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INFLUENCE OF WHEEL TREAD SURFACE ROUGHNESS ON THE NOISE EMITTED BY RAILBOUND FREIGHT VEHICLES

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Abstract *– The increased capacity of freight railway traffic leads to increased noise pollution. The existing regulation TSI NOI defines the maximum noise level allowed to be emitted by railway vehicles. Consequently, the noise tests are mandatory type tests for all new vehicles. Experience from noise tests of different freight wagons have shown that measured noise level depends on many parameters and in most cases is close to the maximum permissible values. Contemporary design of the freight wagons has to be conceived such as to emit as low noise as possible. Accordingly, it is necessary to identify the main influencing sources that affect the noise generation and to find a way to reduce their influence. This paper presents results obtained by measurements of pass-by noise of a freight wagon, with wheels having different wheel tread surface roughness. It appeared that wheel-rail rolling contact as a noise source is very significant and may be critical for assessment of the railbound vehicles.*

Keywords – Railbound vehicles, wheel tread surface roughness, testing, pass-by noise.

1. INTRODUCTION

Railway exterior noise includes a number of different physical sources such as rolling noise, impact noise, traction noise, aerodynamic noise, curving noise, braking noise, horn noise and noise from auxiliary equipment and other components.

Rolling noise is one of the main sources of railway noise. It is generated by the surface roughness (irregularities) in the contact patch between train wheel and rail. This roughness induces vibrations and subsequent sound radiation from wheels, rails and sleepers.

The second member of the contact pair, which has an influence on the noise generation when rolling, is the railway wheel. The surface unevenness might be defined as a roughness deviation (differences between a real wheel radius and the ideal radius). Measurements of wheel roughness have not previously been standardized because the test of the noise generated by different vehicles only requires the control of the test track. This paper presents results obtained by measurements of pass-by noise of a freight wagons, with wheels having different wheel tread surface roughness. Ones corresponding to delivery condition and the other simulating bedding in as the result of running for 1000 km.

1.2 Types of noise test

Noise tests includes measurement sound pressure level inside railbound vehicles and noise emitted into the environment.

Measurements of noise emitted by railbound vehicles into the environment are [2]:

1. stationary noise test (parking noise),
2. constant speed noise test (pass-by noise test),
3. acceleration noise test (starting noise test),
4. braking noise test.

2. CONDITION OF NOISE TESTS

The noise emission contains contributions from the rolling stock, the track and environmental noise.

During noise testing, the following conditions must be met [5]:

1. environmental condition (acoustical

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environment, meteorological conditions and background pressure sound level)
2. track conditions (geometry of line, track superstructure, track quality, acoustic rail roughness [6] and dynamic properties of the track expressed as track decay rates [7])
3. vehicle conditions (loading and operating conditions, wheel tread conditioning and train composition).

2.1 Wagon conditions for constant speed test (pass-by noise test)

According to standard [5], wagon shall be tested in empty condition. The wheel treads shall be as free as possible from irregularities such as flats. The block/tread pair shall be in a run-in condition where block and tread have bedded in sufficiently. Within 24 h before test starting wagon shall be braked starting at 80 km/h until a complete stop with a deceleration which is typical in normal operation (typical main pipe pressure of 4 bars) which ensures that no wheel flats are generated.

Noise from other parts of the train shall not influence the measurements of the vehicle(s) under test. Therefore, for the measurement of a trailed unit, there shall be an acoustically neutral vehicle on one side of at least two units under test, and no vehicle or an acoustically neutral vehicle on the other side (Fig.1).

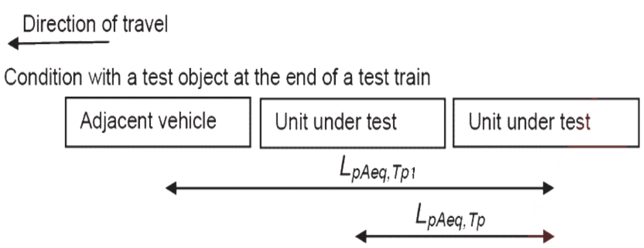

Fig.1. Accessing of the acoustic neutrality of adjacent vehicle

3. TEST RESULT

Laboratory of railway vehicle University of Belgrade was performed pass by noise tests of several types of wagons (Fig.2).

Fig.2. Test wagons pass measurement position

Tab. 1 presents results of measurements for two tank cars and one wagon for containers transportation [8, 10].

Tab. 1. Pass by noise tests results

No	Wagon type	Noise level
1.	Zacns 98 m^3	83 dB
2.	Zacns 88 m^3	83 dB
3.	Sggmrss	83 dB

Results illustrated using examples for pass-by noise measurement of Zacns tank wagon [7].

The basic measured quantities are $L_{pAeq,Tp}$, train speed and pass-by time T_p.

$L_{pAeq,Tp}$ is A-weighted equivalent continuous sound pressure level given by the following formula:

$$L_{pA_{eq},T_p} = 10 \cdot \log\left(\frac{1}{T_p}\int_0^{t_p}\frac{p_A^2(t)}{p_0^2}dt\right) \quad [dB] \qquad (1)$$

where is:

T_p – the measurement time interval in s;
$p_A(t)$ – the A-weighted instantaneous sound pressure at running time t in Pa;
p_o - the reference sound pressure; p_o = 20 µPa

The first test series included four tests at a nominal speed 80 km/h. The second series consisted of five passings at nominal speed 120 km/h. These two series are marked as "right side tests". After that, both tank wagons were turned around vertical axis, and third series with three passes at nominal 80 km/h were performed and thereafter series of four tests at nominal speed 120 km/h. Last two series are marked as "left side tests". At least three measurements at 80 km/h ±5% and three at v_{max} =120 km/h ± 5% should be performed. The results are shown in the table 2.

First column presents raw $L_{pAeq,Tp(vtest)}$ values. Each series gives values within required maximum spread of 3 dB.

Third column represent the speed measured during the corresponding passing of the train. It can be noted that all speeds are within ±5% tolerance of the nominal speed.

In the fourth column are given normalized values regarding actual speed and number of axles per lengths (APL) calculated according to following equation:

$$L_{pA_{eq},T_p(APL_{ref})} = L_{pA_{eq},T_p(v_{test})} - 10 \cdot \log(APL_{wag}/0{,}0225m^{-1}) - 30 \cdot \log(v_{test}/80\ km/h) \quad [dB] \qquad (2)$$

For the Zacns tank wagon of 98 m^3 is:

$$APL_{wag} = \frac{n}{L_{ob}} = \frac{4}{16{,}4} = 0{,}2439\ m^{-1} \qquad (3)$$

n = 4 is number of axles and

L_{OB} =16,4 m is length over the buffers.

v_{test} is actual speed during the measurement.

After normalization, arithmetic mean value of each series of measurements rounded to the nearest integer decibel is given in table 3.

Table 2 Measurement results

Test	Test side	$L_{pAeq,Tp(vtest)}$ (dB)	v_{test} (km/h)	$L_{pAeq,Tp(APLref)}$ (dB)
80-1	Right side tests	83,9	81,63	83,3
80-2		83,5	78,77	83,4
80-3		83,7	77,31	83,8
80-4		84,1	76,83	84,3
120-1		89,0	120,45	83,3
120-2		89,1	120,71	83,3
120-3		88,6	119,62	83,0
120-4		88,6	120,22	83,0
120-5		88,5	121,87	82,7
80-1	Left side tests	84,1	78,17	84,0
80-2		83,6	78,30	83,5
80-3		82,1	78,31	82,0
120-1		89,6	125,18	83,4
120-2		89,6	122,99	83,6
120-3		88,9	125,76	82,7
121-4		87,7	116,07	82,5
Average rounded to the nearest integer				83

Fig. 3 and 4 show an example of LpA(t) during the pass-by test at 80 and 120 km/h. The red line indicates the passage of each wheel of the train composition.

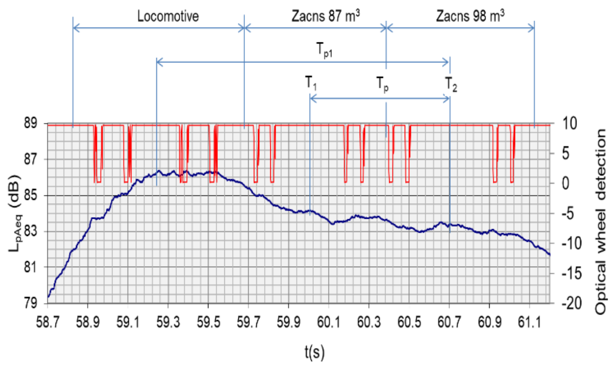

Fig. 3. Example of sound pressure level record at 80 km/h

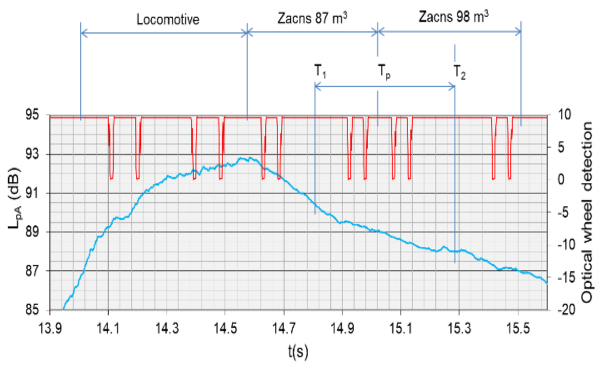

Fig. 4. Example of sound pressure level record at 120 km/h

4. COMPARED TEST RESULTS

In order to experimentally research the effect of wheel tread surface roughness on the noise level, the noise emitted by a rail vehicle was measured. Tank wagon was equipped with new wheels and wheels that have been additionally machining.

The surface finish of new wheels after machining must be 12.5 μm Ra (Roughness Average) or less, as per the meter reading [4].

Fig.5 present test results during the pass-by test at 80 and 120 km/h with new wheel with tread surface roughness 6,5 μm.

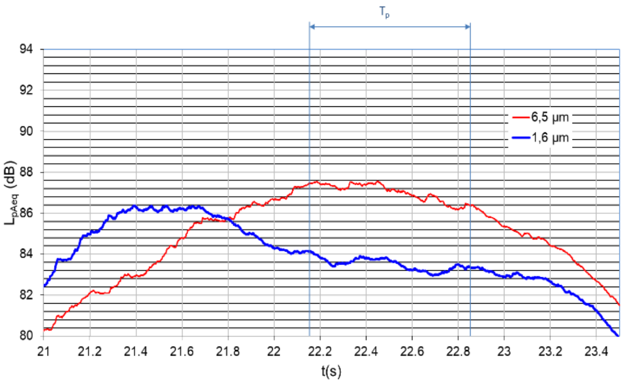

Fig. 5. Sound pressure level record at 80 km/h

After additional machining of the wheel tread surface, a repeated noise test was performed.

Fig. 6 present test results during the pass-by test at 80 and 120 km/h with new wheel with tread surface roughness 1,6 μm.

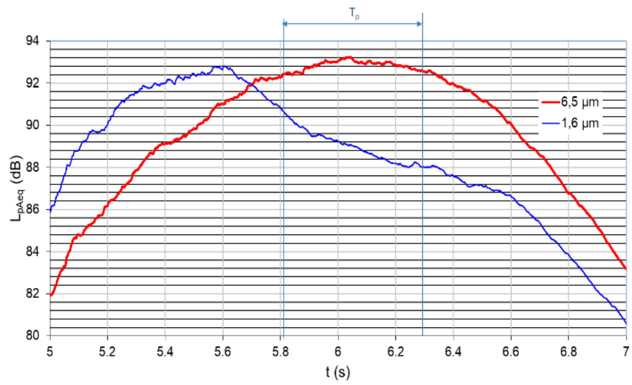

Fig. 6. Sound pressure level record at 120 km/h

Obtained decrease in weighted equivalent continuous sound pressure level in case of measurements with smoother wheel, with Ra=1,6 μm, is 4 dB.

5. CONCLUSION

This paper shows that the new wheels may cause an increased noise level even though they meet the roughness requirement, which is for category 2 of wheels for speeds up to 200 km/h limited to 12,5 μm. Therefore, it is necessary to fully meet the requirement of [5] that the tested vehicle should run at least 1000 km with as much braking as possible. In this way, the tread surface of the wheel will be smoother, and therefore the level of noise emitted by the vehicle will be lower.

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REFERENCES

[1] Directive 2002/49/EC of the European Parliament and of council of 25 June 2002 relating to the assessment and management of environmental noise

[2] TSI Noise (Commission Regulation (EU) No 1304/2014 with amendment M1/2019

[3] EN ISO 3381:2005, *Railway applications - Acoustics -*

[4] *Measurement of noise inside railbound vehicles*

[5] EN 13262:2020, *Railway applications - Wheelsets and bogies - Wheels - Product requirements*

[6] EN ISO 3095:2013, Acoustics - *Railway applications - Measurement of noise emitted by railbound vehicles*

[7] EN 15610:2009, *Railway applications - Acoustics - Rail and wheel roughness measurement related to noise generation*

[8] EN 15461:2011, *Railway applications - Noise emission - Characterization of the dynamic properties of track sections for pass by noise measurements*

[9] Simić, G., Radulović, S., Lučanin, V., *Specific aspects of the rail vehicle pass-by noise measurement*, Proceedings, XIX Scientific-expert conference on railways RAILCON '20, Niš, 2020.

[10] Lutzenberger, S., Létourneaux, F., Jones, C., Eichenlaub, C., Stegemann, B., Czolbe C., *Revision of EN 15610 - Wheel roughness measurements,* Euronoise 2018 - Conference Proceedings, ISSN: 2226-5147

[11] *Pass-by noise test report of Zacns 98 m^3 tank wagon No: LSV-I-6/20 Edition 2*, University of Belgrade Faculty of Mechanical Engineering, 2020

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