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PASS-BY NOISE MEASUREMENTS USING ONE VERSUS TWO IDENTICAL TRAILER UNITS WITHIN AVAILABLE STANDARD METHODS

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Abstract *– This paper analyzes and compares the noise measurement results of rail vehicles obtained by testing with one or two identical trailer units. The test procedure for measurement of the pass-by noise emitted by railway vehicles is generally carried out using the standard method according to ISO 3095, for which it is necessary to perform the measurements with two identical trailer units. In special cases where a series consists of only one unit, i.e. there is no other identical vehicle, testing and signal processing are performed with just one unit. Typically, this is considered an exception. The requirements to provide two identical units can cause certain problems for manufacturers. If the need to modify the prototype arises, it implies changing the two vehicles, which results in increased costs. The paper shows a comparative review of the results and an opinion on the justification of the request to perform tests with two identical trailer units.*

Keywords – pass-by noise, standard test methods, single vs. two trailer units.

1. INTRODUCTION

Bearing in mind that noise tests are mandatory for all new wagons and that the testing of trailer vehicles must be carried out with two identical units, this paper analyzes the justification of having two units as required in the referent standard [1], especially given that for manufacturers, particularly smaller ones with less experience, this can be problematic. Any changes that need to be made to the prototype must be implemented on two wagons instead of one. In extreme cases, if the wagon does not meet all criteria and requirements during some type tests, two prototypes are rejected, not just one. The paper presents a comparative analysis of the measured values of the noise level for both mentioned cases according to the [1] methodology and offers an opinion on the obtained results.

In the papers [2,3], we presented results of the testing of several types of wagons according to the regular procedure from [1] with two wagons, while in this paper, we hypothetically explore what would happen if this requirement did not exist in the standard.

The idea for this comparison arose considering the possibility in the [1] to test just one unit, when there is no series in the classical sense, but the series consists of only one e.g. a special vehicle and manufacturer can provide only one car or wagon for type testing. In such a case, it is permissible to measure this single unit if it is acoustically symmetric. This shall, however, be considered as an exception since, according to [1], the procedure with single unit test leads to an increased measurement uncertainty compared with the regular method. The regular approach to testing is to inform the manufacturer that they are obliged to provide two vehicles under test from the same series.

2. SIGNAL PROCESSING

Applying the signal processing methodology, the characteristic separated parts of the signal were processed once for two identical vehicles (Fig.1.) during the period T_p of passing the middle of the first wagon to the middle of the second wagon by the microphone, and the second time the measurement record of single vehicle was analysed assuming that the vehicle under examination is at the end of the train and measurement time interval T (Fig.2.) begins when the

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centre of the unit passes the measurement position and ends when the noise level measured at the measurement position has decreased by at least 10 dB compared to the maximum noise level measured during pass-by of the unit. For the second approach $T_p = l/(2\cdot v)$ corresponds to pass-by time of half of the unit where is:

l - length of the unit in m;

v - train speed in m/s.

For regular test with two identical units the A-weighted equivalent pass-by noise level $L_{pAeq,Tp}$ shall then be assessed by the following formula:

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

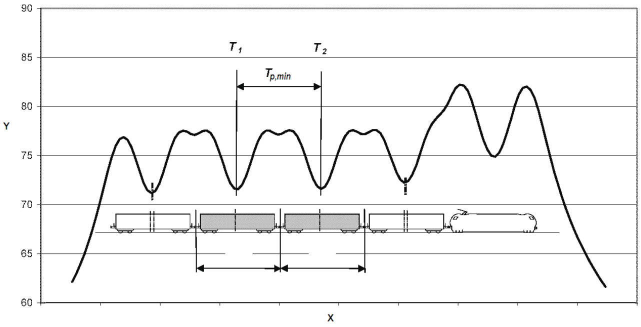

Fig.1. Example of selection of measurement time interval for test with two trailer units [1]

The A-weighted equivalent pass-by noise level $L_{pAeq,Tp}$ for testing of one unit according to [1] shall be assessed by:

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

where is:

$p_A(t)$ – the A-weighted instantaneous sound pressure at running time t in Pa;

T_p – the measurement time interval in s;

p_o - the reference sound pressure p_o = 20 μPa.

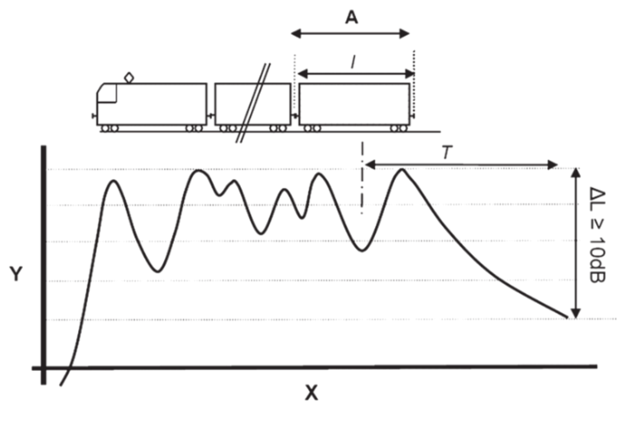

Fig.2. Measurement time interval where only one unit is being tested at the end of the train [1]

3. ENVIRONMENT CONDITIONS

Identical environmental conditions according to [1] as shown in Fig. 3 are provided for all tests. In both cases of testing, there must be an acoustically neutral vehicle in front, which emits a lower level of noise than the vehicle(s) being tested.

In the triangular area between the track and the microphone extending along the track to a distance twice the microphone distance to either side, shall be provided free sound propagation. The level of the ground surface over this area shall be within 0 m to −2 m, relative to the top of the rail. There shall be no reflective covering such as water, ice, tarmac or concrete. No absorptive material snow, tall vegetation or any obstacles shall be in the sound propagation path. No person shall be present in this area. The test performers shall be in a position that does not influence the measured sound pressure level significantly.

The following weather parameters shall be recorded during the noise measurement: wind speed and direction at the level of the highest microphone, temperature, humidity and barometric pressure. Any observed precipitation shall be noted. Heavy rain or wind speed higher than 5 m/s can affect the background noise. The maximum value of the $L_{pAeq,T}$ *during* T =20 s of background noise overall microphone positions shall be at least 10 dB below the $L_{pAeq,Tp}$ obtained when measuring the noise from the unit in the presence of background noise.

The measurement positions of the microphones for testing the trailer units with 120 km/h maximum speed shall be located at 7,5 m from the centreline of the track at a height of 1,2 m above the top of the rail [1].

The noise emission values are only comparable between sites where the track parameters are controlled and known to make them equivalent in terms of acoustic performance.

Fig.3.Sgmnss wagon type at the test site [6]

4. TEST RESULT

At least three measurements at 80 km/h ±5% and three at v_{max} =120 km/h ± 5% should be performed. Tab.1. to 6. present test results for three different types of wagons. Tab.7. presents the review of the results for all three series.

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

The third column represents the speed measured during the corresponding passing 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 the following equations:

$$L_{pA_{eq},T_p(APL_{ref})} = L_{pA_{eq},T_p(v_t)} - 10 \cdot \log(APL_{wag}/0{,}0225m^{-1}) - 30 \cdot \log(v_t/80\ km/h) \quad [dB] \quad (3)$$

$$APL_{wag} = \frac{n}{L_{ob}} \quad (4)$$

n - number of axles and

L_{OB} - length over the buffers.

v_t - actual speed during the measurement.

After normalization, the arithmetic mean value of each series of measurements rounded to the nearest integer decibel is given for both cases.

Tab. 1. and Tab.2. present measurement results of 6-axle flat wagons Sggrss [5].

Tab.1. Measurement results with two Sggrss units

Test	**$L_{pAeq,Tp(vt)}$ (dB)**	**v_t (km/h)**	**$L_{pAeq,Tp(APLref)}$ (dB)**
80-1	83,3	79,59	83,3
80-2	83,6	81,20	83,4
80-3	84,7	80,73	84,6
120-1	88,5	119,70	83,2
120-2	88,4	117,82	83,3
120-3	88,4	119,54	83,1
Average rounded to the nearest integer			83

Tab.2. Measurement results with one Sggrss unit

Test	**$L_{pAeq,Tp(vt)}$ (dB)**	**v_t (km/h)**	**$L_{pAeq,Tp(APLref)}$ (dB)**
80-1	82,2	79,59	82,3
80-2	82,8	81,20	82,6
80-3	82,1	80,73	82,0
120-1	88,4	119,70	83,1
120-2	87,8	117,82	82,7
120-3	87,9	119,54	82,6
Average rounded to the nearest integer			83

If the test was conducted with one vehicle, the average rounded value is the same. On the other hand, the unrounded value is almost 1 dB lower in comparison with regular test with two units.

Tab.3. and Tab.4. present results of measurements with Zacns tank wagons [4].

If we compare the obtained values, we can see that the noise level in the case of one unit testing is higher by about 2 dB in comparison with regular test with two units.

Tab.3. Measurement results with two Zacns

Test	**$L_{pAeq,Tp(vt)}$ (dB)**	**v_t (km/h)**	**$L_{pAeq,Tp(APLref)}$ (dB)**
80-1	83,9	81,63	83,3
80-2	83,6	78,77	83,4
80-3	83,7	77,31	83,8
120-1	89,0	119,71	83,0
120-2	88,6	117,62	82,8
120-3	88,6	118,22	82,8
Average rounded to the nearest integer			83

Tab.4. Measurement results with one Zacns

Test	**$L_{pAeq,Tp(vt)}$ (dB)**	**v_t (km/h)**	**$L_{pAeq,Tp(APLref)}$ (dB)**
80-1	86,0	81,38	85,4
80-2	85,8	78,43	85,7
80-3	85,2	76,22	85,5
120-1	90,7	119,14	85,1
120-2	90,2	117,24	84,9
120-3	90,2	119,67	84,6
Average rounded to the nearest integer			85

The third type of wagon that was tested and compared is a flat wagon Sgmnss for transporting one container up to 40 feet long or some other equivalent combination of shorter containers [6].

Tab.5. Measurement results with two Sgmnss units

Test	**$L_{pAeq,Tp(vt)}$ (dB)**	**v_t (km/h)**	**$L_{pAeq,Tp(APLref)}$ (dB)**
80-1	81,5	78,97	80,4
80-2	81,3	80,30	80,1
80-3	81,3	78,92	80,3
120-1	86,3	117,68	80,1
120-2	86,9	117,59	80,7
120-3	86,3	117,65	80,1
Average rounded to the nearest integer			80

Tab.6. Measurement results with one Sgmnss unit

Test	**$L_{pAeq,Tp(vt)}$ (dB)**	**v_t (km/h)**	**$L_{pAeq,Tp(APLref)}$ (dB)**
80-1	84,4	78,97	83,4
80-2	84,4	80,30	83,2
80-3	84,4	78,92	83,4
120-1	92,8	117,68	86,5
120-2	90,3	117,59	84,1
120-3	92,4	117,65	86,2
Average rounded to the nearest integer			84

The difference in the obtained noise levels for this type of wagon is significant and amounts to 4 dB. This can lead to a completely incorrect conclusion about the noise characteristics of the wagon.

Tab.7. Pass-by noise tests results review

No.	Wagon type	Regular test with two units	Test with one unit
1	Sggrss	83 dB	83 dB
2	Zacns	83 dB	85 dB
3	Sgmnss	80 dB	84 dB

By reviewing the results from Tab.7. it is possible to see different deviations in both directions in the obtained results for different types of wagons, depending on the method of signal processing, i.e. the method of measurement with two or with one vehicle, because of different geometrical characteristics of wagons under test.

5. CONCLUSIONS

According to the performed tests, single-wagon testing is less reliable because the results are shown to be affected by the length of the unit under test. For longer wagons, the impact is less significant, so testing with one wagon yields similar or even lower noise levels. On the other hand, shorter wagons, are found to be more influenced and even noisier.

By analysing the recorded signals, it can be noticed that the time from the end of the wagon to the moment when the noise level becomes lower by 10 dB is almost the same for different types of wagons and consequently, a larger share in the total measurement time interval, in case of shorter wagons, could be the main reason for greater impact.

It should also be emphasized that the normalized reference $L_{pAeq,Tp(APLref)}$ values are significantly affected by the APL coefficient, which practically considers the density of the axles on each wagon. After measurement and normalization, similar instantaneous noise level for shorter wagons can result in lower equivalent noise level. This applies to both approaches of bass-by noise measurements.

In this way, the justification of the standard's requirement that measurement with one unit is less reliable than measurement with two identical ones is confirmed.

For a more reliable conclusion, it is necessary to carry out a test with larger number of wagons with different length and shape.

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