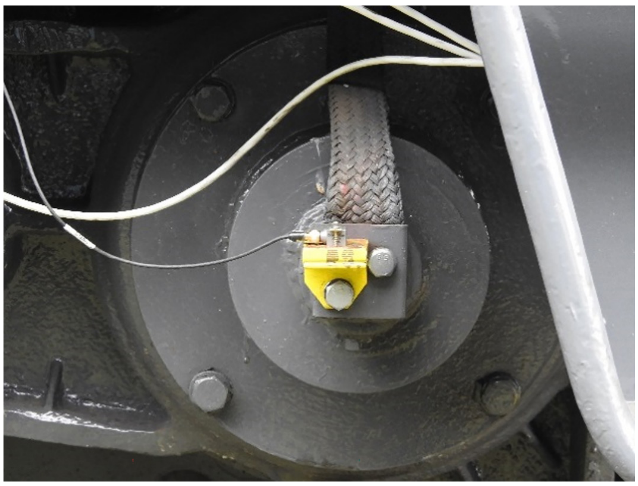

Fig. 5 Acceleration sensor on the axle box (Photo: Zoltán Lukács)

Fig. 6 Measurement data acquisition system in the driver's cab (Photo: Zoltán Lukács)

Fig. 7 Microphone in the driver's cab (Photo: Zoltán Lukács)

performance and the entity managing the change demonstrates that the corresponding essential requirements are met and the safety level is maintained and, where reasonably practicable, improved.

To evaluate the modification the locomotive No. V63,007 was used as a reference vehicle, which has not been converted yet.

4 Testing

The testing of the converted and the reference locomotive was performed on the MÁV Dombóvár – Szentlőrinc line section (Fig. 8). We run the entire line section with both vehicles and recorded the measurement signals (Fig. 9). The evaluation sections were selected based on the recorded signals. The LUXACT instrument measures and registers the angular velocity of the main directions about the axis, so that the angular velocity around the z-axis is suitable for determining the negotiation of the curves.

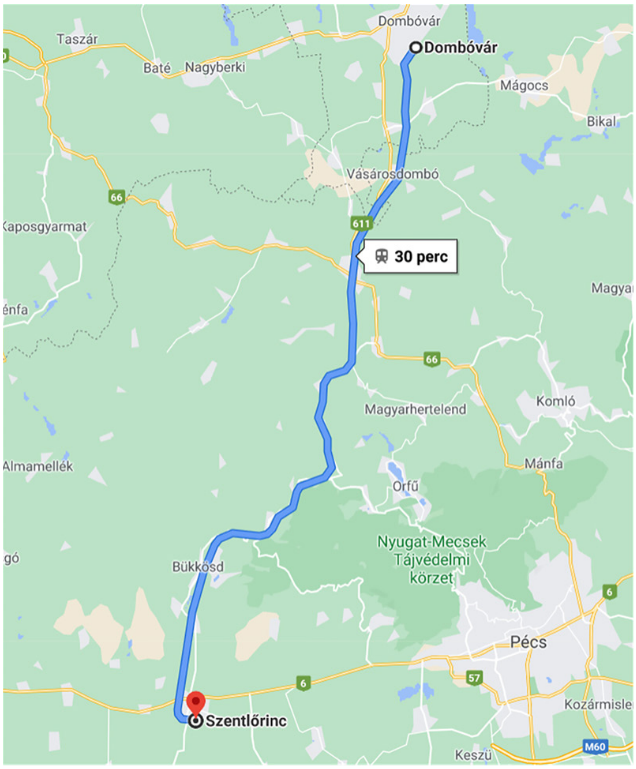

Fig. 8 The route of the testing (Zoltán Lukács)

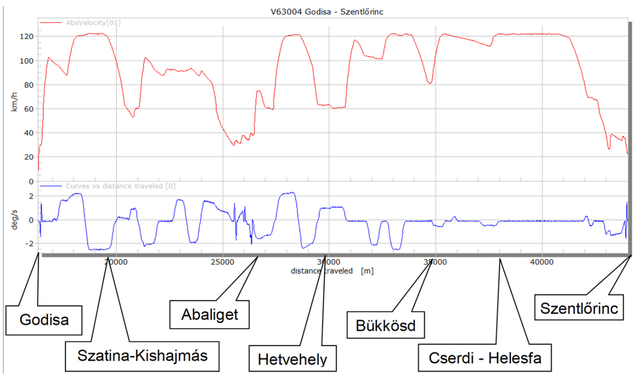

Fig. 9 Travel cycle of the Godisa – Szentlőrinc line section with angular velocity around the z-axis (Zoltán Lukács)

4.1 Running technical tests

We used the requirements of the standard MSZ EN 14363:2005 (Hungarian Standards Institution, 2005) for the implementation of comparative, simplified running measurements. For this, one of the bogies of the vehicles was equipped with acceleration sensors, as shown in Fig. 10.

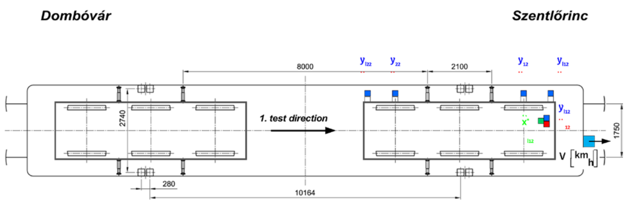

Fig. 10 Disposition of the acceleration sensors (Zoltán Lukács)

From the recorded acceleration values, the running stability of the vehicle is evaluated as follows:

- The recorded axle box acceleration signals are filtered in the 1–10 Hz band.
- From the spectrum of the accelerations thus obtained we look up the weaving frequency of the bogie. (Around 4–7 Hz)
- The accelerations are filtered in a band of ± 2 Hz around this frequency.
- A root mean square (rms) value is calculated every 10 m from the bogie acceleration signal, from which a sliding average is formed at a base of 100 m.
- Calculation of the root mean square of the accelerations:

$$\ddot{y}^{+}_{\mathrm{rms}} = \sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \left[\ddot{y}^{+}(t) \right]^2 dt} \; . \quad (1)$$

- Its value is compared with the limit value according to 5.3.2.2 (f) (2) (c) of the standard MSZ EN 14363:2005 (Hungarian Standards Institution, 2005), which is calculated as follows:

$$\ddot{y}^{+}_{\max.\mathrm{lim}} = \left(12 - \frac{m_{fv}}{5} \right), \quad (2)$$

where T_1–T_2 is the examined interval and m_{fv} is the total weight of the bogie.

4.2 Evaluation of cross-run stability

Transverse accelerations of the first and second axles of the locomotives No. V63,004 and V63,007 in the direction of travel with a band filtering of 1 to 10 Hz (Figs. 11 and 12).

It can be seen from the spectra that in the case of the modified bogie with rubber spring support there is a smaller significant peak at 3.2 Hz, while in the case of the original bogies no significant peak value can be measured.

Amplitude spectrum of transverse accelerations: This is likely since the original frictional connection provides favourable damping for yawing, while the transverse dampers of the converted locomotives, due to their location and characteristics, provide less damping to the yawing motion (Fig. 13).

4.3 Evaluation of running safety

Running safety was assessed at a speed of 120 km/h. This evaluation was performed between Cserdi-Helesfa and Szentlőrinc stations on the same section for both vehicles, on a straight track at a speed of 120 km/h. The studied section ranged from 38 000 to 41 000 m.

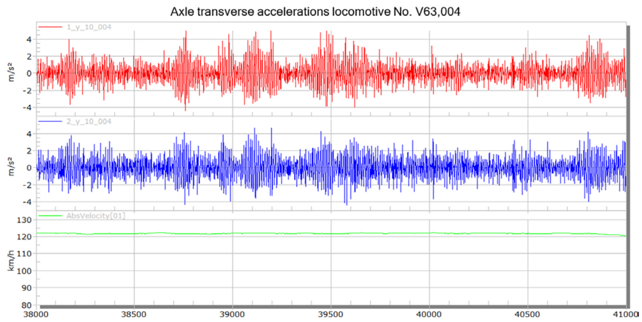

Fig. 11 $\ddot{y}_{12}$ and $\ddot{y}_{22}$ axle box accelerations of locomotive No. V63,004

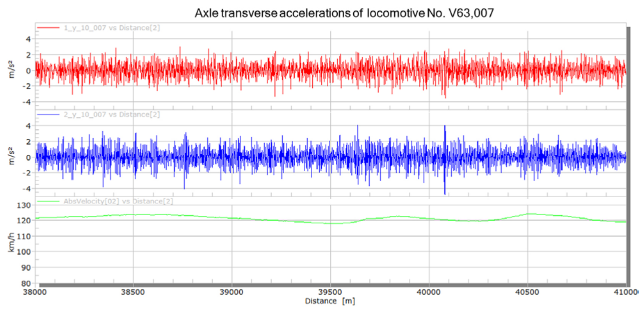

Fig. 12 $\ddot{y}_{12}$ and $\ddot{y}_{22}$ axle box accelerations of locomotive No. V63,007

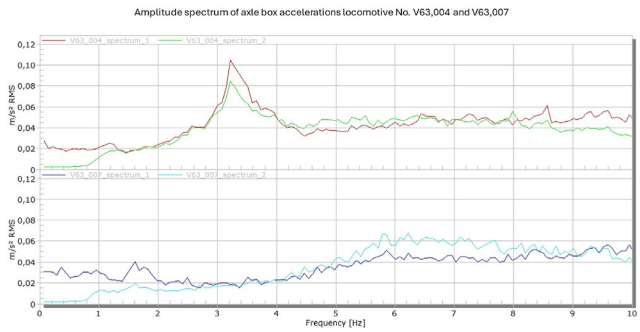

Fig. 13 Amplitude spectrum of axle box accelerations measured on the tested vehicles

Based on the frequencies determined from the amplitude spectrum of the transverse accelerations measured on the axle box, the $\ddot{y}^{+}_{112}$ and $\ddot{y}^{+}_{122}$ transverse accelerations measured at the ends of the bogie frame of the V63,004 locomotive were filtered with a 1.2 to 5.2 Hz, while on the V63,007 locomotive with a 4 to 8 Hz band filtering (Figs. 14 and 15).

A squared mean value sliding on a 100 m base in a 10 m window was calculated from the measured and filtered acceleration signals (Figs. 16–18). This value shall not be greater than $\ddot{y}^{+}_{\max.\mathrm{lim}} = \left(12 - \frac{m_{fv}}{5}\right)\left(12 - \frac{28.3}{5}\right)\frac{\mathrm{m}}{\mathrm{s}^2}$ specified in the paragraph 5.3.2.2 (f) (2) (c) of the standard MSZ EN 14363:2005 (Hungarian Standards Institution, 2005), where the total weight of the bogie is 28.3 t.

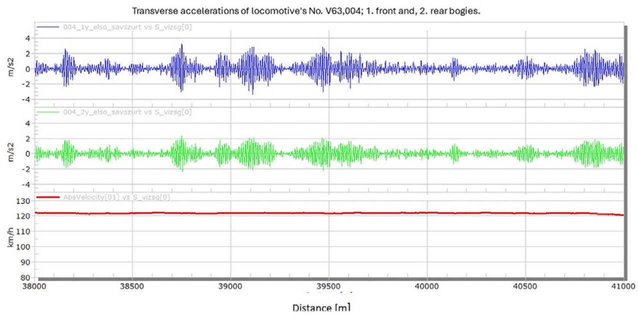

Fig. 14 $\ddot{y}^{+}_{112}$ and $\ddot{y}^{+}_{122}$ filtered transverse accelerations of locomotive No. V63,004

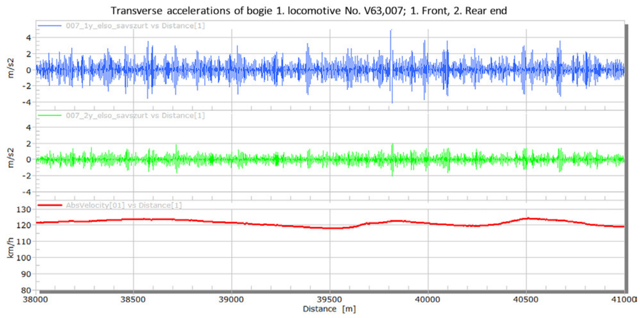

Fig. 15 $\ddot{y}^{+}_{112}$ and $\ddot{y}^{+}_{122}$ filtered transverse accelerations of locomotive No. V63,007

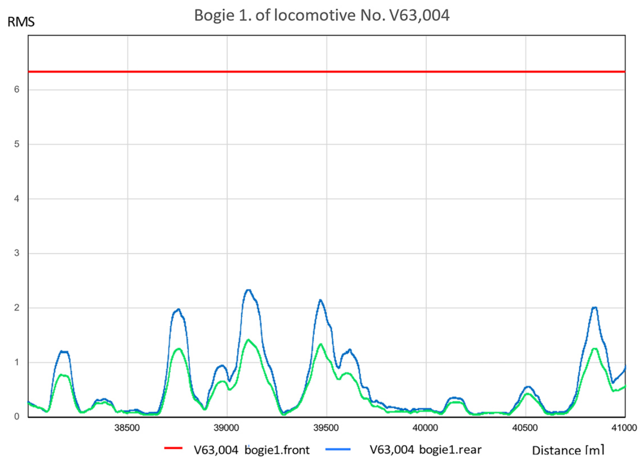

Fig. 16 Root-mean-square values of V63,004 locomotive's bogie frame accelerations

5 Results of the calculations

Mean velocity on the test section: $V_{\text{average}} = 121.7 \frac{\text{km}}{\text{h}}$, standard deviation of the samples: σ = 0.25.

It can be clearly seen from Fig. 18 that the accelerations remain below the limit value for the whole section but increase above 2 m/s^2 in some places. This suggests that in an unfavourable case – a change in wheel profile, track tracing, etc. – the running characteristics may change, the running may become unstable.

Mean velocity on the test section: $V_{\text{average}} = 121.3 \frac{\text{km}}{\text{h}}$, standard deviation of the samples: $\sigma = 1.68$.

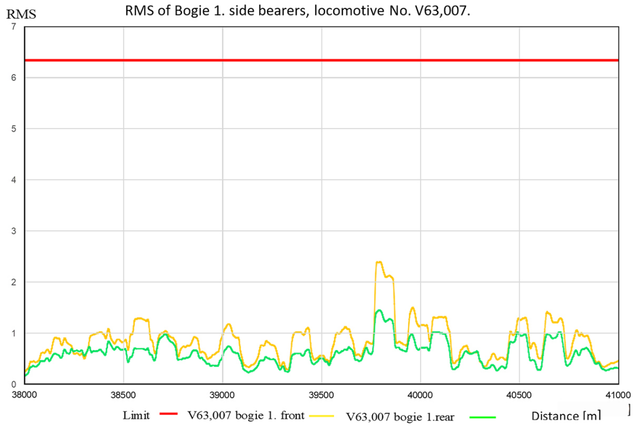

Fig. 17 Root-mean-square values of V63,007 locomotive's bogie frame accelerations with 100 m basis and 10 m window

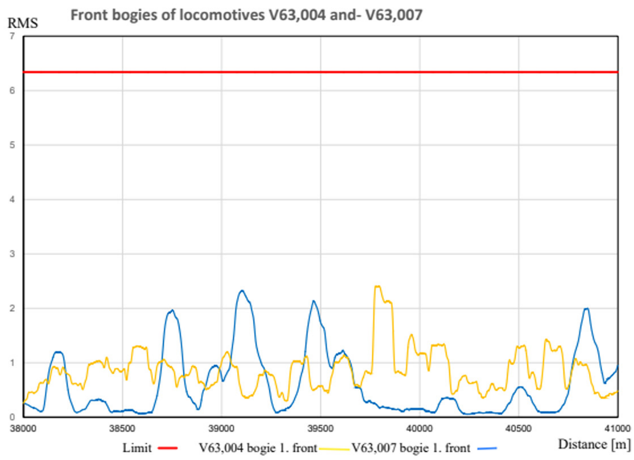

Fig. 18 Root-mean-square values of V63,004 and V63,007 locomotives' bogie frame accelerations with 100 m basis and 10 m window

Accelerations generally remain below 1 m/s^2 and show no tendency to instability.

6 The effect of the modification

It can be seen from Fig. 18 that because of the modification, the running safety characteristics of the vehicle have not deteriorated, the results comply with the requirements of the TSI, the safety level has been maintained or improved.

The test vehicle cab noise data were evaluated on a straight-line section of 3000 m with the maximum speed of ± 5%, a sufficiently long period of measurement, at least 60 s in total for the three evaluation phases, conditions were the same or these conditions were met for the same track section in each series of measurements. The partial results refer to an evaluation time of t = 20 s.

The noise level in the driver's cab of the reference locomotive V63,007: 86 dBA,

The noise level in the driver's cab of the converted locomotive V63,004: 81 dBA, the measured sound pressure level difference: 5 dB.

Table 1 Equivalent A-sound pressure levels measured in the driver's cab

Number of test equipment	Direction	Loc	Driver's cab	$L_{pAeq,\text{measured}}$ [dBA] sub-result	Speed mean value and deviation [km/h]	$L_{pAeq,T}$ [dBA]
45925	Szentlőrinc – Cserdi – Helesfa	V63,007	Rear	85.4 85.3 86.2	126.0 ± 0.2	85.6±0.5
45925	Cserdi – Helesfa – Szentlőrinc		Front	84.9 85.1 86.7	121.3 ± 1.7	85.6±1.0
45926	Szentlőrinc – Cserdi – Helesfa	V63,004	Front	80.7 80.6 81.5	124.6±0.2	80.9±0.5
45926	Cserdi – Helesfa – Szentlőrinc		Rear	80.4 80.9 81.5	121.7±0.3	80.9±0.6

The noise level of the cabs of the converted locomotive measured at the maximum speed according to the MSZ EN 15892:2011 standard (Hungarian Standards Institution, 2011) was reduced by 5 dB because of the modification (Table 1). The requirements of the TSI were met in this case as well.

7 Concluding remarks

Based on the theoretical investigations and numerical simulations, the following conclusions can be drawn:

- in case of the noise level in the driver's cab.
- In case of running safety, the accelerations remain below the limit value for the whole section but increase above 2 m/s^2 in some places. This suggests that in an unfavourable case – a change in wheel profile, track tracing, etc. – the running characteristics may change, and further examination is recommended.
- In case of cross-run stability increase of damping to the yawing motion further investigation should be necessary.
- The modification of UFC-type locomotive body-bogie connection meets the requirement of the operator.

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