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NOISE CONTROL FOR A BETTER ENVIRONMENT

Impact of noise optimized rail grinding on the annoyance of train passings

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ABSTRACT

As presented during Internoise 2017 [1], Deutsche Bahn AG has initialized the research project "Noise Optimized Rail Grinding" to optimize the grinding process of maintaining rail grinding acoustically. Residents previously often complained about annoying whistling sounds caused by trains passing after the grinding process. The aim of the project is to minimize these annoying sounds by optimizing the grinding process. The entire project of DB Netz AG is comprising as project partners six different grinding companies, DB Systemtechnik and Möhler + Partner Ingenieure AG. Möhler + Partner engineers were responsible for the psychoacoustic project part.

In a first step, the state of the art of the annoyance caused by three different kinds of trains passing at three different time intervals after the maintaining rail grinding of all participating grinding companies was evaluated by psychoacoustic experiments. In a second step, a threshold of acceptance was determined for the various whistling train passings. By means of the received psychoacoustic data, a threshold for the rail roughness was extracted by DB Systemtechnik and distributed to the participating grinding companies for an optimization process. In a last step, the actually achieved improvement in annoyance was evaluated again in listening sessions.

Keywords: Railway Noise, Rail Grinding, Psychoacoustics, Annoyance
I-INCE Classification of Subject Number: 61

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1. CONCEPT

To prevent cracks and roughness on the surface of rails, the DB Netz AG, infrastructure company of Deutsche Bahn AG, is grinding frequently the rails of its track network. During this process the railhead is profiled completely new. However, the profiling leads to corrugations in lateral direction. Therefore, the residents quite often complaint about whistling noise during train passings after the grinding process. This whistling noise is clearly visible in the spectrum as a tonal component and correlates with the roughness of the corrugation.

In the context of the project “Noise Optimized Rail Grinding” of DB Netz AG, psychoacoustic experiments were designed to minimize the annoyance of the described tonal whistling noise. As a result, the grinding process was optimized to the benefit of the residents.

Figure 1 shows a flow chart of the whole project “noise optimized rail grinding” of DB Netz AG comprising as project partners the participating grinding companies (yellow), DB Systemtechnik (blue) and Möhler + Partner Ingenieure AG (green).

First, the different participating grinding companies machined single rail sections on a test track. In the following DB Systemtechnik measured and recorded various train passings on all measurement sections. To realize a realistic scenario all signals were afterwards filtered with transfer functions to receive signals at different points of immission (as e.g. “garden in front of the house” or “living room with closed windows”). Subsequently, the signals were evaluated by Möhler + Partner Ingenieure AG in listening sessions to assess the annoyance. The main annoying tonal components of the signals were then modified systematically and by further listening session a threshold of acceptance was detected. Based on the resulting target curves for acceptable train passings, DB Systemtechnik calculated by means of a TWINS simulation its required rail surface. With these information the grinding companies revised and changed their grinding process and another loop of measurements was figured out. After a third loop a subjective validation was finally conducted by Möhler + Partner Ingenieure AG.

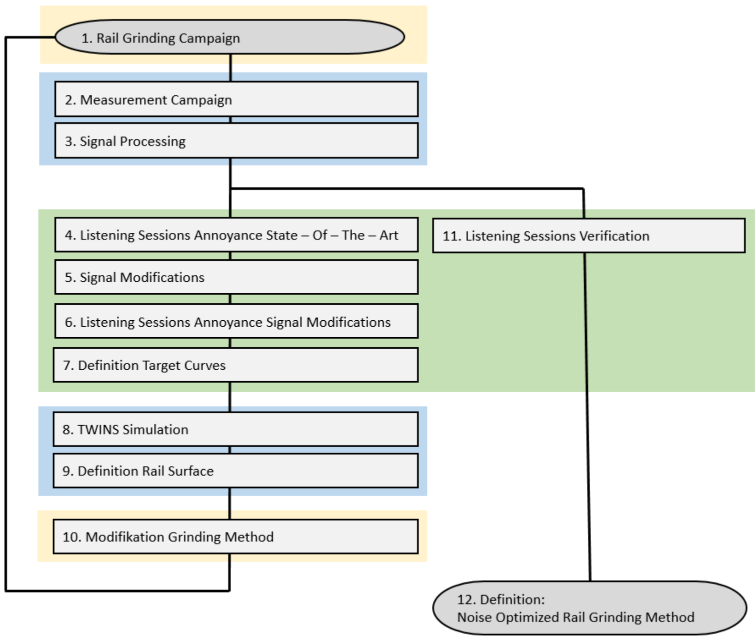

Figure 1: Overall concept of the project “Noise optimized rail grinding” of DB Netz AG Yellow: DB Netz AG, blue: DB Systemtechnik, green: Möhler + Partner Ingenieure AG

2. ANNOYANCE: STATE OF THE ART

2.1 Stimuli

In the first experiments (#4 of Figure 1) the annoyance of train passings on eight different track sections (six grinded sections and two reference sections) of three kind of trains (IC-train, a train set “ET440” and a conventional passenger train “DoSto”) at three different time intervals after grinding were evaluated at three different points of immission. The full matrix of varying parameters is figured in Table 1.

Grinding section	Train passing on track	Time interval after grinding (in loading tons)	point of immission
$\begin{pmatrix}1R\\1A\\1B\\1C\\2R\\2A\\2B\\2C\end{pmatrix}$	$\begin{pmatrix}IC\ @\ 200km/h\\ET440\ @\ 140km/h\\DoSto\ @\ 120km/h\end{pmatrix}$	$\begin{pmatrix}0\\700k\\2Mio\end{pmatrix}$	$\begin{pmatrix}garden\ in\ front\ of\ the\ house\\living\ room\ /\ tiltedwindow\\living\ room\ /\ closedwindow\end{pmatrix}$

Table 1: Matrix of all evaluated parameters for the first experiments.

2.2 Psychometric Method

To evaluate these stimuli regarding to their annoyance the psychometric method of magnitude estimation with anchor sound was used. The anchor of the evaluation was always the passing of the same train at the reference track which was not grinded at all. Figure 2 shows one sequence of the listening session. Each sequence

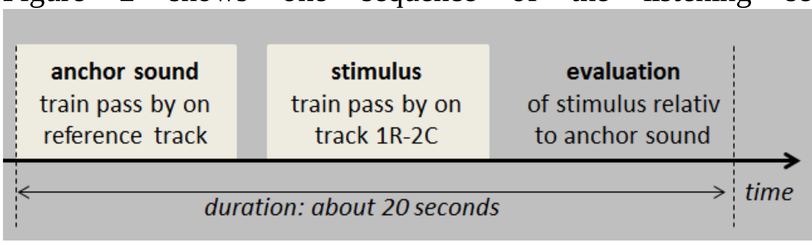

Figure 2: Sequence of the listening session “annoyance state of the art” (magnitude estimation with anchor sound)

2.3 Results

Figure 3 shows the medians and the interquartile ranges of all 20 subjects. The figures on the left hand illustrate the annoyance caused by a IC passing with 200 km/h on the different grinding sections, the figures in the middle show the results for a “ET440” passing with 140 km/h and on the right hand the annoyance caused by a “DoSto” passing with 120 km/h. The upper, middle and lower figures represent respectively the data of the three different evaluated points of immission.

The red symbols illustrate the annoyance directly after the grinding process with zero loading tons on the track, the blue symbols represent the annoyance after 700.000 loading tons and the green one that after 1.000.000 loading tons.

For all charts the evaluation of the reference signals (1R and 2R) indicates a good reliability of the subjects. The maximum annoyance results for immediate passings after the grinding process (red data points), evaluated at the point of immission 1 (upper panels) and in particular for the pass by of IC-trains and “DoSto”-trains. However, huge differences between the different grinding sections can be stated: whereas section 1A and 1C register even improvements in annoyance after the grinding process, section 1B, 2A, 2B and 2C show deteriorations in annoyance up to a factor of 2.5.

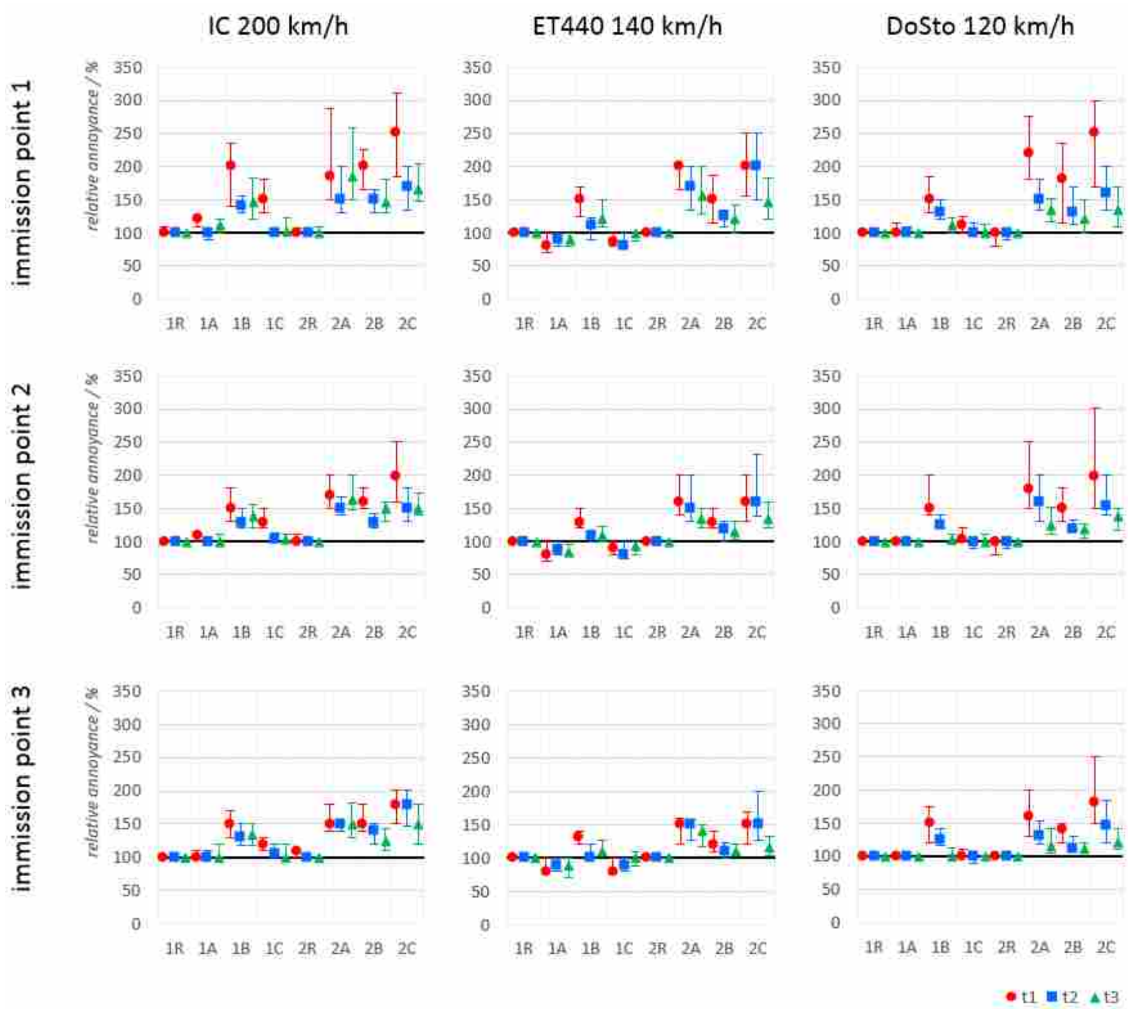

Figure 3: Annoyance caused by trains passing after the grinding process on the respective grinding section. Upper graphs: point of immission 1 (garden in front of the house), middle graphs: point of immission 2 (living room with tilted windows), lower graphs: point of immission 3 (living room with closed windows). Red: t1 (zero loading tons), blue: t2 (700k loading tons), green: t3 (1mio loading tons).

3. THRESHOLD OF ACEPTANCE

3.1 Stimuli

In the next step (#5 of Figure 1) the most annoying tonal pass by signals of the previous experiment ("worst-case" signals) were modified systematically. To receive signals with different strengths of tonal components two train passings of the same train on the reference track and on a grinded track were mixed with varying level relation. The details of this method were presented during Euronoise 2018 [2]. For a pair of two train passings (reference and worst-case signal) seven signals were realized by a stepwise decrease of the tonal components. This was done for four different passings of each kind of train.

3.2 Psychometric Method

These seven modified signals were evaluated together with their two basic signals (reference and worst-case signal) with the method of Random Access. Therefore, the subjects had to rank all signals regarding their annoyance. After arranging the signals, the subjects had to put an arrow on that signal, which was just no more acceptable.

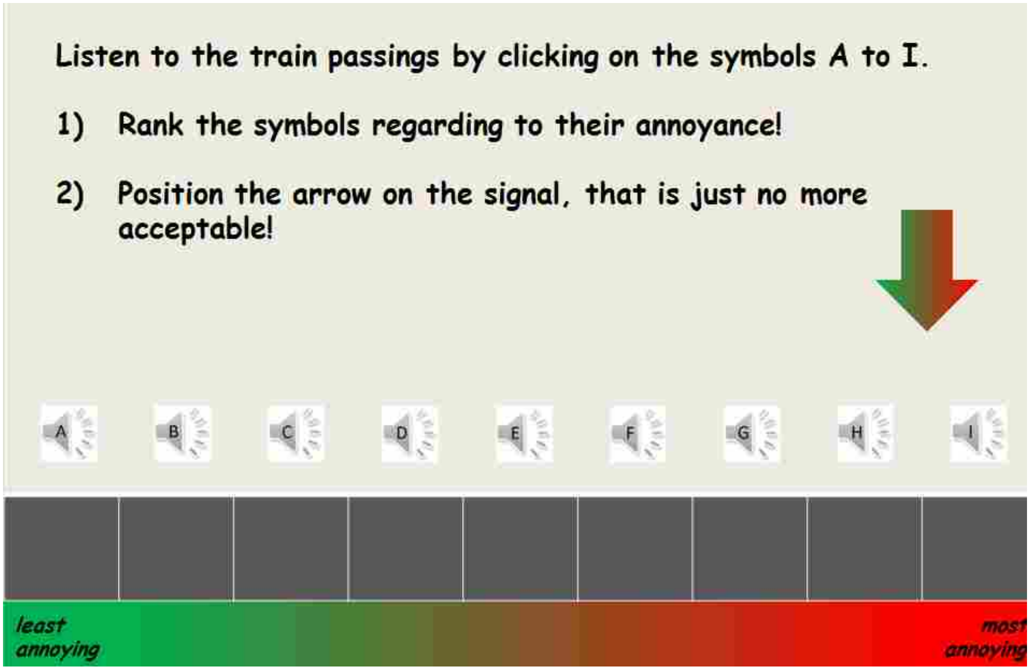

Figure 4: Psychometric method for the detection of the threshold of acceptance

3.3 Results

Figure 5 shows the results of all 12 (3 trains x 4 reference-/worst-case-pairs) experiments. The percentage of acceptance is figured for each evaluated stimulus. With defining a threshold of 75% acceptance, the signals fulfilling this criterion were extracted and analysed regarding their spectrum. In that way, for each train a target spectrum was defined that met the threshold of acceptance. This spectral information was the input for an "inverse" TWINS simulation done by DB Systemtechnik (#8 of Figure 1) to define the rail roughness (#9 of Figure 1) for an optimum grinding process.

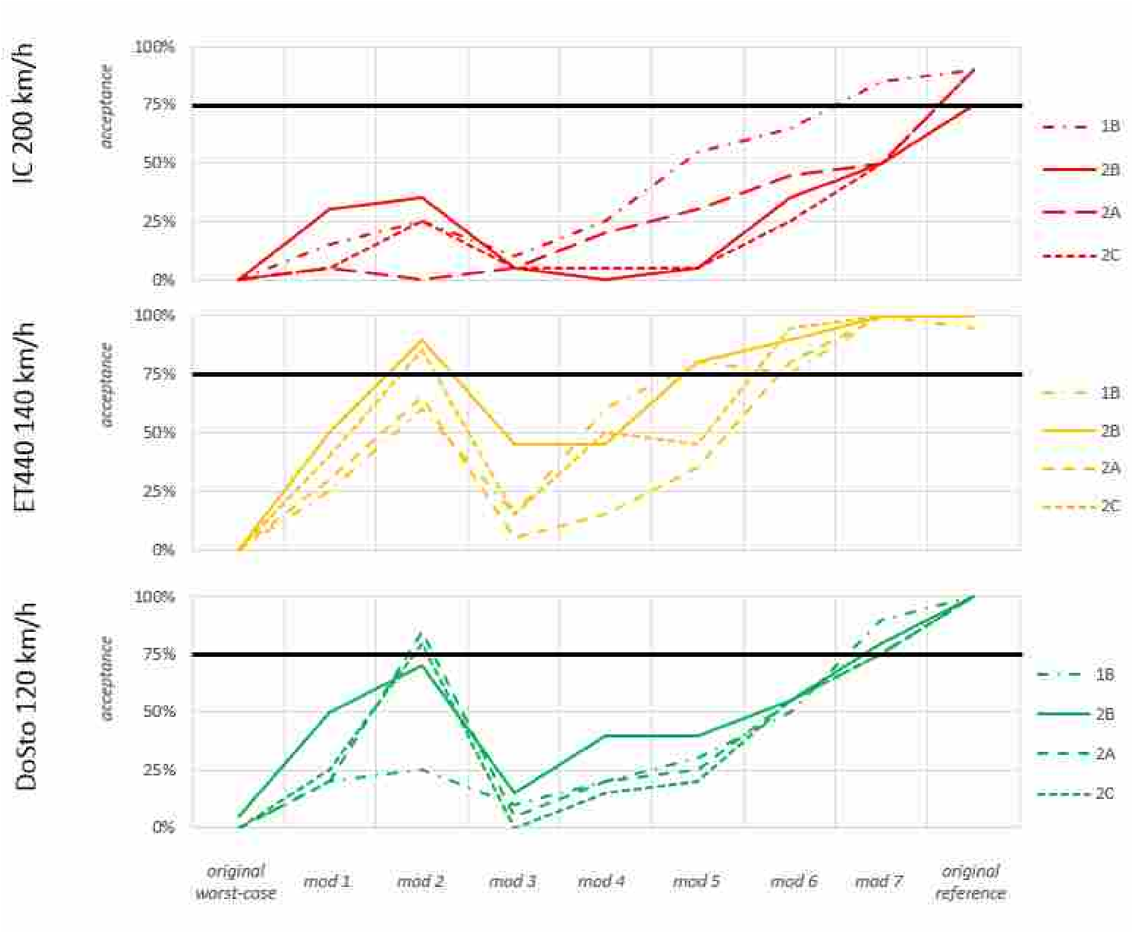

Figure 5: Threshold of acceptance for the different kind of trains

4. ANNOYANCE: VALIDATION

After modifications in the grinding process by the grinding companies (#10 of Figure 1) another loop of grinding and measurement was conducted. After a third loop, a subjective validation of the grinding modifications was done by repeating the listening sessions of the first experiment.

Figure 6 shows the direct comparison between the first listening sessions (filled symbols) and the validation experiment (open symbols) for each grinding company participating on both experiments. Again the median and the interquartile ranges of all 20 subjects are presented. The left charts illustrate the data for the point of immission 1 (garden in front of the house), the right charts illustrate the data for the point of immission 3 (living room with closed windows).

The track sections 1A and 1C were already during the first experiment among the best, which is also the case for the results of the validation, even if there can be determined a faint deterioration between the state-of-the-art and the validation experiment. Track sections 1B, 2A and 2B however can register clear improvements between the state-of-the-art and the validation experiment. In particular the passings of the "ET440"-train on section 2A and the IC-train passings on track section 2B were evaluated considerably less annoying during the validation experiment.

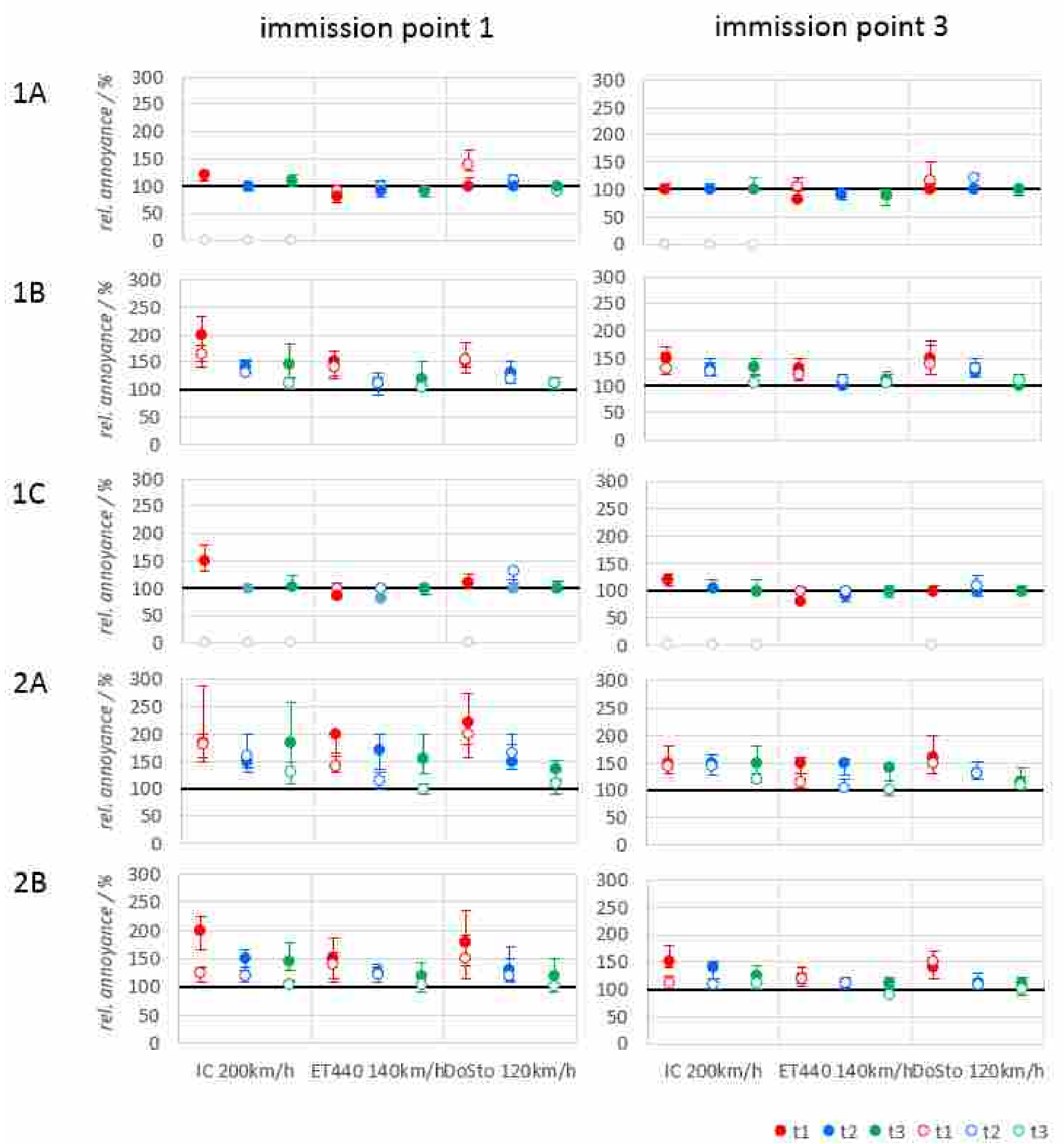

Figure 6: State-of-the-art (filled symbols) versus validation (open symbols).

5. CONLUSION

By taking into account the psychoacoustics into the consideration of rail noise an effective improvement of disturbing noise for the residents can be pursued. In the present study limiting curves for the grinding process based on psychoacoustic experiments were developed to modify the proceeding in an optimum way for the residents' perception.

6. REFERENCES

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