**Mechanics Transport Communications**

*Academic journal*

ISSN 1312-3823

issue 3, 2011

article № 0637

http://www.mtc-aj.com

# INFLUENCE OF TRAIN TYPE AND RAIL SURFACE ROUGHNESS ON RAILWAY TRAFFIC NOISE

**Stjepan Lakušić, Marijan Bogu , Ivo Haladin**

laki@grad.hr, bogut@koncar-institut.hr, ihaladin@grad.hr

*University of Zagreb Faculty of Civil Engineering, Kaciceva 26, Zagreb, KONČAR – Electrical Engineering Institute, Fallerovo setaliste 22, Zagreb* **,** *University of Zagreb Faculty of Civil Engineering, Kaciceva 26,Zagreb*

**CROATIA**

***Abstract****: Growing public awareness on noise pollution puts great emphasis on noise monitoring and mitigation measures. Railway traffic is one of the most widespread noise pollution sources in the western world. Among other factors, irregularities (roughness) on the wheel tread and the rail head cause vibrations within the vehicle and the track that lead to the generation of rolling noise. In order to conduct typical noise measurements caused by rail vehicle movement over the rails' running surface the control of geometry state of the railway track and surface roughness has to be conducted. A railway track has to meet the regulated geometry and roughness values in order to be eligible for typical noise measurements.*

*Noise and rail roughness measurements have been conducted on 100m long sections of two railway lines M104 (section Vrpolje - Ivankovo) and M105 (section Velika Gorica - Sisak). Section have been selected based on geometrical elements of the mentioned track and a relatively good overall condition which allow reaching train speed of 160 km/h and permanent way evaluation according to TSI-noise directive (2006/66/EC). Track evaluation consisted of geometry elements and rail surface roughness verification. Typical noise measurements of passing passenger and freight trains have been conducted at both test sites. Through the analysis of measured noise levels on two different test sites, several rail surface irregularities and their influence on vehicle noise levels have been observed. Influence of train speed and configuration has been observed. Special attention has been devoted to the different "weak spots" on railway lines (road-railway crossings, rail joints). The impact of these weak spots on the rolling noise levels has been analyzed and evaluated. Processing and analysis led to several conclusions on the effect of rail roughness on increased noise levels in the surrounding environment.*

***Key words****: noise, rail roughness, railway vehicles*

## INTRODUCTION

Standards and regulations related to noise in the environment where people are living and working, especially in urban areas, are getting more rigorous every year. Due to this fact the measures for traffic noise reduction have been defined [1], among which the noise reduction at source represents the primary measure of noise mitigation. Other measures are reduction of noise propagation (environment planning and management, noise protection barriers), noise protection at the destination (sound insulation of residential buildings) and economical measures supported by regulations (charges for vehicles producing high noise levels, grants for noise reduction, research funding).

European Commission working group that is dealing with railway noise has declared in 2003 a strategy and priorities for noise reduction [2]. Utmost attention has been dedicated to rolling contact noise between wheel and rail because different geometrical irregularities on the wheel (flat spots, mechanical faults) as well as on the rail (wave deformation, corrugation, rail joints, welding faults) affect the elevated noise levels.

Straightness of the rail running surface is a topic of interest of the scientific project “Noise and vibration of tram and railway tracks” that has been started in 2006 by the Department for Transportation, Faculty of Civil Engineering, University of Zagreb. The presence of irregularities on the rail running surface exposes the track to higher dynamical forces and increases the wheel vibrations [3]. Influence of rail surface straightness on environmental noise levels is investigated through typical noise measurements of a new low-floor electric train observed along with other passenger and freight trains operating on the measured railway lines.

## ALLOWED NOISE LEVELS

In the Republic of Croatia, according to the Rulebook on Technical Conditions for Railway Traffic Safety that all the railway vehicles have to meet [4], new railway vehicles have to be built in such a way that the noise emission during its operation has to be in accordance with the Directive 2006/66/EC (TSI-Noise) [5].

In Europe, TSI-Noise Directive is mandatory since 2006 and according to it the railway vehicles can have a limited influence on the surrounding environment. Directive prescribes highest allowed noise levels that the vehicles in European railway network such as electric locomotives, diesel locomotives, electric commuter trains, diesel commuter trains, passenger and freight wagons are allowed to produce. Highest allowed noise levels are prescribed for stationary vehicles, accelerating vehicle, a vehicle at the constant speed of 80 km/h as well as the noise in the driver’s cab [6].

From the aspect of noise impact on the environment where people are living and working, the most important noise level limit is one of the railway vehicles moving at constant speed [7], [8]. Table I shows the highest allowed noise levels of the environmental noise which has to be measured according to the adequate regulations [9], i.e. 7.5 m away from the centre line of a railway track and on a level of 1,2 m and 3,5 m above the top of rail. Noise should be measured at speed of 80km/h and at maximum vehicle speed (but not more than 190 km7h). A-valued equivalent continuous noise levels at the maximum speed V should be calculated to the referent speed of 80 km/h by subtracting the expected rolling noise gain:

$$L_{pAeq,Tp}(80) = L_{pAeq,Tp}(V) - 30\log\frac{V}{80},$$

where $T_p$ is the time of vehicle passing. Expected rolling noise gain equals 5,3 dB for the speed of 120 km/h or 9,0 dB for the speed of 160km/h. Calculated value is compared to measurement at speed of 80 km/h and the higher of the two values is applicable.

**Table I** *Environmental noise limits produced by railway vehicle at 80 km/h (TSI-Noise)*

| **Railway vehicle** | $L_{pAeq,Tp\,@\,7,5\,m}$ **dB(A)** |
|---|---|
| Electric locomotive | 85 |
| Diesel locomotive | 85 |
| Electric commuter train | 81 |
| Diesel commuter train | 82 |
| Passenger wagons | 80 |
| Freight wagons | 82 - 85 |

## TRACK MEASUREMENTS AND RESULT ANALYSIS

Type noise measurements of railway vehicles have to be conducted on a referent test track in order to eliminate the influence of different irregularities that could affect noise measurement outcome. However, if such test track is not available, it is possible to perform the measurements on a railway track in exploitation if it meets the required condition of geometrical configuration, surrounding environment, rail roughness etc. described in EN ISO 3095:2007 [9].

In this case measurements have been conducted on 100 m long sections of two railway lines M104 (section Vrpolje – Ivankovo) and M105 (section Velika Gorica – Sisak), Figures 1&2. These sections have been selected based on the geometrical elements that allow testing the trains at a maximum speed. The results of a measuring train (received from HŽ Infrastructure) have also been analyzed.

**Figure 1** *Railway line M105 (Vrpolje – Ivankovo)*


**Figure 2** *Railway line M105 (section V.Gorica - Sisak)*

In frame of permanent way validation on the described sections, the control of geometry (track gauge, cant, weld and isolated joint state and position, Figure 3) and rail head roughness (Figure 4). Both measured sections have met the required geometry standards according to the Croatian standards for railway track maintenance [4], [10].

**Figure 3** *Manula track geometry measurement*

**Figure 4** *Rail surface roughness measurement*

Since measurements of rail roughness have been conducted with 1 m long measuring device, wavelengths up to 0,1 m. According to EN ISO 3095:2007 both sections have been evaluated as suitable for typical noise measurements in terms of rail roughness. As described in Figure 5 and 6, both the whole analyzed spectrum of both railway lines fits in the tolerant range according to the standard, hence the sections have been positively evaluated.

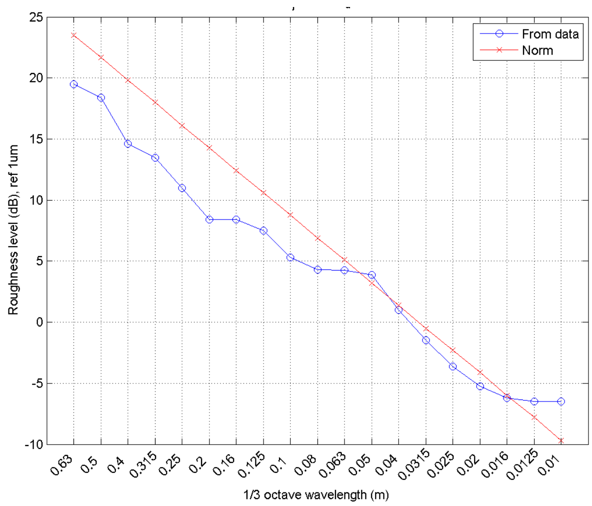


**Figure 5** *Rail roughness on section Vrpolje - Ivankovo*

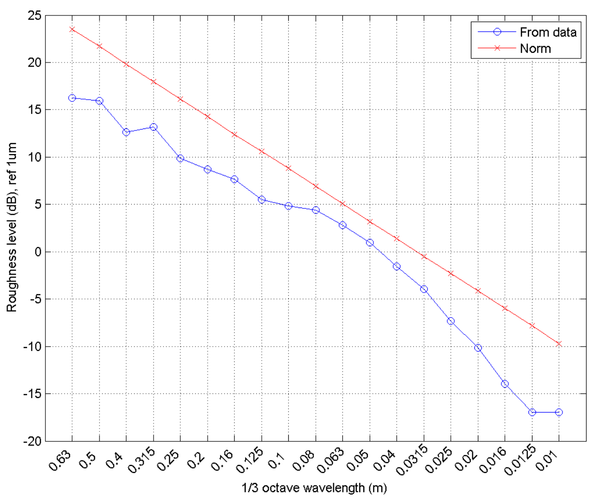


**Figure 6** *Rail roughness on section V. Gorica - Sisak*

## NOISE MEASUREMENT RESULTS

Noise has been measured using three microphones on two stands (Figure 7). On a section Vrpolje – Ivankovo results measured on stand A (microphones at 1,2 m and 3,5 m above top of the rail) have been selected as applicable for typical noise measurements since they have been positioned far from the spotted track irregularities. Stand B (microphone at 1,2 m above top of the rail), however, has been positioned near the insulated rail joint in order to estimate the influence of irregularities such as rail discontinuity on elevated noise levels in the environment.

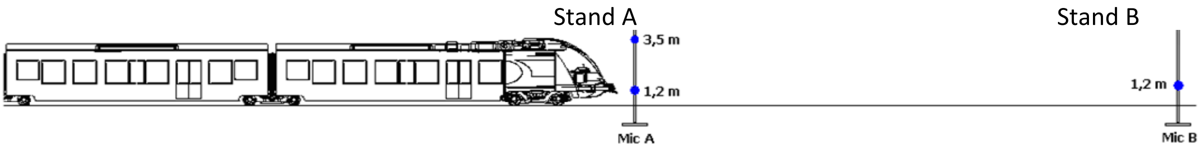


**Figure 7** *Microphone positioning for typical noise measurement*

Results of the measured A-valued equivalent continous noise levels for an new electric commuter train - EMV (made by Koncar Electric Vehicles), a standard passenger train (electric locomotive 1141 and 4 wagons) and freight train (electric locomotive 1141 and 24 freight wagons) are shown in the Table II. EMV noise has been recorded at running speed of 80, 120 and 160 km/h, while passenger and freight trains have been recorded at standard running speed of 120 and 80 km/h according to the train timetable.

**Table II** *Noise measurement overview. Three train types at different speed.*

| Train speed (km/h) | Train type | Pass by time $T_P$ (sec) | $L_{pAeq,Tp@7,5m}$ dB(A) | | |
|---|---|---|---|---|---|
| | | | Mic A - 3.5 m | Mic A - 1.2 m | Mic B - 1.2 m |
| 80 | EMV<br>Freight | 3,38<br>17,50 | 79,3<br>92,8 | **80,4**<br>**93,7** | 82,2<br>94,5 |
| 120 | EMV<br>Passenger | 2,25<br>3,63 | 84,5<br>91,0 | **85,4**<br>**92,4** | 87,5<br>94,3 |
| 160 | EMV | 1,69 | 88,4 | **89,1** | 92,2 |

### Influence of train type on noise levels

In accordance with the method of determining environmental noise levels of railway vehicles according to TSI-Noise directive results of measurements of microphone at stand A, height 1,2 m, have been standardised to the referent speed of 80 km/h (correction of -5,3 dB @ 120 km/h and -9,0 dB @ 160 km/h). Noise levels for different train types are as follows: EMV 80 dB(A), passenger train 87 dB(A) and freight train 94 dB(A) (Figures 8, 9 and 10). Noise levels of new EMV are 7 dB(A) lower compared to a standard passenger train and even 14 dB(A) lower than a freight train.

**Figure 8** *EMV ŽFBH 4412*

**Figure 9** *Passenger train*

**Figure 10** *Freight train*

Figures 11, 12 and 13 describe the comparison of noise levels time profiles of all three measured vehicles at different operating speed.

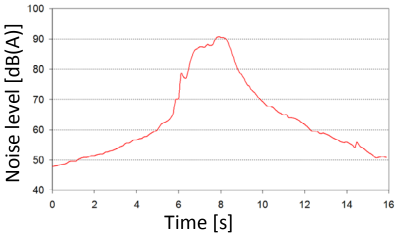


**Figure 11** *Measurement @ 160 km/h (EMV)*

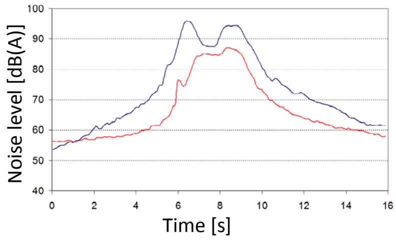


**Figure 12** *Measurement @ 120 km/h (EMV and passenger train)*

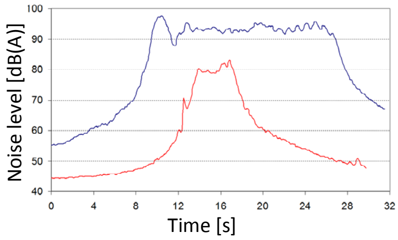


**Figure 13** *Measurement @ 80 km/h (EMV and freight train)*

**Influence of rail head roughness on noise levels**

According to the measurement results at microphones on stands A and B, elevation 1,2 m in Table II, the influence of rail roughness on overall passing train noise can be estimated. Namely, microphone on the stand B has been installed next to the insulated rail join that directly affects the elevated noise levels of a passing train, Figure 7. On described position the recorded irregularities of the rail surface reach up to 0,5 mm in the vertical plain. Measured noise levels hence cannot be used for typical noise measurements, but give an interesting result for determining the influence of irregularities on elevated rolling noise levels.

In all five measurements, microphone B measured higher A-valued equivalent continuous noise levels $L_{pAeq,Tp\ @\ 7,5\ m}$, that microphone A, dependent on the train operating speed. Highest measured difference is 3 dB (A) at 160 km/h. At 120 km/h for a passenger train and 120 and 80 km/h for the EMV the difference is 2 dB(A). Measured difference for the freight train at the speed of 80 km/h is 1 dB(A). The figures 14, 15 and 16 clearly show the mentioned difference in noise levels as well as the distinct peaks in noise measurements on microphone B due to each axel run over the irregularities.

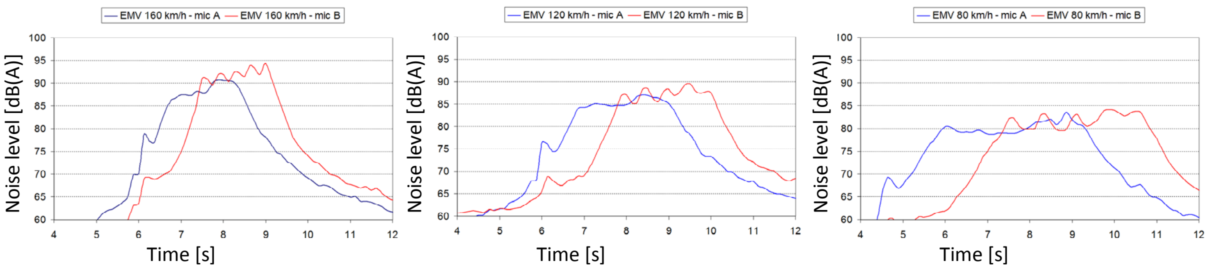


**Figure 14** *Comparison of noise at stands A and B at different speed of passing EMV (160, 120 and 80 km/h)*

On a measurement site Velika Gorica – Sisak, local rail surface irregularities have been spotted in the area of road-railway crossing. Recorded deviation of a rail surface measured up to 0,37 mm in the vertical plane. Noise measurements on this measurement site showed the increase in equivalent rolling noise levels up to 2 dB(A) in the area of road-railway crossing.

**CONCLUSION**

While measuring noise levels of railway vehicle the state of the railway track that the measurements are conducted on should also be considered. Permanent way state plays a significant role in rolling noise formation and emission in the environment that should not be ignored. Beside this obvious influence on environmental noise it has been demonstrated that it can affect the results of the railway vehicle noise measurements up to the point that they do not comply with the regulations if the problem has not been isolated on time.

By examining the permanent way state (tracks, fastenings, sleepers and ballast bed) it can be concluded that all the track elements have been properly installed and that no irregularities that could affect the traffic safety or require speed limitations. It has also been established that the roughness of rail surface measured according to TSI-Noise and ISO-3095 standards is acceptable for typical noise measurements.

Noise measurements of different vehicle types allowed a comparison of noise levels emitted to the environment. Passenger and freight trains that operate on described railway lines as well as the EMV in the testing phase have been observed. The high recorded noise levels of passing freight train have been expected due to the high axel loads, length of the composition and different wagon shape. Furthermore it has been interesting to compare a standard passenger train with four wagons and a new commuter train – EMV at the same operating speed. Measured noise levels at the speed of 120 km/h reveal a difference of 7 dB(A) in favour of the EMV that ultimately makes a significant difference for the quality of life in the area surrounding the railway line.

By placing the noise measuring devices near the spotted irregularities of rail surface (insulated rail joint and road-railway crossing) it has been possible to analyze the effect of these irregularities on elevated noise levels. Depending on the vehicle speed and type of irregularity the recorded increase in noise level varies from 1 to 3 dB(A).

Conducted measurements and analysis results of passing railway vehicle noise levels indentified a significant influence of different type and proper maintenance of railway track and vehicles on the emitted noise levels. Results and findings of such researches are very important factor for the future constructions and reconstructions of railway tracks as well as the vehicle acquisition especially for railway operators in urban areas where the noise pollution highly affects the quality of life.

*Acknowledgment*
*Presented research was performed within the project "Noise and vibration on tram and railway tracks" No. 082-0000000-218, financed by Croatian Ministry of Education, Science and Sport.*

## LITERATURE

[1] S. Lakušić, V. Dragčević, T. Rukavina: Mitigation measures for traffic noise abatement in urban areas, Građevinar, 57 (2005) 1, 1-9.
[2] The Working Group Railway Noise of the European Commission: Position Paper on the European strategies and priorities for railway noise abatement, Brussels, 2003.
[3] S. Lakušić, M. Bogut: Impact of rail weld geometry on tram wheel vibrations, The 36th International Congress & Exhibition on Noise Control Engineering (INTER-NOISE 2007), Istanbul, Turkey, Paper N260, 28-31 August, 2007.
[4] Rulebook on technical conditions for safety of railway traffic which railway tracks have to comply with, Narodne novine RH 147/2008
[5] Directive 2006/66/EC (TSI-Noise): Technical specification for interoperability relating to the subsystem ´Rolling stock - noise´of the trans-European conventional rail system
[6] M. Bogut, A. Briški Vukovski, D. Paljan: Dopuštene razine buke i postupci mjerenja razine buke tračničkih vozila, Automatizacija u prometu '09, Ploče, 2009.
[7] S. Khan, M. Ulhas, V.Goel: Synthesis of pass-by railway noise, Acoustics '08, Paris, 2008.
[8] F.Poisson, P.E.Gautier: The railway noise reductions achieved in the Silence project, Acoustics '08, Paris, 2008.
[9] HRN EN ISO 3095:2007 Railway applications – Acoustics – Measurements of noise emitted by railbound vehicles (ISO 3095:2005)
[10] Rulebook 314 on mainenance of track and railway facilities, Croatian Railways

# ВЛИЯНИЕ НА ВИДА НА ВЛАКА И ГРАПАВИНАТА НА РЕЛСОВАТА ПОВЪРХНОСТ ВЪРХУ ШУМА ОТ ЖЕЛЕЗОПЪТНИЯ ТРАФИК

**Stjepan Lakušić, Marijan Bogu , Ivo Haladin**

*University of Zagreb Faculty of Civil Engineering, Kaciceva 26, Zagreb, KONČAR – Electrical Engineering Institute, Fallerovo setaliste 22, Zagreb* **,** *University of Zagreb Faculty of Civil Engineering, Kaciceva 26,Zagreb*
**CROATIA**

***Ключови думи:*** *шум, грапавина на релсата, железопътни возила.*

***Резюме:*** *Нарастващата обществена загриженост относно шумовото замърсяване поставя силен акцент върху мониторинга на шума и мерките за намаляването му. Железопътният трафик е един от най-разпространените източници на шумово замърсяване в западния свят. Наред с другите фактори, грапавината на бандажите на колелата и на главата на релсата причиняват вибрации в превозното средство и на релсовия път, които водят до генериране на шум при търкаляне. За извършване на типични измервания за шума, причинен от движението на подвижния състав по повърхността на релсите, трябва да се осъществи контрол на състоянието на геометрията на железния път и грапавината на повърхността. Железопътната линия трябва да отговаря на регламентираните стойности за геометрията и грапавината, за да са допустими за типични измервания на шум.*

*Проведени са измервания на шума и релсовата грапавина на 100-метрови участъци по две железопътни линии – M104 (участък Vrpolje - Ivankovo) и M105 (участък Velika Gorica - Sisak). Участъкът е избран въз основа на геометричните елементи на релсовия път и относително доброто му състояние, които позволяват достигане на скорост от 160 km/ h и постоянна оценка на пътя в съответствие с TCOC- директива за шума (2006/66/EO). Оценката включва проверка на елементите на геометрията и на неравностите на релсовата повърхност. Проведени са измервания на шума от преминаването на пътнически и товарни влакове в двата експериментални участъка. Чрез анализ на измерените равнища на шума на двете места са забелязани нередности в релсовата повърхност и влиянието им върху нивата на шума от подвижния състав. Наблюдения са извършени и върху влиянието на скоростта и конфигурацията на влака. Специално внимание е отделено на различните "слаби места" на железопътните линии (железопътни прелези, железопътни връзки). Анализирано и оценено е въздействието на тези слаби места върху равнището на шум при търкаляне. Обработката и анализът водят до заключението, че релсовата грапавина влияе върху повишаване на шума в околната среда.*