Comparison of the geometrical requirements for guideways of Transrapid and wheel-on-rail

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ABSTRACT: This article describes the geometrical requirements for guideways at track-bound high speed systems at the example of the Transrapid and of the wheel-on-rail system. In spite of quite different procedure with the manufacturing and examination of the guideways geometrical criteria can be compared with each other. The article arrives at the conclusion, that the tolerance requests at the geometry are approximately identical with both systems.

1 INTRODUCTION

Passengers in track-bound high speed transportation systems expect a quiet, pleasant journey. Sudden acceleration or small continuous wavelike movements cause uneasiness up to the travel sickness. For the passengers the comfort is just as important, as equipment and service in the vehicle.

In order to fulfill this purpose for the guideways of the track-bounded high speed transportation systems geometrical requirements in the respective guidelines are pre-set.

In the following the requests of the guideway of the Transrapid and of the roadbed of the high speed wheel-on-rail system of the DB are compared.

2 SUPPORT AND GUIDANCE

The Transrapid is supported and guidanced according to the principle of the electromagnetic levitation with the result that it does not affect his guideway. With this principle (Figure 1) the electromagnets installed in the vehicle produce an accelerating strength in the co-ordination with the statorpacks attached in the guideway.

For the lateral guidance of the vehicle guiding-magnets in the vehicle hold the lateral distance to the guidance rails.

The distances to the statorpacks and the guidance rails are controlled by an electronic system. The support- and guiding-magnets follow the statorpacks and the guidance rails at a distance of approx. 10 mm.

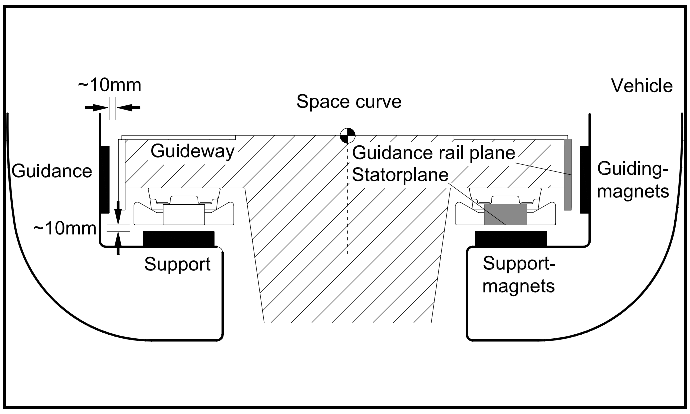

Figure 1: Support and guidance at the Transrapid

The loads arising from supporting and guiding are separated, brought in the guideway touch-freely and two-dimensionally.

At the wheel-on-rail system the supporting and guiding are contact-afflicted about the wheel contact point on the rail head realizes.

The support occurs via importing of the loads over the wheel disk of the train in one point on the rail heads.

The guiding occurs via the geometrical design of the running surfaces of the wheel tires (Double cone) (Figure 2).

The geometry of the wheel tires guarantees a trouble-free operation in straight and curved routes (performance like sinus).

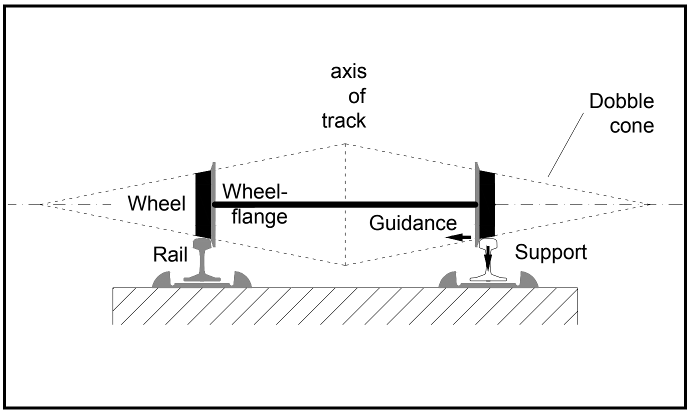

Figure 2: Support and Guidance at wheel-on-rail

The wheel flange arranged inside the wheel tire is used at the wheel-on-rail-system as a redundancy. The wheel flange does not come into force before the forces of the sinus are exceeded.

As the embracing of the guideway by the Transrapid, the wheel flanges offer a nearly corresponding derailment guard.

3 GUIDEWAYS

3.1 Line routing

The line routing of high speed lines is the result of an iterative process.

At the Transrapid the results of the line routing – horizontal and vertical section - are merged into the space curve.

The results of the line routing at the wheel-on-rail-system are considered as layout geometry (horizontal) and as gradient geometry (vertical) always separately.

3.2 Fabrication techniques of the guideways

At the Transrapid the guideway girders were produced up to now as a part of the space curve in girder factory and equipped with the system components of statorpacks, guidance rail and gliding rail under workshop conditions.

These single parts (girders) are subjected to a geometrical examination at the finished system components directly in the factory.

Every single guideway girder including his function levels leaves the factory thus quality-safeguarded. After the transportation to the installation site on the route the guideway girders are mounted and fine-positioned at the girder joints and assigned thus to the defined space curve. The quality assurance, that is the correct 3-dimensional assignment to the space curve, only still occurs at the girder joints.

At wheel-on-rail high speed tracks come both railway constructions to the use: Tracks with permanent system and tracks with ballast superstructure. At both roadbed systems the finishing of the rails is made in several manufacturing levels on the construction site. As a last working step the direction of the rail occurs at the ballast superstructure by means of stuffing.

At the permanent system the concrete sleepers are adjusted and spilled. Then the rails are laid out.

In both cases the geometrical examination (Quality assurance) is carried out after finishing the track in the sleeper-distance at the rail heads on the construction site.

4 GUIDEWAY GEOMETRY - TOLERANCES

4.1 Guidelines

For the comparison, the engineering rules system specification [1] and guideway geometry specification [2] are used for the Transrapid.

At the wheel-on-rail system the guideline family 883 [3] and the catalog of requirements to the construction of the permanent system [4] are used.

The geometrical examinations of the guideway / track occur at different construction places (at the Transrapid under workshop conditions in the girder factory / at wheel-on-rail under construction site conditions). On that the guidelines are correspondingly synchronized.

The following comparison of the geometry requests of both systems refers to the functional components for the supporting and guiding.

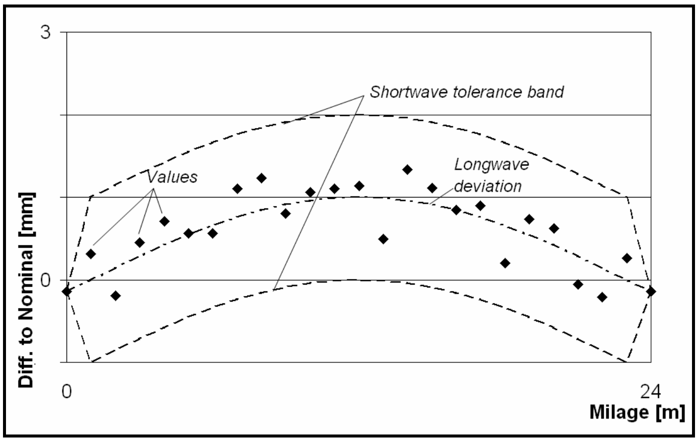

Figure 3: Transrapid – one-span-girder: longwave and shortwave deviation

4.2 *Guideway geometry Transrapid*

The engineering rules of guideway geometry specification [2] define the requests at the function planes of the guideway and their permissible deviations (Tolerances) from the nominal values.

These tolerances are valid for a guideway girder, finished equipped and under load of dead weight of the girder.

The geometrical examination occurs to the outfit of the girders with the functional components in the manufacturing plant.

Weather-conditional influences to the measurements are excluded.

In order to be able to understand the function levels of the guideway girders in a reproducible geometrically form, the measurement points are (< 1032 mm) well-defined.

4.2.1 *Longwave tolerance*

The measurements are evaluated for each function plane separately.

On basis of the defined space curve geometry the deviations to that can be represented graphically (Figure 3).

Under consideration of the static system (one-span-girder, two-span-girder) a fitted curve is calculated from all data points. In this case every girder span is considered for itself. The maximum deviation of the so determined actual-geometry for the nominal-geometry shows the maximum value of the long-wave tolerance.

The tolerated deviations for the stator plane are ± 1 mm. For the guidance rail plane the tolerated deviations are depending the girder lengths.

4.2.2 *Shortwave tolerance*

The shortwave tolerance overlaps the long-wave deviation. At the stator plane the upper and lower border is put with 1 mm over and under the long-wave actual-deviation. The tolerance width is thus 2 mm. Within this tolerance band all discrete measured values must lie. The shortwave tolerance contains all material, manufacturing and built-in tolerances of the function elements.

At the guidance rail plane the tolerance band is specified with ± 2 mm.

This shortwave tolerance band is related to the complete girder. Within a 2 m section, the change of inclination criterion has to be fulfilled (Figure 4).

The permissible maximum change of inclination in the stator level is ± 1.5 mm/m. For the guidance rail plane this maximum value is ± 2.0 mm/m.

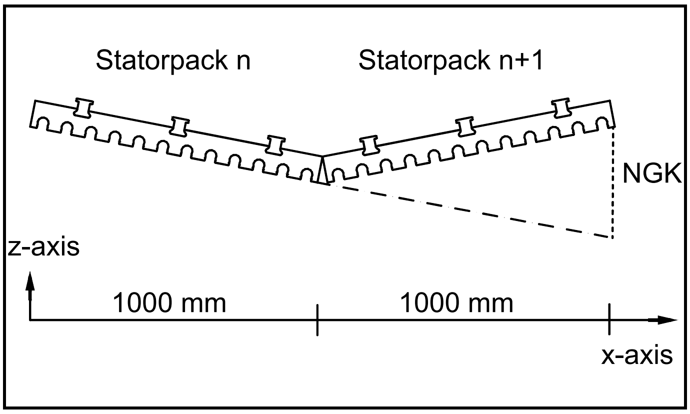

Figure 4: Transrapid: Change of inclination criteria at the the stator plane

If the functional planes are discontinued within a girder, as it is for example the stator plane, further tolerance requirements are existing at these points.

At these points (gaps) the permissible tolerances are also to be considered (for example statorpack: gaps < 0.4 mm).

4.2.3 *Space curve tolerances*

The permissible deviations to the space curve are defines at the supports. For a girder length of 24 m deviations of 5.0 mm are permitted in y- and z-direction.

4.3 *Wheel-on-rail guideway geometry*

At wheel-on-rail the geometrical view are separated into an internal and an external geometry.

4.3.1 *Internal geometry*

The internal geometry describes the form of the rail. It is determined by the continuity of the relative situation relationships of neighbored rail points to each other.

Unsteadiness of drive is located by measurements with the roadbed test vehicle (german: Oberbaumesswageneinheit).

In a further step this unsteadiness is recorded by geodesic measurements and is evaluated by a computational long chord principle. The dot distances of the measurements result from the sleeper margin (for example 0.625 m).

Single continuity deviations and periodic deviations are located by the division into 2 investigation fields, the shortwave one and the longwave field.

4.3.1.1 Shortwave area

For the locating of single deviations of the continuity the measurement points are examined in the local area to each other. At that a chord length of 30 m is fit in by calculation. In Intervals of each 5 m the difference of the 2 measurement-points are considered to the 2 nominal values. The tolerance for this delta consideration is 2 mm on 5 m (for y- and z- direction).

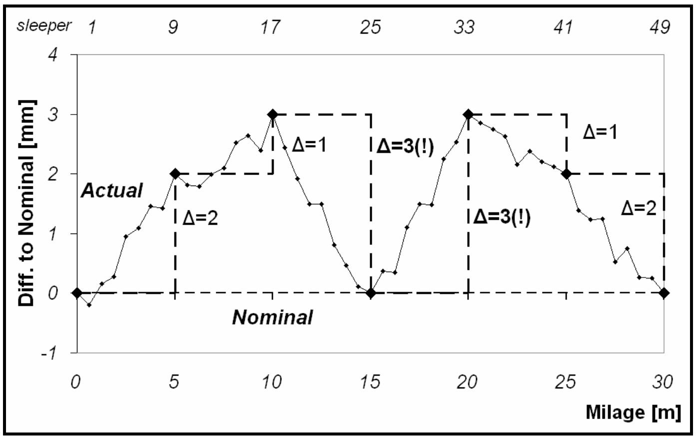

Figure 5: Wheel-on-rail - Internal, shortwave deviation for the determination of single deviation

Following example results from figure 5. With a basis of 5 m the value-difference (at the sleepers) are compared to the nominal-values. The difference of value 25 to 17 and 33 to 25 are 3 mm. The internal shortwave deviation is too high.

4.3.1.2 Longwave field

In the long-wave field periodic effects are supposed to be discovered. In the same procedure, however with a chord length of 300 m, pitches are put at intervals of 150 m to each other in relation. The maximum deviation of the pitches between the nominal- and actual-curves for y- and z-direction is 10 mm in chord middle. The corrected values of the geometry in plan and profile must be considered.

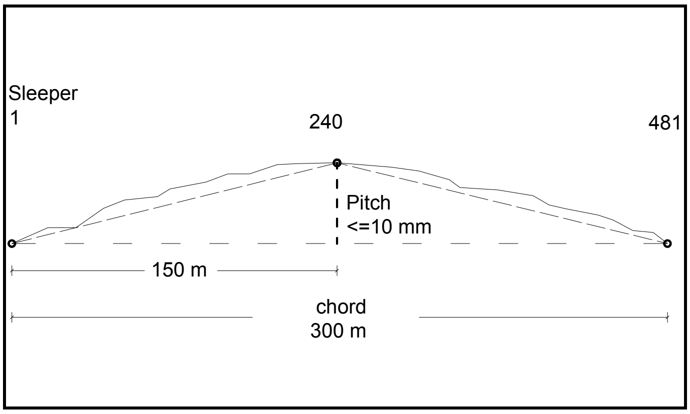

Figure 6: Wheel-on-rail - Interal, long-wave deviation for the determination of periodic effects

A quasi continuous examination is realized by overlapping of the chord (Figure 6) in each case around half the length (150 m).

5 COMPARISON OF BOTH SYSTEMS

The following comparison of both systems considers the inner geometry.

5.1 Gauge

The gauge is determined at both systems with similar procedures. The measurement points are at the Transrapid 170 mm below the gliding plane at the guidance rails, at which wheel-on-rail are the measurement points 14 mm below rail head upper edge.

The gauge in both systems is tolerated with ± 2 mm within the guideway and track.

5.2 Cant/Superelevation

The term “cant” of the Transrapid is similar with the superelevation of the tracks of the wheel-on-rail-system. The guideway of the Transrapid turns around the space curve unlike the wheel-on-rail system where the inner rail will be lowered.

The cant tolerance of the stator plane is ± 2 mm to the basis 1110 mm.

The permissible tolerance for the rail superelevation is specified with ± 2 mm to the basis 1500 mm.

5.3 Change of inclination criterion (NGK)

The inclination change criterion (Chapter 4.2.2) of the Transrapid becomes in that one

- Stator plane (z-direction) with 1.5 mm/m
- Guidance rail plane (y-direction) with 2.0 mm/m.

A comparable criterion of the wheel-on-rail system is the internal, shortwave geometry. This is with 2 mm related to 5 m length indicated in each case for layout (y-direction) and height (z-direction).

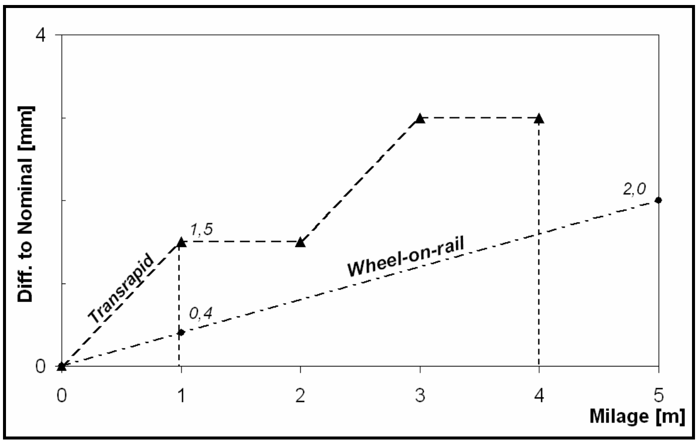

Figure 7: Comparison of change of inclination criterion and internal shortwave geometry

The comparison of figure 7 shows the permissible change of inclination in z-direction for both systems. Standardized onto a consideration length of 1 meter the comparative value turns out

- 1.5 mm/m at the Transrapid
- 0.4 mm/m at the wheel-on-rail-system

It results from that that this tolerance request is significantly higher for NGK at the wheel-on-rail-system.

5.4 Tolerance ranges

At the Transrapid, the stator level (z-direction) is used for this comparison. The tolerance range is built up in two steps. The longwave deviation is considered as a deflection line, characteristic for the guideway girder. The maximally permissible deviation is related per girder field into both directions (+/-). In this case this tolerance is at the most 1 mm in girder middle of the nominal-height.

The shortwave tolerance overlaps the long-wave deviation. The upper and lower border is put with 1 mm over and under the longwave Actual-deviation. The tolerance width is thus 2 mm.

At the wheel-on-rail-system similar approaches are valid for situation and height deviations. In this case the track sections are examined in 2 length steps. In a shortwave the track course may differ around 2 mm on 5 m. Longwave the track course may deviate with 10 mm on 150 m length.

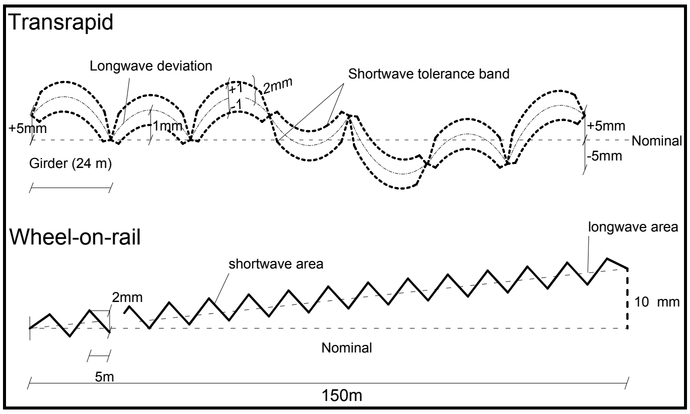

Figure 8: Comparison of the internal geometry by means of tolerance ranges

In order to be able to compare the two systems it was preceded as follows.

The shortwave tolerances are directly comparable. Related to a basis of 5 m a tolerance range width of 2 mm is available for both systems (see figure 8).

Basis for the long-wave tolerances in the wheel-on-rail-system is the middle of the chord of 300 m, thus 150 m. At the Transrapid system there are not any guideway girders with a length of 150 m, therefore two points of view make sense.

In the first case the basis of 150 m is formed into several guideway girders (see fig. 8). The permissible deviations from the space curve at the Transrapid system dependent on the girder length. This value is 5 mm at each beginning and/or end of a 24 m one-span-girder and can be used at every girder joint in different direction (+/-).

At the wheel-on-rail system the tolerance refers to a fixed basis of 150 m and goes up continuously from 0 to 10 mm (see figure 9).

For the second point of view the basis of the wheel-on-rail system (150 m) is calculated into the length of a guideway girder (24 m).

Based to this 24 m section, the tolerance is reduced to 1.7 mm.

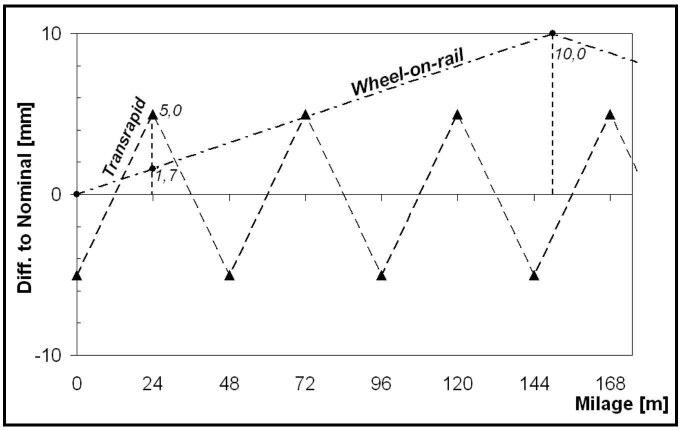

Figure 9: Comparison of the long-wave tolerances

6 SUMMARY

The comparison of the geometrical requests between the Transrapid and wheel-on-rail shows that similar tolerance requests are made.

The tolerances for

- Gauge
- cant/superelevation
- shortwave deviation

correspond to each other.

The tolerances for

- change of Inclination
- long-wave deviation

differ significantly.

During the change of inclination the requirements at the track of the wheel-on-rail system is approximately 4-times higher as the guideway of the Transrapid.

During the long-wave deviation the request is approximately 3-times so high.

Although the Transrapid is designed for speeds up to 500 k.p.h., the requirements are not higher in comparison to the up to 300 k.p.h. designed wheel-on-rail system.

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