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Do Steel Bridges Prevent Rail Corrugations?

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Abstract

Rail corrugations (germ. "Schlupfwellen") are wear pattern, which emerge during the transits of railway vehicles at narrow railway curves (R ≤ 250 m) and they are a menace to railway operators, especially if their railroad network exists in mountains. Therefore ÖBB started recently a research program "OBO" (Optimierter Bogenoberbau) for better understanding and avoidance of "Schlupfwellen", which is mainly experimentally oriented. As a representative test track was the extended famous narrow curve at the valley of Brixen close to Kitzbühl chosen, and two Measurement sites where there established, one embedded in the ballasted track bed and another one on a steel bridge, situated in this curve. Measuring the passing trains, a rearly astonishing fact was discovered: Whereas in the ballasted track all well known typical features occur (vibration, bending and torsion of the rail,...), which produce the wear created Schlupfwellen and the dedicated grumbling noise, the wheelsets run properly on the steel bridge track and pass "friendly" the associated curve segment! Dicussing the ascertained fact, it was realized that on many European steel bridges such phenomena happens! The paper ends assuming that a broad-band vibration of the rail heads upon the steel bridge reduces the friction coefficient in the wheel/rail contact area ("Flange oilers"). This can be the reason for the smooth travel at the bridge. This may also be the basis for a technical application to overcome the generation of Schlupfwellen?

1. Introduction

Rail corrugations (german: "Schlupfwellen") are wear pattern, which emerge during the transits of railway vehicles in narrow railway curves (Fig. 1).

Rail corrugations are a menace for railway operaters! The corrugations derive from the flange striking against the rail head in a narrow curve, by which bending

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and torsion of the wheel set axle occurs [1], because the wheel set does not adjust itself deliberately into a proper curve passaging position (Fig. 2).

Fig. 1. Wear pattern on the rail head of a narrow curve [1]

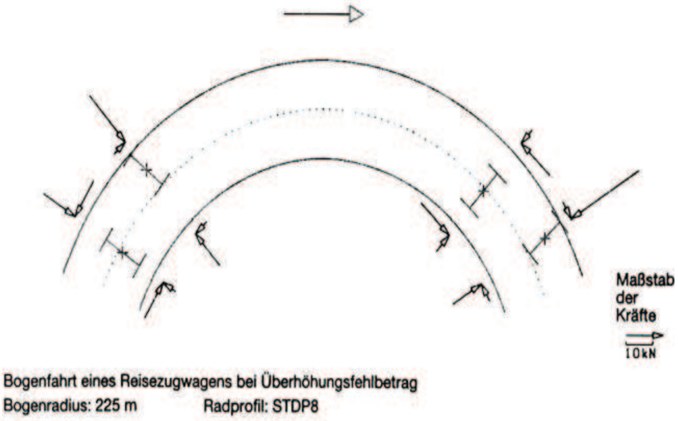

Fig. 2. Simulation of the wheel set positions of a 4 axle-vehicle in a narrow curve [2]

By this a torsion/bending vibration of the axle is excited, which causes creepage wear in the contact area and creates the mentioned wear pattern.

In 2001 the Österreichische Bundesbahn (ÖBB) started within the frame of the research pro- ject "OBO" (optimierter Bogenoberbau) investigations of the mechanics of rail corrugation and trying – if possible – the development of remedial actions against the undesired wear phenomenon. As a test curve for the mainly experimentally oriented undertaking the "Brixentaler Bogen" was chosen (Fig. 3), which crosses the river “Windacher Ache” by a bridge, called the “Hohe Brücke” (Fig. 4).

Fig. 3. Test curve of Brixental between Hopfgarten and Westendorf

Fig. 4. The railway line traverses at the „Hohe Brücke“ the river “Windacher Ache”

This bridge shows a very funny feature: The up-hanging part of the bridge is constructed by iron, whilst the downwards bridge part is made from concrete (Fig. 4).

The Brixentaler curve, which exhibits a mean radius of about 250 m and the train travels up to an average speed of 70 km/h, contains upwards as well as downwards huge numbers of rail corrugations! As it was not clear to the OBO-team, wether there is some influence to the generation of rail corrugations by the track bed (which is different in the case of the ballasted track from the bridge track), it was decided to install two identical measurement sites (constructed in the same way), as well at the ballasted track as that of the bridge (Fig. 5, 6).

Fig. 5. The measurement site in the ballasted track (see the rail corrugations!)

Fig. 6. The measurement site on the steel bridge (without rail corrugations!)

At the test track a special test train was operated with a vehicle composition, given in Fig. 7:

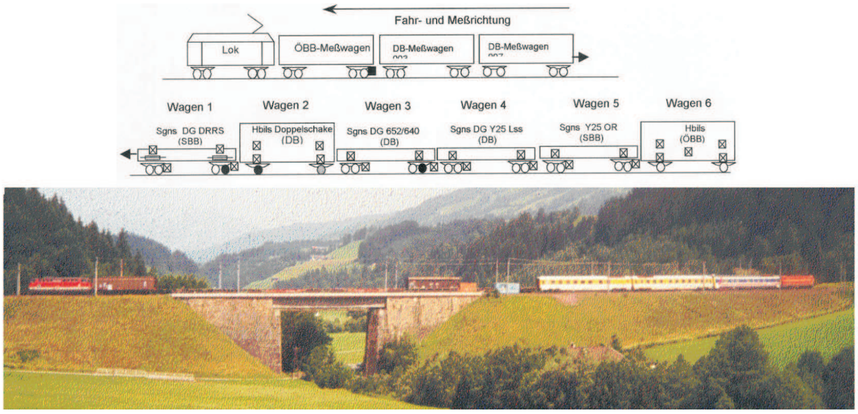

Fig. 7. The test train of the measurement project OBO at the Brixen valley, supplemented by an additional diesel-loc yoked to vehicle 6

The test procedure was done in that way, that the test train was pulled upwards by the locomotive at the upper end, and afterwards rolling downwards with the default test speed by the locomotive at the down end of the train (Fig. 8). By this campaign a lot of measurement results were gained…

Fig. 8. The test train, passing the reference measurement equipment (km 178,6)

2. Measurement Results

For the purpose of our paper we select from the immense number of measurement results only those, which are important for our conclusions presented in this paper. We see in Fig. 9 the lateral displacement vibration of the inner rail head (green colour), the lateral displacement (red colour) of the associated rail foot and the filtered vertical displacement of the same rail head (blue colour) for identification of the position of the wheel sets; Sgns Y25 is going behind Sgns DG 652/640. One can see, that the rail is mainly inclining. The consequences are, that bending of the wheel set axle occurs, and that severe creepage in the contact area is to be expected! Fig. 10 shows the respective power spectral density.

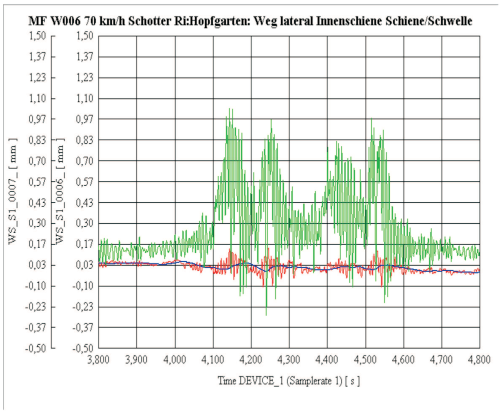

Fig. 9. The lateral displacement vibration of the inner rail head (green colour), the lateral displacement (red colour) of the associated rail foot and the filtered vertical displacement of the same rail head (blue colour) for identification of the position of the wheel sets; Sgns Y25 is going behind Sgns DG 652/640

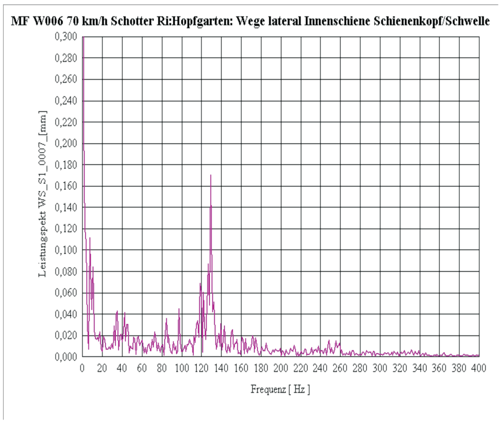

Fig. 10. Power spectral density of the inner rail head vibration

Now we compare the above measured results with Fig. 11:

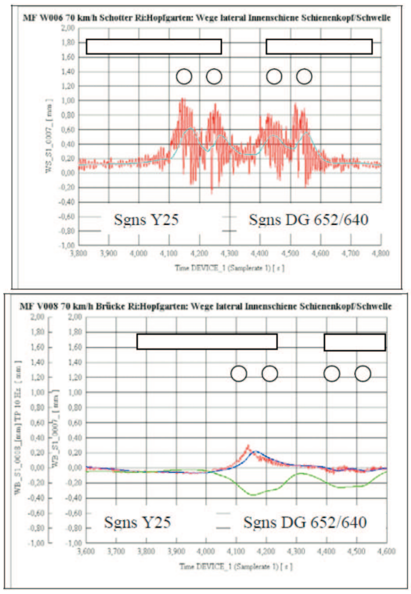

Fig. 11. Lateral displacements (as Fig. 9) at the ballasted track, compared with the equivalent signals at the bridge; Sgns Y25 is going behind Sgns DG 652/640

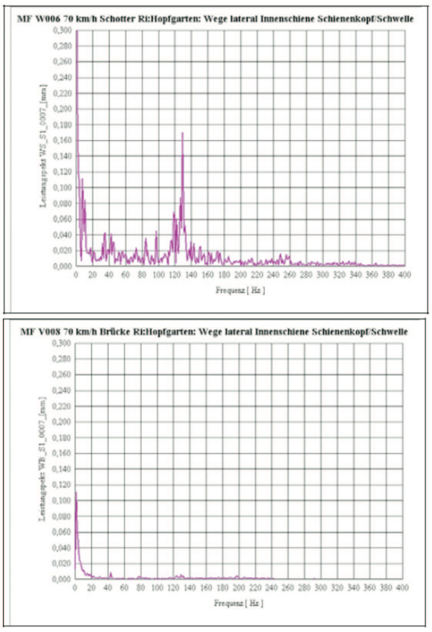

Fig. 12. Lateral power spectral density for the time signals of Fig. 11

The result is obvious:

The rolling on a narrow curve at a steel bridge is much more quiet then on ballasted track!! No rail corrugation occurs.

This fact is also confirmed by experience with other steel bridges in Germany and Norway.

3. Interpretation of Measurement Results

What have we seen?: The dynamic behaviour, measured with similar devices, same speed, same wheel/rail-profiles, same wagons and rails, same environmental conditions, is very dif- ferent in both cases. But why?? The conclusion of the authors: The only difference (!) are the type of vibration of the rail heads at both sites and therefore this vibration reduces in the bridge case the friction coefficient remarkably. This effect is comparable with the artificial rail head lubrication, activated by some raiway operators, suffering from rail corrugation.

In Fig. 13, 14 the power spectral density of the vertical vibrations of the sleeper in the case of ballasted track is compared with the sleeper of the steel bridge. One can clearly see, that the broadband vibration, caused by the structure of the steel bridge, is beneficial for avoidance of rail corrugation. You can even hear the change of noise, when you are sitting in a train, pass- ing suddenly a steel bridge.

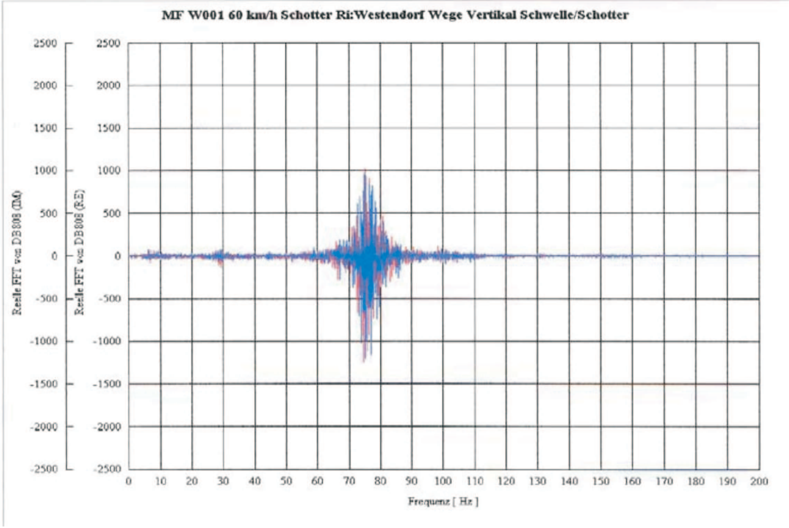

Fig. 13. Ballasted track, power spectral density of vertical sleeper vibration

The reduction of the friction coefficient by vibration of the contact area can be found also in the literature: Eg Thomsen [3] described such experiments:

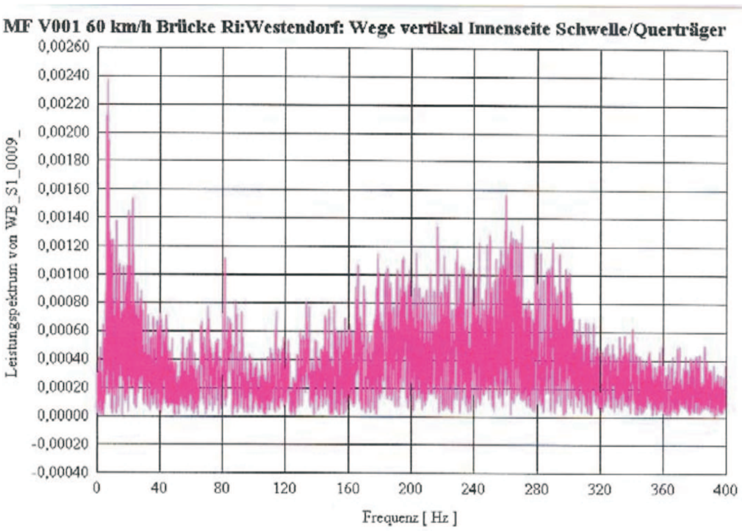

Fig. 14. Steel bridge, power spectral density of vertical sleeper vibration

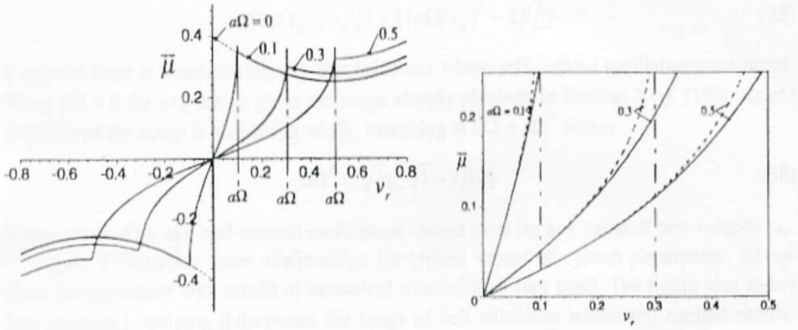

Figure 7 (a) Effective friction characteristic $\bar{\mu}\,(v_r)$ as given by (47) for different intensities $a\Omega$ of fast excitation (parameters as for Figure 4). Fast excitation smoothens the characteristic, at sufficiently large intensity canceling the negative slope. (b) Initial part of the friction-velocity characteristic: (– – –) Using (47) as in Figure (a); (——) Using third order Taylor expansion (48)–(49).

Also Popow [4] came to the same result by theoretical and experimental research of Coulomb's friction (Fig. 15).

Does there even exist the possibility of a technical use of such vibrations, by artificial excitation of rails or wheel sets to avoid rail corrugations?? A broadband excitation will be necessary, low amplitudes (μm) are sufficient!

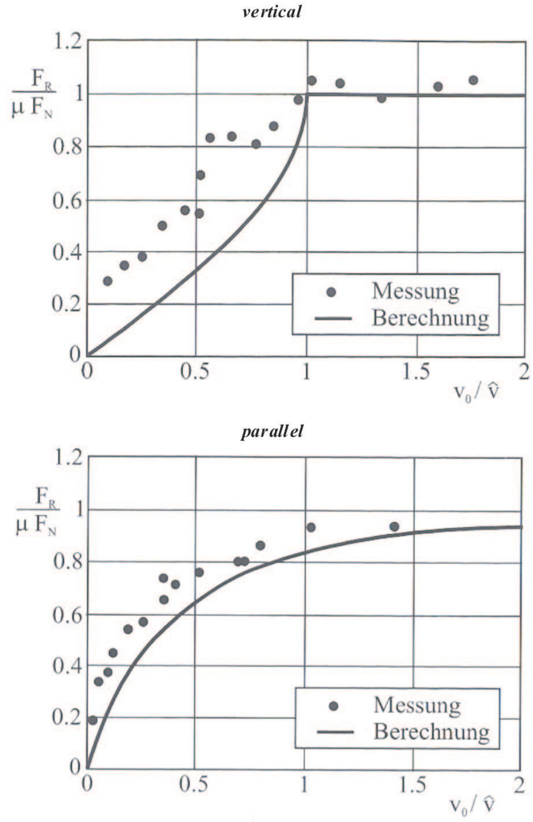

Fig. 15. The influence of vibration on the friction coefficient

References

1. Bergander B., Blenkle C., Meinke P., Stephanides J.: Über die Stabilität enger Bogendurchfahrten von Eisenbahnradsätzen, Der Eisenbahningenieur, Heft 2 (2001).
2. Eickhoff B, Scott G.: Fahrzeug und Gleis als gemeinsames System, ETR 45, Heft 7/8 (1996).
3. Thomsen J.J.: Using fast vibrations to quench friction induced oscilla- tions, Technical Universität ofDenmark, Lingby/Kopenhagen.
4. Popov V.L.: Kontaktmechanik und Reibung, Sprinter Verlag (2009).