22nd International Conference
ENGINEERING MECHANICS 2016
Svratka, Czech Republic, 9 – 12 May 2016

NEW APPROACH TO ASSESMENT OF RAILWAY VEHICLE DYNAMICAL RESPONSE IN THE COURSE OF PASSING OVER TURNOUT

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Abstract: *In the course of a vehicle passing over a turnout, a significantly difference of dynamical response appears in vertical direction. Although a frog is the most loaded part of each turnout, a switch area is equally important part of a turnout from this point of view; so called suspended support of the switch area is tested at new turnout structures. The methodology for determination of the equivalent loading of a turnout frog in the course of a vehicle passing has been developed to evaluation of the frog loading. A vertical acceleration measured on the wheelset axle box of a vehicle passing over the frog is an input parameter for the calculation of the equivalent loading. Assessment of a vehicle dynamical response during passing over the suspended part in the switch area is also based on the vertical dynamical response measurement detected by acceleration sensors located on the wheelset axle box but this response is evaluated by statistical methods. Actually in cooperation with a turnout producer and one of the train operators, the turnouts of several types and in different operational condition are monitored since 2014 with application of the mentioned methodology. The reference vehicle for the monitoring of selected turnouts is an electric locomotive of axle load 22 t. The verification of optimized design of some turnouts in terms of loading of their parts is the main purpose of this research.*

Keywords: Turnout, Frog, Railway vehicle, Acceleration, Measurement.

1. Introduction

Perfect knowledge of operational conditions is the basic presumption of ensuring of operational reliability of a railway track structure if we need to increase a maximum operational speed. Passing of railway vehicle presents a high dynamic loading in wheel-rail contact in the course of passing over a turnout frog in straight direction. The turnout switch part (tongue area) is also important from this point of view. Suspended rail support in this area is actually tested at new turnouts.

Actually, there is no universal method, which would be able to evaluate the turnout loading level in the course of different vehicle types passing. Modelling of this phenomenon is very difficult because a turnout is an inhomogeneous element in common track, which is a place of dynamical impact in the course of contact of wheel with the frog. Therefore to explanation of these dynamical phenomena, we deal with experimental research in this field many years.

2. Determination of vehicle dynamical response in the course of passing over turnout

There is possible to use acceleration measuring principle for measurement of a vehicle dynamic response. Measured acceleration signal is friendly to assessment, therefore the acceleration measured on the wheelset axle boxes was chosen as an input quantity for evaluation of vehicle dynamical response. Wheelset axle box has unsuspended connection with wheelset and it is also friendly to installation of measuring chain (sensors, cable connections). It is necessary to find such place which has unsuspended

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connection with the axle box (see fig. 1, left). For detection of maximum loading of turnouts components the a locomotive of axle load 22 t (see fig. 1, right) was chosen as measuring vehicle.

Fig. 1: Acceleration sensor placing on the wheelset axle box of measuring vehicle (illustration photo).

Signals of acceleration are recorded with the sampling rate of 20 kHz. For the next assessment, the signals are filtered by a band pass filter in the range 20 ÷ 500 Hz. Example of the filtered vertical acceleration signal measured on a wheelset axle box in the course of passing over a turnout frog is presented in fig. 2.

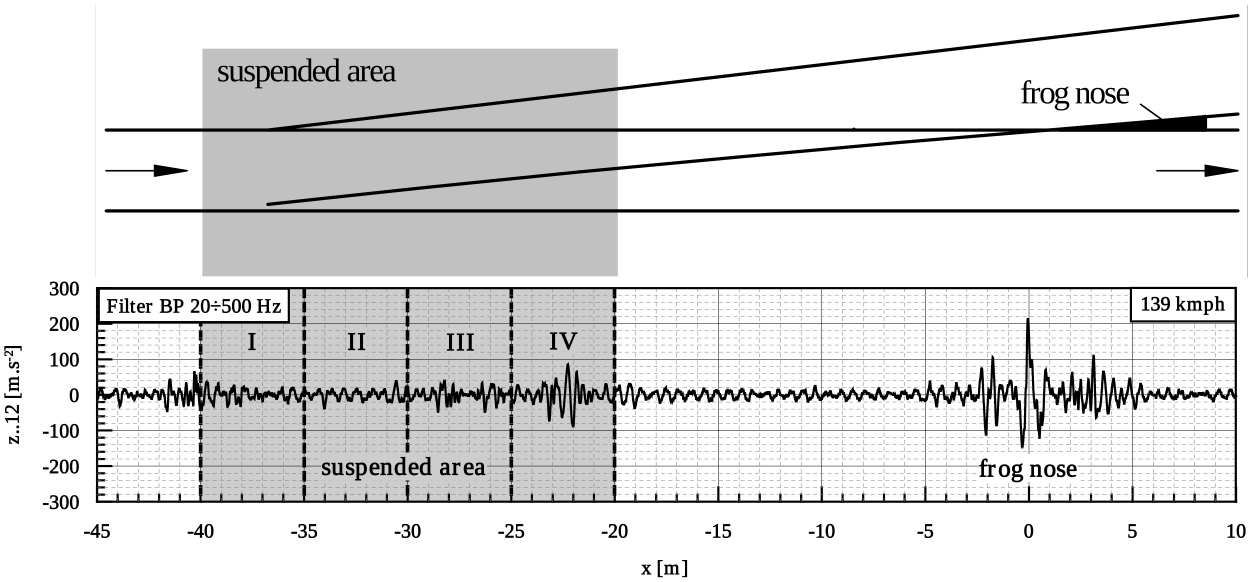


Fig. 2: Filtered vertical acceleration signal measured on the wheelset axle box in the course of passing over whole turnout

3. Assessment of vehicle dynamical response in the course of passing over turnout by calculation of equivalent loading

Base on long-time experience the new methodology of assessment of vehicle dynamical response in the course of passing over a turnout frog has been created. This methodology utilizes so called equivalent loading in wheel rail contact and it was certified in 2014.

The calculation of the equivalent dynamical force between wheel and rail in the course of passing of appropriate wheel over a frog area utilizes the vertical acceleration measured on a wheelset axle box of a vehicle (see fig. 2).

Due to the fact that natural frequencies of vertical motion of suspended vehicle parts are multiply lower than frequency of the vertical motion of a wheel in the course of passing over a turnout frog area, the calculation of the dynamic component of the equivalent force is carried out only with respect to inertia forces of unsuspended vehicle parts, i.e. relative mass of wheelset axle boxes included $m_{\text{w\_r}}$ per a wheel (see fig. 3).

Dynamical component of the equivalent force ($\ddot{z}$ – measured acceleration):

$$F_{\text{eq\_dyn}} = m_{\text{w\_r}}.\ddot{z} \tag{1}$$

Equivalent loading of a frog area part ($m_{\text{v\_r}}$ – relative mass of a vehicle per a wheel):

$$F_{\text{eq}} = m_{\text{v\_r}}.g + F_{\text{eq\_dyn}} \tag{2}$$

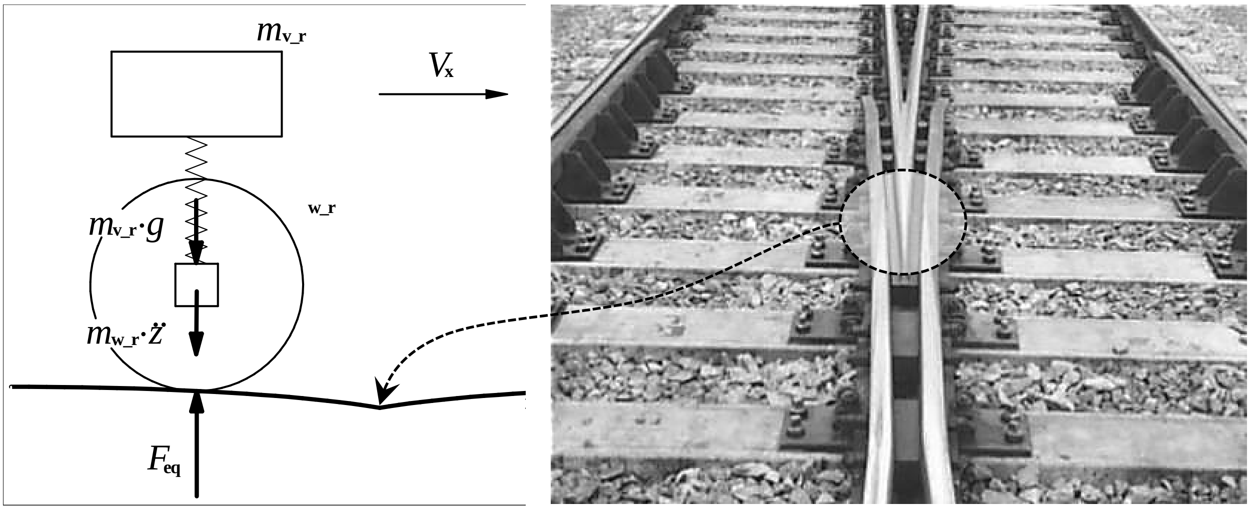


Fig. 3: Simplified dynamical model of a vehicle (left) in the course of passing over a turnout frog (right).

Example of results of carried out measurements in the course of passing over selected turnouts are presented in fig. 4. The values of turnout frog equivalent loading are displayed in form of columns and they are completed by vehicle actual speed. These columns present the equivalent loading caused by appropriate wheels in the range of vehicle passing over a turnout.

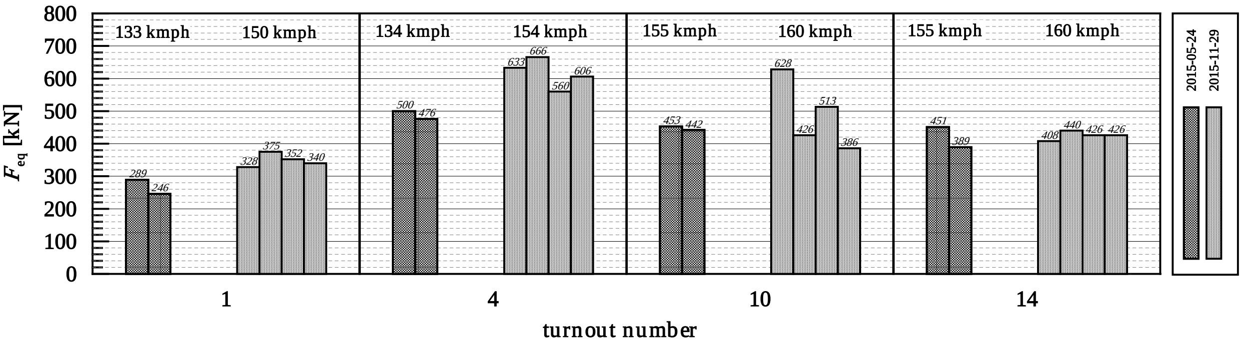


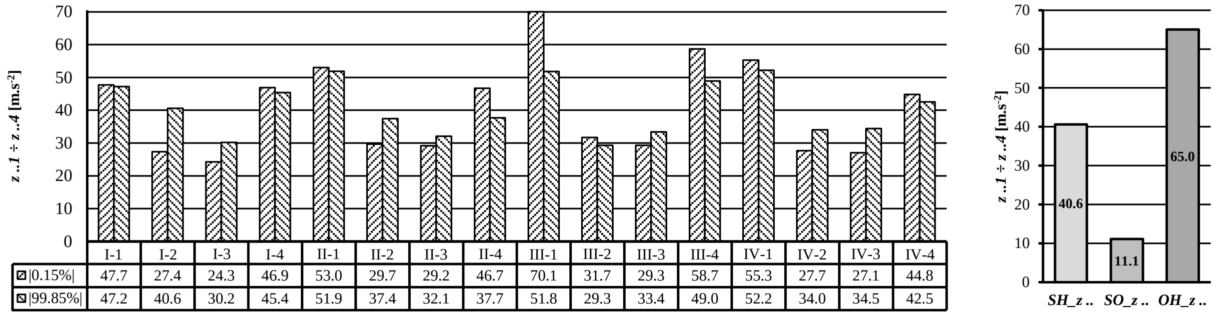
Fig. 4: Example results of the equivalent loading of the selected turnout frogs (measurement 2015-05 – sensors placed only at one bogie; measurement 2015-11 – sensors placed at both bogies).

4. Assessment of vehicle dynamical response in the course of passing over turnout suspended part

Determination of so called vertical acceleration estimated value ($OH\_z..$) (3) of a vehicle dynamical response in the course of passing over a turnout suspended part is a result of an assessment. The calculation of this quantity is based on statistical evaluation of measured acceleration on the wheelset axle box in four 5m sections in the suspended area of a turnout.

Estimated value ($SH\_z..$ – mean percentiles value; $SO\_z..$ – standard deviation):

$$OH\_z.. = SH\_z.. + 2{,}2 \cdot SO\_z.. \tag{3}$$



	I-1	I-2	I-3	I-4	II-1	II-2	II-3	II-4	III-1	III-2	III-3	III-4	IV-1	IV-2	IV-3	IV-4
|0.15%|	47.7	27.4	24.3	46.9	53.0	29.7	29.2	46.7	70.1	31.7	29.3	58.7	55.3	27.7	27.1	44.8
|99.85%|	47.2	40.6	30.2	45.4	51.9	37.4	32.1	37.7	51.8	29.3	33.4	49.0	52.2	34.0	34.5	42.5

Fig. 5 Presentation of statistical evaluation of vertical acceleration in turnout suspended area.

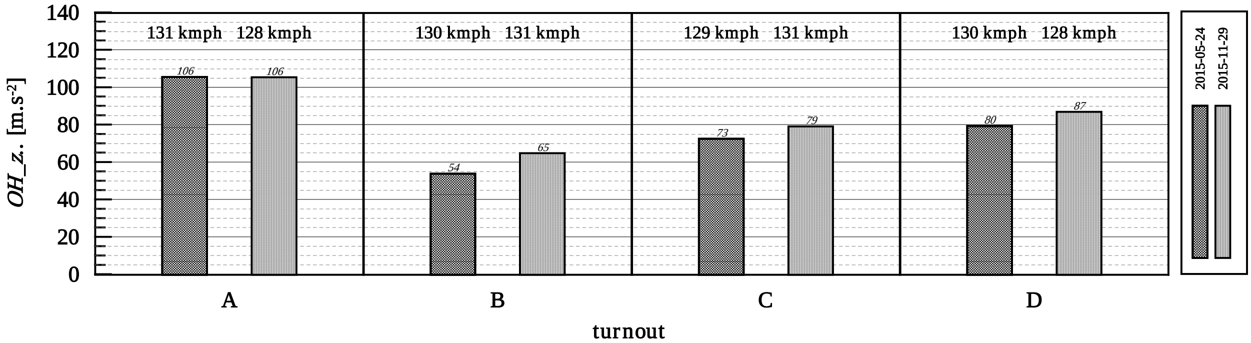


Fig. 6 Example of determination of acceleration estimated values and assessment for selected turnouts.

5. Conclusion

From the assessment of the equivalent loading of the turnout frogs we can recognize an increased value relate to passing speed for turnouts No. 1 and 4 (opposite to turnout e.g. No. 14). This equivalent loading growth partially appears at turnout No. 10, but only for the first and the third wheelset.

Realization of the certified methodology, which has been actually taken place within our research activities for company DT Výhybkárna a strojírna, a.s., is aimed to comparing of different turnouts structures with a point of view of vehicle dynamical response in the course of turnout passing during several years operation. Development of sensoric diagnostic system for optimization of turnout maintenance based on vehicle as well as track response is our future intension.

Acknowledgement

This paper was supported by Technological Agency of Czech republic within the project No. TE 01020038.

References

Grin, G. (2013) Verschleiß und Belastung von Weichenherzstücken. Diploma thesis, Technische Universität Dresden.

Gerber U., Zoll A., Fengler W. (2013) Fahrzuegbasierte Beurteilung des Herzstückverschleßes. Eisenbahningenieur 09/13, pp. 26 ÷ 30.

Müller R., Nelain B., Nielsen J., Said S., Rücker W., Bongini E. (2013) Description of the vibration generation mechanism of turnouts and the development of cost effective mitigation measures. Report RIVAS_UIC_ WP3-3_D3_6_V02.

Zelenka J., Hába A., Kohout M. (2014) Determination of equivalent loading of railway turnout frog area in the course of vehicle passing based on EN 14363 approaches. Certified methodology.

Hába A., Zelenka J., Kohout M. (2015) Determination of Equivalent Loading of Turnout Frog. In: Proc. Vibroengineering, Vol. 6, JVE International Ltd., Kaunas, pp. 217 ÷ 222.

Zelenka J., Hába A., Kohout M. (2015) Vyhodnocení ekvivalentního zatížení vybraných výhybek ve stanici Dlouhá Třebová. Technical report CKDV-WP5-2015-AH-01.

Zelenka J., Hába A., Kohout M. (2015) Vyhodnocení měření zrychlení na lokomotivě řady 380 při průjezdu vybranými výhybkami stanice Ústí nad Orlicí. Research report DP-03-15.