SLOVENSKI STANDARD
SIST-TP CEN/TR 17792:2022

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Železniške naprave - Geometrijski parametri stika kolo-tirnica - Tehnično poročilo in temeljne informacije o standardu EN 15302

Railway Applications - Wheel-rail contact geometry parameters - Technical report and background information about EN 15302

Bahnanwendungen - Rad-Schiene-Berührgeometrieparameter - Technischer Bericht und Hintergrundinformationen zur EN 15302

Applications ferroviaires - Paramètres géométriques du contact roue-rail - Rapport technique et informations générales sur l'EN 15302:2021

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45.060.01	Železniška vozila na splošno	Railway rolling stock in general

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Railway Applications - Wheel-rail contact geometry parameters - Technical report and background information about EN 15302

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Ref. No. CEN/TR 17792:2022 E

SIST-TP CEN/TR 17792:2022

Contents

Page

iTeh STANDARD PREVIEW
(standards.iteh.ai)
SIST-TP CEN/TR 17792:2022
https://standards.iteh.ai/catalog/standards/sist/c2ac8dbf-f328-43eb-80cf-f7e828434ba9/sist-tp-cen-tr-17792-2022

SIST-TP CEN/TR 17792:2022

iTeh STANDARD PREVIEW
(standards.iteh.ai)
SIST-TP CEN/TR 17792:2022
https://standards.iteh.ai/catalog/standards/sist/c2a08d16-1328-43eb-86cf-f7e828434ba9/sist-tp-cen-tr-17792-2022

SIST-TP CEN/TR 17792:2022

European foreword

This document (CEN/TR 17792:2022) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

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https://standards.iteh.ai/catalog/standards/sist/c2ac8dbf-1328-43eb-86cf-f7e828434ba9/sist-tp-cen-tr-17792-2022

SIST-TP CEN/TR 17792:2022

1 Scope

This document provides background information regarding the changes from EN 15302:2008+A1:2010 to the revised version dated 2021, including the reasons for decisions and additional explanation and guidance that is not appropriate in the standard.

The range of equivalent conicity results obtained with different software tools is described. The additional wheel-rail contact parameters, rolling radii coefficient and nonlinearity parameter, are explained. More information is also provided on the different calculation methods and the updated reference profiles for the assessment. The influence of simplifications used in determination of equivalent conicity is discussed.

To provide more information on the importance of considering the complete measurement and calculation process, methods for plausibility checks, eliminating outliers and assessing the uncertainty and repeatability of measurements are included as well as assessments of the smoothing process.

Guidance is given on fields of application of the wheel-rail contact parameters, on the selection of appropriate reference profiles (choice of reference rail profile and rail inclination for assessing wheel profiles and vice versa) and on handling special cases.

As some references in EN 14363 to wheel-rail contact test conditions have caused difficulties in understanding, clarifications issued by ERA are mentioned.

Interpretation of equivalent conicity results, using tools such as conicity maps, is discussed and various approximations such as ‘quick conicity’ assessments are also described.

Information is included on possible additional wheel-rail contact parameters, not yet ready for standardization, but where further experience is needed.

NOTE In this document the commonly used term “wheel-rail contact geometry” is used as a synonym for the more precise term “wheelset-track contact geometry”.

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2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

SIST-TP CEN/TR 17792:2022

4 Overview of the most important changes made to EN 15302

4.1 List of main changes

The list below provides an overview of the main changes introduced in the revised EN 15302:

— extension of the Scope;

— introduction of new wheel-rail contact geometry parameters (rolling radii coefficient, nonlinearity parameter);

— improvement of the description of the methods for evaluation of equivalent conicity including the determination of the lateral peak displacements;

— introduction of additional methods for evaluation of equivalent conicity;

— improvement of the description of the reference profiles;

— introduction of the additional reference wheel profile C;

— reference results based on analytical solutions;

— hints for plausibility checking of measured wheel and rail profiles;

— revised assessment of the profile smoothing process;

— new assessment of the complete process for determination of wheel-rail contact parameters.

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In this Technical Report the ideas behind the mentioned changes and a more detailed explanation are given where necessary.

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4.2 Additional wheel-rail contact geometry parameters

4.2.1 Rolling radii coefficient

In addition to the now well-established parameter “equivalent conicity”, which describes the contact geometry in straight track and in curves with very large radii based on a simplified model of the run of the wheelset, an additional parameter for the guiding behaviour of the wheelset in curves with small and very small radii is defined. This parameter, the so-called rolling radii coefficient, is intended to describe the capability of achieving a radial position of a wheelset in the curve. Details are given in 5.2 and 6.6.

4.2.2 Nonlinearity parameter

Equivalent conicity is traditionally used to assess the wheel-rail contact geometry in regard to running stability. However, the equivalent conicity as a linearized parameter does not consider the nonlinearity of wheel-rail contact geometry. One value of equivalent conicity is usually used to characterize the wheel-rail contact geometry: the equivalent conicity value for a wheelset displacement amplitude of 3 mm. However, the same value of equivalent conicity for a wheelset displacement amplitude of 3 mm can arise from a large number of very different contact geometries, see Figure 1.

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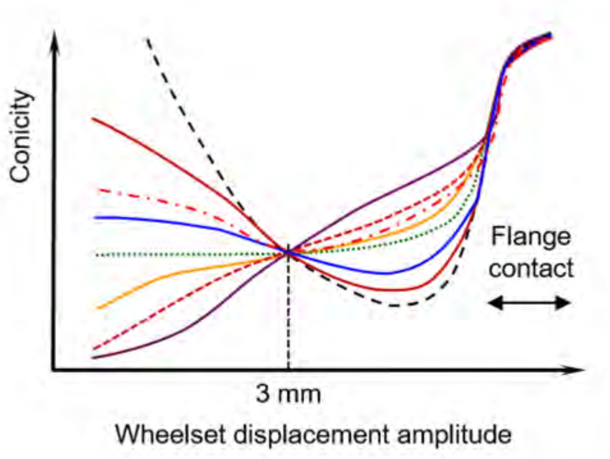

Figure 1 — Possible equivalent conicity functions determined from a set of wheel-rail contact geometries with the same equivalent conicity value for a wheelset displacement amplitude of 3 mm.

Simulation studies [1] and [2] demonstrated, that the vehicle's dynamic behaviour at the stability limit depends on the overall properties of the wheel-rail contact geometry; therefore, also on the overall shape of the equivalent conicity function for a range of wheelset displacements inside of the clearance between wheelset and track (i.e. before flange contact).

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A second parameter called nonlinearity parameter is proposed in [2] to enhance the characterization of the wheel-rail contact geometry. This parameter represents the slope of the conicity function between the wheelset amplitudes of 2 mm and 4 mm. The nonlinearity parameter does not replace the equivalent conicity as used for the characterization of wheel-rail contact geometry regarding the stability. It should be understood as additional information complementing the equivalent conicity. While the equivalent conicity value for a wheelset amplitude of 3 mm represents a "level parameter" for the assessment of contact geometry regarding the instability limit according to EN 14363, the nonlinearity parameter has to be understood as a "performance parameter", characterizing the vehicle performance at the stability limit as well as the sensitivity of vehicles to the lateral excitation by track irregularity. Details are given in 5.3 and 6.7.

SIST-TP CEN/TR 17792:2022
https://standards.iteh.ai/catalog/standards/sist/c2ac8db1-1328-43eb-86cf-f7c828434ba9/sist-tp-cen-tr-17792-2022

4.3 Methods for evaluation of equivalent conicity

The description of all evaluation methods was largely improved. All calculation steps are now explained. In particular, the two-step integration method was clarified (see 5.4 for details), and a description of the direct integration of the differential equation has been added (see 5.5 for details).

Moreover, it is pointed out that the linear regression and the harmonic linearization (see 5.6 for details) are approximations, which may give good results but have to be used with care.

Harmonic linearization has been developed in the 1970s to determine linearization parameters required for linearized calculations of railway vehicle dynamics. As the method is usually available in simulation tools, it is also used for the determination of equivalent conicity of measured profiles of wheels and rails. It was thus decided to include this method in the current revision of the standard EN 15302.

4.4 Assessment of the smoothing process

As in the former versions of EN 15302, the effects of profile errors originating from the profile measurement still have to be assessed. However, the definition of the errors to be used for the assessment is revised and updated according to the performance of current measuring systems as well as of the increased available computation power. Further, new quality numbers for the equivalent conicity and the rolling radii coefficient are introduced describing the ability of the tested smoothing algorithms to deal

SIST-TP CEN/TR 17792:2022

with measuring errors. Hence it can be checked if the smoothing process meets the requirements taking the measuring accuracy of the used profile measuring system into account.

More details are provided in 5.8.

4.5 New assessment of the complete process

According to EN ISO 10012:2003 (Measurement management systems - Requirement for measurement processes and measuring equipment), an effective measurement management system ensures that measuring equipment and measurement processes are fit for their intended use and is important in achieving product quality objectives and managing the risk of incorrect measurement results.

An important part in/of the measurement management system is the metrological confirmation including estimation of measurement uncertainty. The commonly used method for the estimation of measurement uncertainty is described in ISO/IEC Guide 98-3:2008 - Guide to the expression of uncertainty in measurement (GUM: 1995). A measurement cannot be properly interpreted without knowledge of its uncertainty.

Corresponding to these standards a new assessment method for the complete process of wheel-rail contact parameter determination (including measurement and calculation) is introduced in EN 15302. In 5.9 of this Technical Report an example is given for the possibility of estimation of measurement uncertainty applied to the wheel-rail contact parameters derived from measured rail profiles.

The different methods applied today for assessment of measuring uncertainty are at least as strict as the requirements used when the current limit values for wheel-rail contact parameters were established. The limit values already include a margin for measuring uncertainty and no additional adjustment of the result or the limit value shall be made.

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5 Technical background to and justification of changes in the revised EN 15302

5.1 Equivalent conicity

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5.1.1 Review of equivalent conicity results obtained with different software tools

In the beginning of the revision of EN 15302 a benchmark comparison of currently used calculation methods for equivalent conicity tan γ_e was carried out in order to check the tolerances given in the Standard against the methods. The test included all combinations of the reference wheel profiles with the reference rail profile A as defined in the EN 15302:2008+A1:2010 as well as a selected wheel-rail combination representing the special case described in B.3 of that document (hollow worn wheel profile). The tan γ_e functions have been calculated for the following methods:

- direct integration of the differential equation of lateral wheelset motion;
- harmonic linearization;
- two-step integration as described in EN 15302:2008+A1:2010, Annex B;
- linear regression as described in EN 15302:2008+A1:2010, Annex C;
- analytical solution (where applicable).

In some cases, the methods are applied also accounting for the elasticity in the wheel-rail contact (non-elliptical contact patches) and/or the effect of the axle's roll angle around the axis longitudinal to the track due to the lateral shift of the wheelset. All the tested methods are implemented in at least two different software tools. In total the calculation results listed in Table 1 have been provided for the benchmark.

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Table 1 — Available results for equivalent conicity

Identifier	Method	Roll angle considered	Elastic contact
DB Netz	Direct Integration	No	No
ITCF (DMA)	Direct Integration	No	No
ALSTOM	Two-step Integration	No	No
SNCF (Klingel)	Direct Integration	No	No
SNCF (Ann. C)	Linear Regression	No	No
SNCF (SIMPACK)	Direct Integration	?	No
Siemens (integ.)	Direct Integration	No	No
Siemens (Ann. B)	Two-step Integration	No	No
Siemens (Ann. C)	Linear Regression	No	No
Siemens (harmonic)	Harmonic Linearization	No	No
Siemens (RSGEO)	Harmonic Linearization	Yes	No
Siemens (SIMPACK integ.)	Direct Integration	No	Yes
Siemens (SIMPACK harm.)	Harmonic Linearization	No	Yes
DB Systemtechnik	Two-step Integration	No	No
IIR (ETQ)	Linear Regression	Yes	No
IIR (Vampire)	Linear Regression	Yes	No
NR	Two-step Integration	No	No

iTeh STANDARD PREVIEW
(standards.iteh.ai)
SIST-TP CEN/TR 17792:2022
https://standards.iteh.ai/catalog/standards/sist/c2ac8dbf-1328-43eb-86cf-f7e828434ba9/sist-tp-cen-tr-17792-2022

The calculation results of the different methods are shown in the following Figures together with the reference results and the respective tolerances according to EN 15302:2008+A1:2010, Annex F. Figure 2 contains the results for the symmetrical cases (identical profiles and identical wheel diameters at left- and right-hand side) whereas Figure 3 provides the graphs for the cases with a wheel diameter difference of 2 mm and Figure 4 for the asymmetrical wheel profiles. The analytical solutions are not plotted here because they are nearly identical to the related original reference results.

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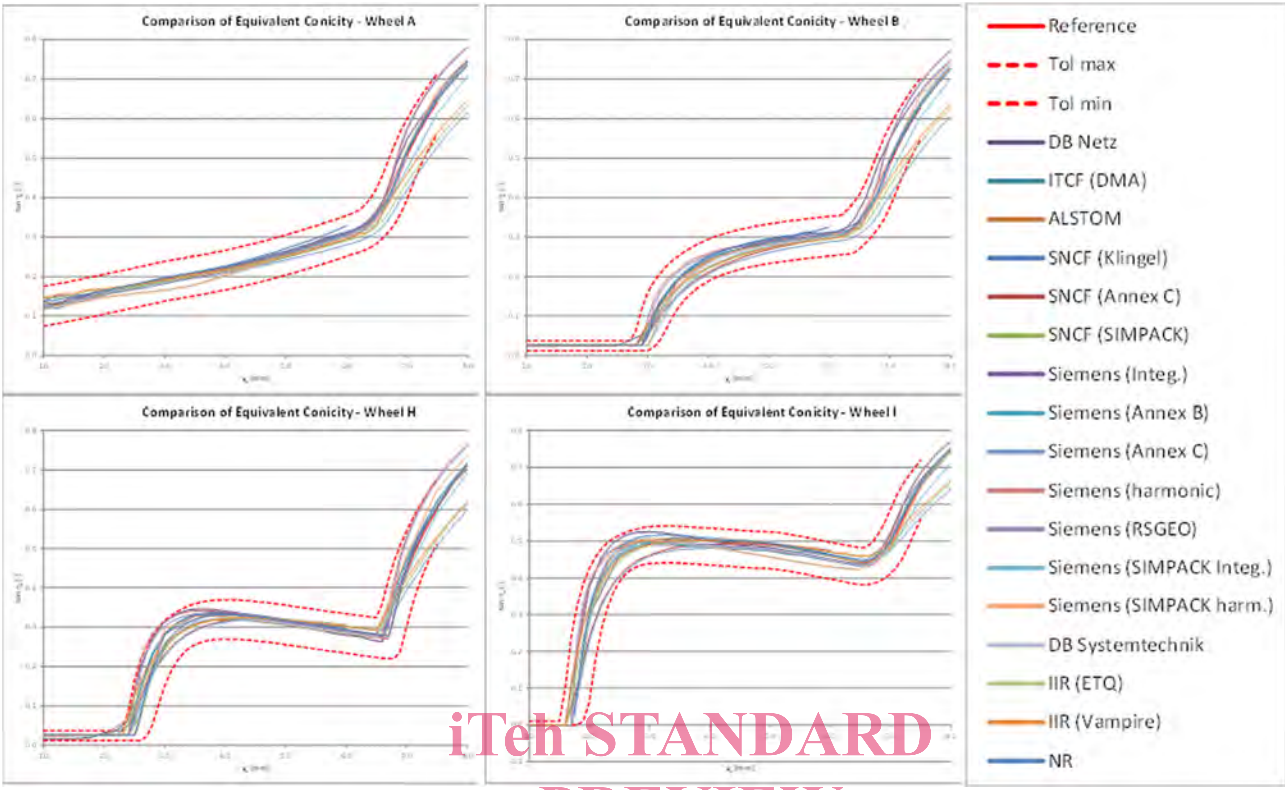

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Figure 2 — Calculation results for equivalent conicity of various calculation methods (reference profiles in nominal condition)

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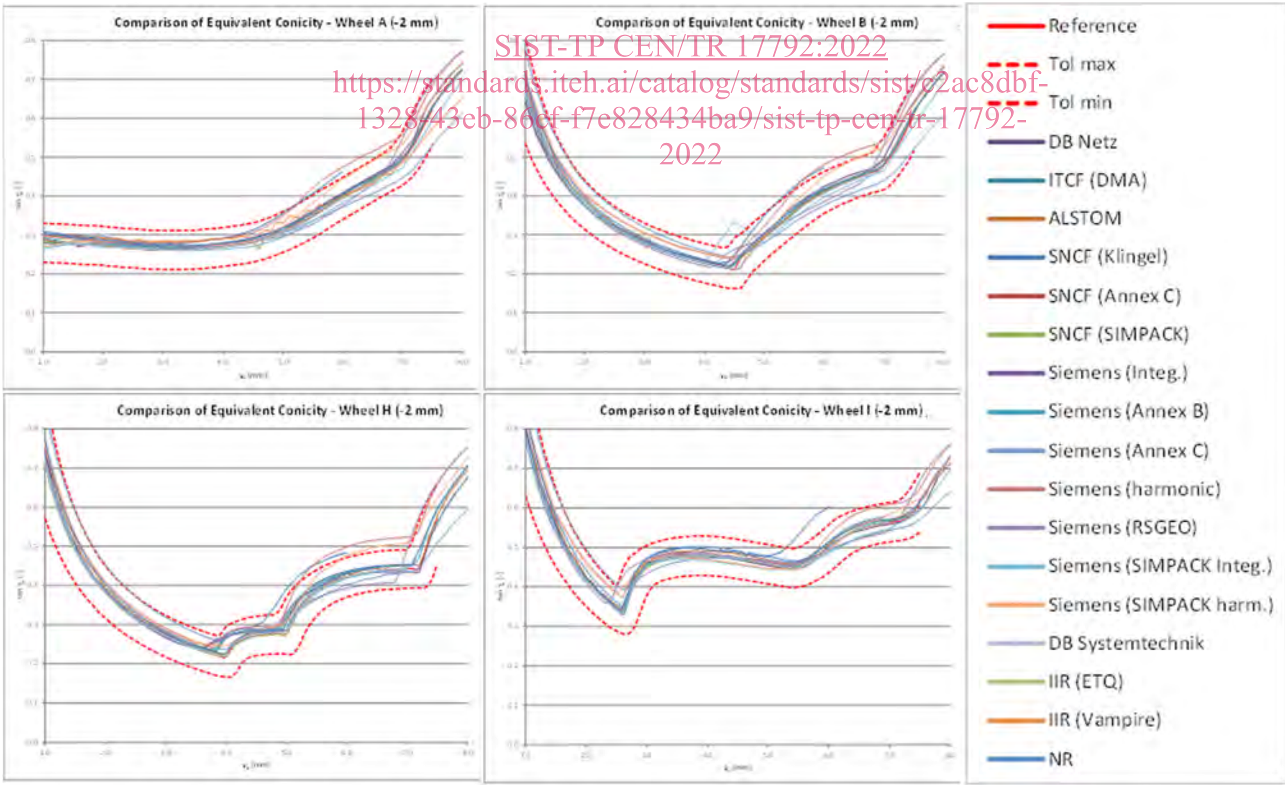

Figure 3 — Calculation results for equivalent conicity of various calculation methods (wheel diameter difference of 2 mm applied)

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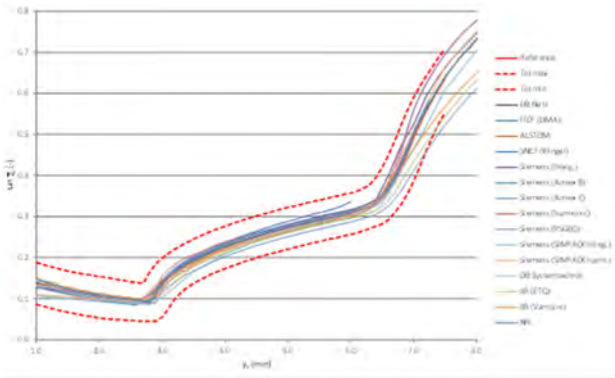
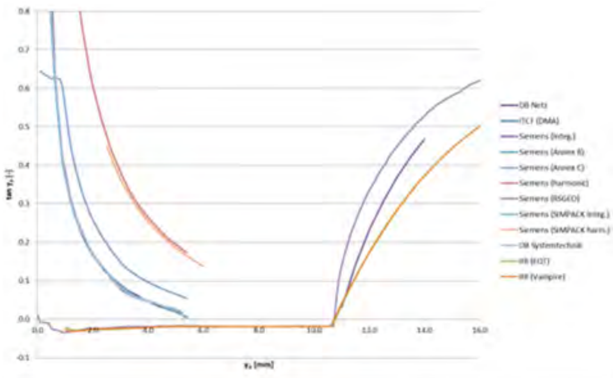


a) Comparison of equivalent conicity wheels A+B



b) Comparison of equivalent conicity worn wheel

Figure 4 — Calculation results for equivalent conicity of various calculation methods (asymmetrical wheel profiles)

Except for the wheel-rail combination representing the special case described in B.3 (right diagram in Figure 4), the comparisons show good agreement of the different methods and also confirm that the tolerance bands for the equivalent conicity as given in EN 15302 are practical. There are only a few methods providing results partly outside the tolerances, mainly for large lateral wheelset amplitudes where the contact position is at or close to the wheel flange. As the practical meaning of equivalent conicity values for this range of lateral wheelset amplitudes is very limited (see also below) it was decided to restrict the normative range for which a new calculation method shall be tested against the reference results to amplitudes of 1 mm to 6 mm.

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The performed investigation showed also the high importance of a unique definition of the lateral wheelset displacement. In the beginning, for some methods the lateral wheelset displacement was measured at the centre of gravity of the wheelset. In combination with the consideration of the roll movement around the longitudinal axis this resulted in significant deviations of the equivalent conicity functions. Therefore, the revised EN 15302 contains a clear statement now: “the lateral displacement of the wheelset as used in this document is considered at the top of rail level”.

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The large scatter of conicity results for the special case with the hollow worn wheel, see the right diagram of Figure 4, showed that there is a need for more information on how to deal with such cases. Therefore, a new Annex H has been added to EN 15302 explaining the possible existence of multiple solutions. It is also important to understand that the negative values of equivalent conicity shown by some calculation tools have no physical meaning.

5.1.2 Comparison with multibody system simulation results

In order to find out up to which lateral displacement the obtained kinematic wheelset movement provides a physically reasonable assessment, multibody system (MBS) simulations have been performed and the resulting wavelengths of the lateral wheelset motion have been compared with the wavelengths of the respective kinematic wheelset trajectory. The dynamic solutions for the lateral wheelset motion are found by means of simulations of a single vertically loaded wheelset with a soft primary suspension moving along straight track. Starting with an initial lateral displacement the lateral wheelset trajectory is calculated and analysed. The equivalent conicity is calculated based on the changing wavelength according to Klingel's formula and plotted against the related wheelset amplitude, see Figure 5.

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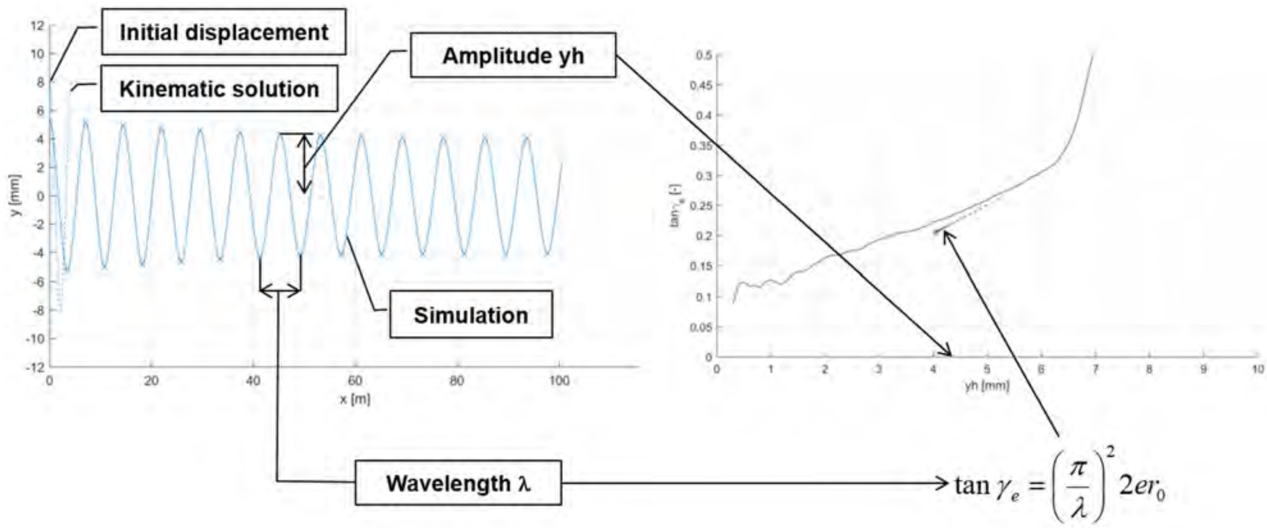

Figure 5 — Determination of equivalent conicity by means of MBS simulation

By varying the input parameters speed, primary stiffness (in the range below 2e6 N/m) and wheel-rail friction coefficient a wide range of amplitudes has been covered. In the following Figures the resulting conicity values (coloured markers) are compared to an example of the kinematic solution (solid line) for all the reference cases of EN 15302.

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SIST-TP CEN/TR 17792:2022
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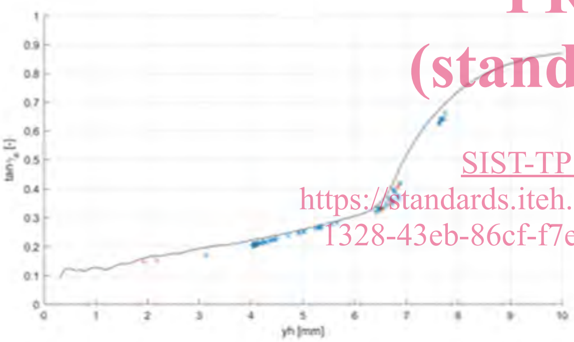
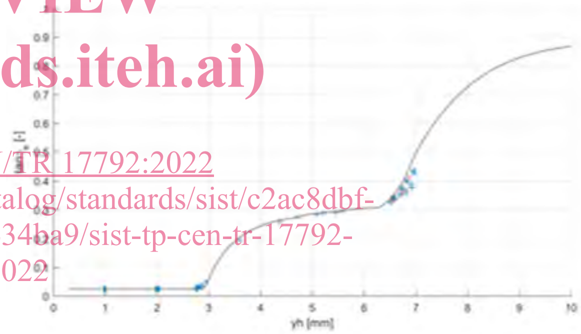
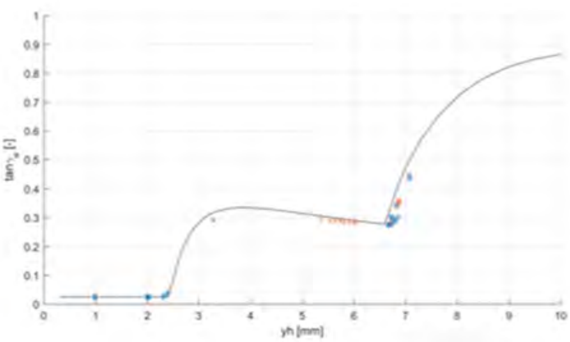


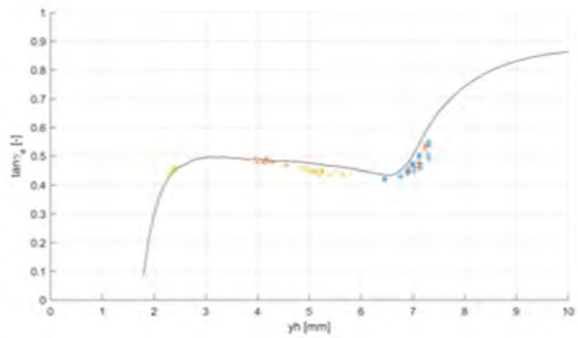
a) wheel A/rail A



b) wheel B/rail A



c) wheel H/rail A



d) wheel I/rail A

Figure 6 — Comparison of kinetic and kinematic solutions for equivalent conicity (reference profiles in nominal condition)

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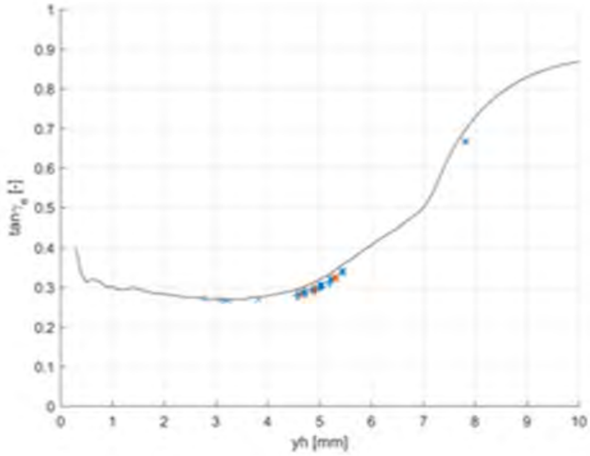
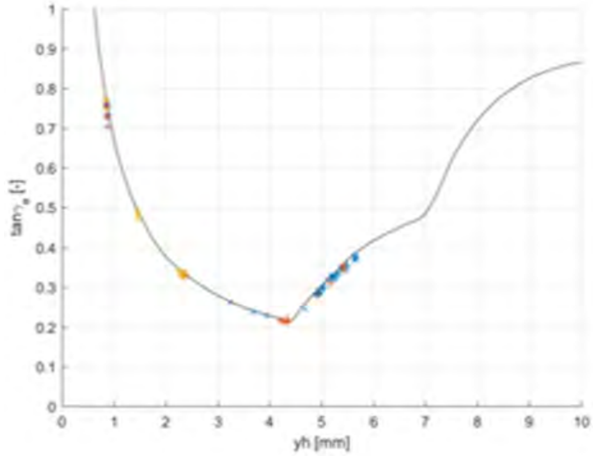
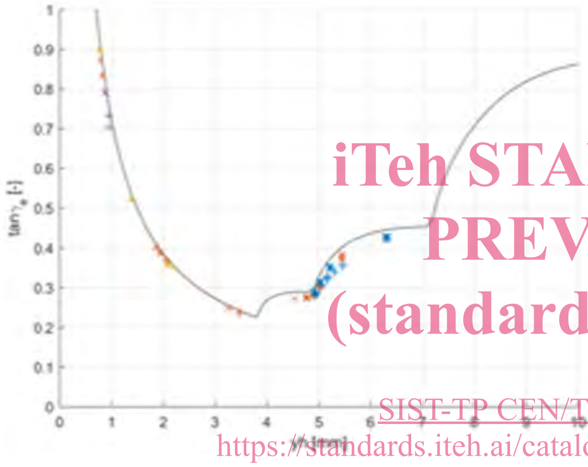


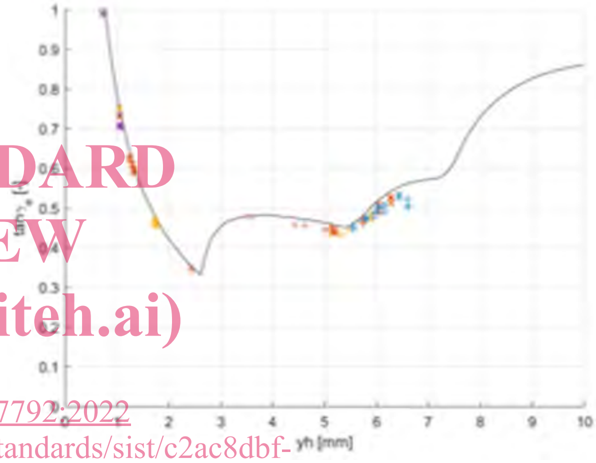
a) wheel A (ΔD = 2 mm)/rail A



b) wheel B (ΔD = 2 mm)/rail A



c) wheel H (ΔD = 2 mm)/rail A



d) wheel I (ΔD = 2 mm)/rail A

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Figure 7 — Comparison of kinetic and kinematic solutions for equivalent conicity (wheel diameter difference of 2 mm applied)