KRAV

Gångdynamiska förutsättningar för trafik med axellaster upp till och med 35 ton

TDOK 2016:0508

Version 1.0

2016-10-21

KRAV

Skapat av (namn och organisatorisk enhet)	Dokument-ID	Version
Marika Thalén	TDOK 2016:0508	1.0
Fastställt av	**Dokumentdatum**	
Chef VO Underhåll	2016-10-21	-
Dokumenttitel		
Gångdynamiska förutsättningar för trafik med axellaster upp till och med 35 ton		

Innehållsförteckning

TMALL 0170 Krav v 1.0

TRAFIKVERKET

Syfte

Detta dokument upprättas i syfte att säkerställa redogöra för de gångdynamiska förutsättningarna för trafik på järnvägsinfrastruktur med höga axellaster upp till och med 35 ton. De förutsättningar som ges beskrivs närmare i bilagan till detta TDOK.

Marika Thalén

UHtö

Detta TDOK är direkt tillämpligt och träder i kraft från och med 2017-02-01.

Detta är ett nytt dokument och ersätter inte något tidigare utgivet dokument. Därmed finns det inte någon form av övergångsregel från tidigare kravdokument.

1 Omfattning

Detta TDOK är tillämpbart för trafik på järnvägsinfrastruktur som är avsedd för höga axellaster och hänvisar till Rekommendationen ”Running dynamics requirements and recommendations for vehicles with an axle load higher than 22,5 or 25 tons and up to and including 35 tons”. Rekommendationen är framtagen av Nordic railway track cooperation (NBS) och är accepterad genom samarbetet inom Nordic Infrastructure Managers (NIM).

Rekommendationen utgör en definition av processen för de gångdynamiska förutsättningarna för svensk järnvägsinfrastruktur och riktar sig till godsvagnar med axellast över 25 ton till och med 35 ton samt för lok som har axellaster om 22,5 ton upp till och med 35 ton.

2 Definitioner och förkortningar

Definitioner och förkortningar återfinns i Rekommendationen “Running dynamics requirements and recommendations for vehicles with an axle load higher than 22,5 or 25 tons and up to and including 35 tons”.

3 Gångdynamiska förutsättningar för trafik med axellaster upp till och med 35 ton

3.1 Bakgrund

I dag är det endast Malmbanan (Boden – Riksgränsen) i Sverige som tekniskt och prestandamässigt klarar att tillåta järnvägsfordon trafikera med exceptionellt höga axellaster. Banans kapacitet och bärförmåga ställer höga krav på material och komponenter i spåret och används huvudsakligen för transporter av malm, vilket står för mer än 40 % av alla godstransporter i Sverige.

För att definiera gångdynamiska förutsättningar för trafik på järnvägsinfrastruktur avsedda för höga axellaster har rekommendationen "Running dynamics requirements and recommendations for vehicles with an axle load higher than 22,5 or 25 tons and up to and including 35 tons" tagits fram genom ett samarbete mellan de nordiska länderna. Dokumentet är framtaget med utgångspunkt från nuvarande Malmbanan och Ofotenbanen (Luleå – Narvik) i Sverige och Norge.

I dokumentet definieras rekommendationer för att kunna göra en värdering av de tekniska gångegenskaperna för trafik med godsvagnar och lok. Dokumentet kan således även användas vid en tillämplighetsvärdering när det är aktuellt att godkänna järnvägsfordon som har exceptionellt höga axellaster. Detta medför att det finns en tydlighet och att det är säkert och ekonomiskt försvarbart för trafik på avsedda banor.

Med hänvisning till Driftskompatibilitetsdirektivet (EU) 2016/797 daterat den 11 maj 2016 som i sig hänvisar till specialfall och öppna punkter i angivna Tekniska Specifikationer för Driftskompatibilitet (TSD), så kan detta dokument med sina referenser ligga till grund för svensk nationell teknisk regel. Detta medför att bilagd rekommendation, utan diskriminering, är transparent för marknaden.

4 Referenser

1) Europaparlamentets och rådets direktiv (EU) 2016/797 av den 16 maj 2016 om driftskompatibiliteten hos järnvägssystemet inom Europeiska unionen.
2) NIM Teknikmöte 27/10 i Helsingfors: Mötesanteckningar i e-brev 28 oktober 2016 angående beslutande av dokument NBS Technical specification R 35
3) NBS Technical specification R 35, Date 10-11-2016.

5 Bilaga

NBS, Nordic Railway track cooperation: Rekommendationen R 35, daterad den 10 november 2016. "Running dynamics requirements and recommendations for vehicles with an axle load higher than 22.5 or 25 tons and up to and including 35 tons."

TRAFIKVERKET

Versionslogg

Fastställd version	Dokumentdatum	Ändring	Namn
1.0	2016-12-21	Nytt dokument	Bernt Andersson

Bilaga

NBS NORDIC RAILWAY TRACK COOPERATION	**RECOMMENDATION** FROM THE NBS GROUP	**R 35** Pages: 25 Enclosures: 0 Date: 10-11-2016

Running dynamics requirements and recommendations for vehicles with an axle load higher than 22,5 or 25 tons and up to and including 35 tons

SUMMARY

This document defines the process for assessment of the running characteristics of wagons and locomotives for the Norwegian and Swedish rail networks being able to carry a maximum axle load:

- exceeding 25 but not 35 tons (wagons) (25t<P≤35t)
- exceeding 22,5 but not 35 tons (locomotives) (22.5t<P≤35t)

The combination of speed and cant deficiency for each type of vehicle has to be specified. Acceptable running characteristics of a railway vehicle (hereafter called vehicle) are essential for a safe and economic operation of a railway system.

The objective is to quantify the vehicle's performance under known representative conditions of operation and infrastructure. The traffic on the Swedish/Norwegian Malmbanan/Ofotbanen is defined as representative for vehicles assessed following this regulation.
The recommendation is written in English.

1 Scope

In the present document text with requirements is written in normal style and left hand margin. Informative text is written in italics and with left side indentation.

Present TSIs or European norms (ENs) for running dynamics acceptance do not contain any rules for acceptance of wagons with a maximum axle load exceeding 25 tons and for locos with a maximum axle load exceeding 22,5 tons. No publication of any such international regulations is anticipated in the foreseeable future.

However, in Sweden as well as in Norway, traffic with vehicles with a maximum axle load exceeding these values exists. No Swedish nor Norwegian national rules for running dynamics acceptance of such vehicles existed prior to this regulation.

This document defines the process for assessment of the running characteristics of wagons and locomotives for the Norwegian and Swedish rail networks being able to carry a maximum axle load:

- exceeding 25 but not 35 tons (wagons) ($25t<P\leq35t$)
- exceeding 22,5 but not 35 tons (locomotives) ($22.5t<P\leq35t$)

Assessment of multiple units (EMU, DMU), passenger coaches and Special vehicles (OTMs) following this regulation is possible but it is probably not realistic.

The combination of speed and cant deficiency for each type of vehicle has to be specified.

Acceptable running characteristics of a railway vehicle (hereafter called vehicle) are essential for a safe and economic operation of a railway system. They are related to

- the vehicle,
- the operating conditions,
- the characteristics of the infrastructure (track layout design and track quality) and
- the contact conditions of the wheel-rail interface

The objective is to quantify the vehicle's performance under known representative conditions of operation and infrastructure. The traffic on the Swedish/Norwegian Malmbanan/Ofotbanen is defined as representative for vehicles assessed following this regulation.

Before axle loads > 30 tons can be introduced on Ofotbanen, an upgrading of the permanent way has to be executed.

If a vehicle complies with the requirements of this regulation it is also assumed to comply with otherwise used running dynamics regulations for vehicles with a maximum axle load not exceeding 22,5 or 25 tons. It is thus considered suitable to be operated on the rest of the Swedish and Norwegian network at an axle load not exceeding what is there allowed.

This regulation describes methods to assess the vehicle performance in the following areas:

- Risk for rail surface damage (Chapter 6)
- Safety against derailment on twisted track (Chapter 6)

- Running safety under longitudinal compressive forces in s-shaped curves (Chapter 6)
- Evaluation of the torsional coefficient (Chapter 6)
- Running safety, track loading and ride characteristics (Chapter 7)

The vehicle performance is assessed in two stages. The first stage comprises to investigate the basic characteristics and low speed behaviour.

Usually the first stage is executed before first runs on the line under controlled operating conditions.

In the second stage the Running Behaviour is assessed. The assessment of a vehicle according to the elements listed above can be performed either by physical testing, simulation or comparison with a known solution (dispensation). Details about the requirements for the choice of the appropriate assessment method are given in this document.
The combinations of operational conditions (speed and cant deficiency) that the vehicle has been assessed for shall be given in the test report.

The establishment of this document was based on existing rules, practices and procedures. The following principles were applied:

- *The railway system requires comprehensive technical rules in order to ensure an acceptable interaction of vehicle and track.*
- *The performance of new railway vehicles has to be evaluated and assessed before putting them into service.*
- *It is of particular importance that the existing level of safety and reliability is not compromised even when changes in design and operating conditions are demanded, e.g. by the introduction of higher speeds, higher wheel forces, modification in the suspension, etc.*
- *It is possible to demonstrate compliance with the requirements of this standard by comparison of relevant parameters or by simulation if changes are made to the design or to the operating conditions.*
- *Previous experience from the acceptance process and rules used for previous and existing vehicles with high axle load was used in writing this regulation*
- *Existing and upcoming documents, in particular UIC518, EN 14363:2005 and EN14363:2016 were used when writing this document*

The requirements in this regulation are minimum requirements only. Additional requirements may be set out in a contract between the vehicle supplier and the vehicle buyer.

This applies specifically to the ride characteristics requirements set out in this regulation which are recommended as minimum requirements only.

2 References

2.1 Normative references

[N1] UIC 518:September 2009 “Testing and approval of railway vehicles from the point of view of their dynamic behaviour – Safety – Track fatigue – Running behaviour”

[N2] EN 14363:2005 “Railway applications - Testing for the acceptance of running characteristics of railway vehicles - Testing of running behaviour and stationary tests”

[N3] EN 14363:2016 “Railway applications – Testing and Simulation for the acceptance of running characteristics of railway vehicles – Running Behaviour and stationary tests”

[N4] EN 15273-1 “Railway applications - Gauges - Part 1: General - Common rules for infrastructure and rolling stock”

[N5] EN 15273-2 “Railway applications - Gauges - Part 2: Rolling stock gauge”

[N6] EN 15663:2009 “Railway applications. Definition of vehicle reference masses”

[N7] 321/2013/EU, Technical specification for interoperability relating to the subsystem rolling stock — freight wagons, (WAG TSI), dated 2013-03-13.

[N8] 1302/2014/EU, Technical specification for interoperability relating to the ‘rolling stock — locomotives and passenger rolling stock’ subsystem of the rail system in the European Union, dated 2014-12-12,

[N9] EA-4/16 G:2003 “EA guidelines on the expression of uncertainty in quantitative testing.” European co-operation for Accreditation.

[N10] GUM - Guide to the Expression of Uncertainty in Measurement. First edition 1995. ISBN 92-67-10188-9. International Organization for Standardization.

[N11] TDOK 2013:0347: “Banöverbyggnad – spårläge - Krav på spårläge vid byggande och underhåll”, 2015-04-01.

[N12] EN 13848-6:2012: ” Railway applications - Track - Track geometry quality - Part 6: Characterisation of track geometry quality”

[N13] Jernbaneverket/teknisk regelverk/Overbygning/530 Prosjektering (see https://trv.jbv.no/wiki/Overbygning/Prosjektering)

[N14] Jernbaneverket/teknisk regelverk/Overbygning/531 Bygging (see https://trv.jbv.no/wiki/Overbygning/Bygging)

[N15] Jernbaneverket/teknisk regelverk/Overbygning/532 Vedlikehold (see https://trv.jbv.no/wiki/Overbygning/Vedlikehold)

[N16] EN 15839 “Railway applications – Testing for the acceptance of running characteristics of railway vehicles – Freight wagons – Testing of running safety under longitudinal compressive forces“.

2.2 Other references

[O1] Extent from general wagon specification written by LKAB 1998, Section Running Dynamics

[O2] Extent from Contract between LKAB and Bombardier Transportation on procurement of locomotive IORE, Appendix 5 (External interface requirements), Section 6 (Running Dynamics), 1998

[O3] Lars Andersson, Interfleet Technology, document number TS4914, issue 1.0, "Laboratory Report 1239-73x. Review and test of method for running dynamics requirements, 25-35 tons axle load"

[O4] Hartwig, Peter, "FoU Control of wheel and rail contact Stresses (K-008491)", dated 2016-05-13

3 Definitions and symbols

3.1 General

See ref [N3], Section 3 and Annex V.

3.2 Definitions

Notion	*Description*
Malmbanan	The railway line in Sweden connecting Boden – Kiruna – Riksgränsen and Svappavaara – Kiruna. The heavy haul connection often denoted Malmbanan is Luleå – Riksgränsen, but strictly speaking the part Luleå – Boden belongs to Norra Stambanan.
Ofotbanen	The railway line in Norway connecting Riksgränsen – Fagernes freight terminal/Narvik
IORE	12 axle articulated locomotive type supplied by Bombardier Transportation to LKAB
Resisting bogie yaw moment	The moment between bogie and carbody that occurs due to yaw motion of the bogie relative to the carbody.
Flexibility coefficient	Swedish: Krängningskoefficient. A measure on the lower sway characteristics of the vehicle, the relation between the lateral acceleration expressed in a carbody coordinate system and the same expressed in the track plane.

3.3 Symbols

Notion	*Description*
C_t^*	Carbody torsional coefficient [Nm^2]
Q_0	Static wheel load [N]
m_{veh}	Vehicle mass [t, ton]
j, n	Index for axle (axle 1, 2, …, *j, …, j+1, …, n-1, n*), n is the number of axles in the vehicle [-]
1, 2	Index for left and right [-]
g	The gravitational acceleration, in Sweden and Norway 9,81 [m/s^2].
Δq_j	The wheel load difference between left and right of axle j. [kN]
V_{adm}	Maximum allowed operational speed [km/h]
I_{adm}	Admissible cant deficiency [mm]
R_m	Mean value of curve radii of all test sections in the test zone [m]
V	Test speed [km/h]
I	Test cant deficiency [mm]
R	Curve radius [m]
ρ	Curvature (1/R) [m^{-1}]
L_{ts}	Length of track section [m]
$n_{ts,min}$	Minimum number of track sections [-]
$2Q_{0j}$	Axle load for wheelset j [kN]. $2Q_{0j} = P_{0j} \cdot g$ where *g*=9.81 m/s^2.

P_{0j}	Axle load for wheelset j [t, ton]
Δy_{σ}^{0}	The standard deviation of the lateral track irregularities in one test section [mm]
Δz_{σ}^{0}	The standard deviation of the vertical track irregularities in one test section [mm]
H	Height of centre of gravity for complete vehicle [m]
$2b$	Lateral distance between left and right wheel's running circles, can be assumed to be 1500 [mm].

4 Deviations from requirements

If deviating from some points of the requirements of this standard for a particular assessment, these deviations shall be reported and explained. Then the influence on the assessment of the vehicle in terms of the acceptance criteria shall be evaluated and recorded. The outcome of this study shall be considered as an integral part of the requirements of this standard when applied to the assessment process of the vehicle, as long as evidence can be furnished that the level of running safety and track loading is at least the equivalent to that ensured by complying with these rules.

5 Test Requirements

5.1 Measuring uncertainty

The measuring uncertainty shall be stated in the test report and calculated according to EA-4/16 Ref [N9] or GUM Ref [N10]. Taking into account the different methods now used for assessment of measuring uncertainty, these requirements are at least as strict as the requirements used when the limit values were established. The limit values already include an allowance for this measuring uncertainty and no additional allowance shall be added to the results.

5.2 Fault modes

See ref [N3], Section 5.2.2.

5.3 Test vehicle

See ref [N3], Section 5.3.

5.4 Assessment of test results

See ref [N3], Section 5.4.

5.5 Documentation of test

See ref [N3], Section 5.5.

6 First stage assessment

6.1 General

The assessment described in this section is performed before the vehicle normally is allowed on regular tracks for instance for dynamics performance assessment as described in Section 7 of the present document.

6.2 Risk of rail surface damage assessment

In heavy haul traffic the stresses in the contact patch are often within the plastic shakedown or ratcheting regime, why rail surface damage is a common occurring phenomena.

An analysis equivalent to [O4] concerning vehicle design and choice of wheel profile shall be carried out and presented.

6.3 Safety against derailment on twisted tracks

See ref [N3], Section 6.1 with the following deviations.

6.3.1 Possible simplification if the vehicle bogie is a bogie with negligible torsional stiffness

If a bogie with a negligible torsional stiffness is used and if method 3 of ref [N3], Sections 6.1.1and 6.1.5.3 is chosen, then the wheel un-loading measurements following ref [N3], Section 6.1.5.3.2 may be omitted and be replaced with the following procedure:
By analysis from drawings it shall be ensured that no part of the bogie structure intrudes into other parts of the wagon that may cause the wheel unloading to become large.

A low torsional stiffness in this case means that if one wheel is lifted the wheel load re-distribution due to this lift is negligible, i.e. the wheel unloading that not lifted wheels are subjected to is negligible.

A common design for bogies for heavy haul freight wagons is the so-called three-piece bogie. One important characteristic of this bogie is that its torsional stiffness around the longitudinal axis is very low, in this context negligible.

One example of such an intrusion may be that the bogie side frame comes into contact with the carbody structure of the wagon when track twist is simulated by a wheel lift.

In case the bogie is referred to as a bogie with negligible torsional stiffness, this must be motivated in the test report.

6.3.2 Possible simplification for certain carbody/bogie interface

In the case when method 3 is used and in the case when the interface between carbody and bogie consists only of a so-called centre casting, possibly in combination with constant contact side bearers, the bogie rotational test to derive the X-factor, see ref [N3], Section 6.1.5.3.3, may be omitted and be replaced with the following procedure:

By calculations it shall be ensured that the X-factor will not exceed the limit value given in ref [N3], Section 6.1.5.3.4. In the calculation a margin of at least 10% to the limit value shall be demonstrated.

If non-constant contact side bearers are used, these do not need to be included in the calculations, since they would not be in contact if the test is actually performed.

The following shall be considered:

- Verified friction coefficient used from drawings
- The vertical contact force between side bearers and carbody as well as between centre pan and bogie
- Deflection of bogie structure or of carbody structure do not need to be considered if it can be expected that the influence of these only have negligible influence. This shall be motivated in the report.
- Since the X-factor test is performed at very low speed and if the bogie yaw resistance is independent from yaw speed and yaw angle within the tested region, a static calculation of the resisting yaw moment is sufficient.

6.3.3 Vehicles not fit for using method 3 according to ref [N3]

Method 3 in ref [N3] section 6.1.5.3 can only be used where all of the following conditions are fulfilled:

- The vehicle in question is a vehicle where sub-systems important to the running dynamics properties can be said to be designed according to state-of-the art principles.
- Vehicles with two two-axle bogies per carbody or articulated vehicle with two axle bogies.

  In the case of articulated vehicles particular requirements are put on the test site for the wheel unloading test.
- The nominal flange angles of the wheels are between 68° and 70°.

In the case a vehicle does not qualify for using method 3, as an alternative to use method 1 or 2 of ref [N3], section 6.1, computer simulations according to ref [N3], may be used to show compliance with the requirements. In this case method 2 shall be simulated. The model validation process shall follow the principles given in ref [N3], annex T so that the model can be shown to be fit for purpose.

6.4 Safety against derailment under longitudinal compressive forces in S-shaped curves

For locomotives no assessment is required.
For vehicles with central couplers without side buffers no assessment is required.
For freight wagons with side buffers or with other wagon coupling devices that could cause large forces resisting the train movement in curves, the procedure in EN 15839 [N16] shall be followed.

6.5 Evaluation of the torsional coefficient of a car body C_t^*

In the case when a wheel unloading test according to Section 6.2 is required it is necessary to determine the torsional coefficient. It is also needed if the vehicles shall be assessed for safety against derailment under longitudinal compressive forces, see Section 6.4.
In such case, see ref [N3], Section 6.3.

6.6 Assessment of the flexibility coefficient

The flexibility coefficient is used for gauge investigations defined in EN 15273-1 [N4] and required in EN 15273-2 [N5]. This is not part of the dynamics assessment but is mentioned here for information since the same test laboratory executing other tests mentioned in this regulation often also measures the flexibility coefficient.

Two methods (one suitable for the workshop and one for dynamic measurements in track tests) for determining the flexibility coefficient are given in ref [N3], Section 6.4.

6.7 Weighing

The following load cases shall be considered:

- Empty: Operational Mass in Working Order as specified in EN 15663:2009 [N6].
- Laden: Design Mass under Normal Payload as specified in EN 15663:2009 [N6].

For wagons wheel loads for empty and laden state shall be derived. Weighing is needed for the empty state. The derivation of the loaded state can be performed using calculations by theoretically adding the load up to the maximum admissible axle load for the vehicle.
A representative selection of wagons shall be selected for weighing. If the results are consistent no more weighing is needed. As an alternative it is allowed to measure only one wagon if this is complemented with a conservative and well-proven round-off procedure.
For locomotives without any fuel tanks for traction, wheel loads for the laden state shall be derived by weighing. It is enough to execute this as a type test (one vehicle from the series, usually the vehicle used for dynamic testing).
The following properties shall be derived for each relevant load condition for the test vehicle and reported in the test report:

Overall mass of the vehicle:	$m_{veh} = \dfrac{\sum_{j=1}^{n}\left(Q_{j1}+Q_{j2}\right)}{g}$
Axle load for each wheelset:	$2Q_{0j} = Q_{j1} + Q_{j2}$
Maximum axle load of the vehicle	$2Q_{0\max} = \text{Max}\left(Q_{j1}+Q_{j2}\right) \text{for j} = 1 \text{ to n}$

The assessment criteria of the vehicle mass shall be stated in the contract between supplier and purchaser.

Furthermore the wheel load difference for empty wagons and laden locomotives shall be derived for each axle:

$$\Delta q_j = \frac{|Q_{j1} - Q_{j2}|}{Q_{j1} + Q_{j2}}$$

In the case any Δq_j is larger than 0,05 (5%) safety against derailment on twisted tracks (see 6.2) as well as compliance with the limit value for *Y/Q* for dynamics assessment (see 7.5) for this higher value shall be demonstrated.

7 Second stage – dynamic performance assessment

7.1 General

See ref [N3], Section 7.1.

For convenience it is recommended to select the combination of V_{adm} and I_{adm} based on the conditions used on Malmbanan/Ofotbanen. Such combinations are given in Section 8.3.

There is no lower V_{adm} for which vehicles are granted dispensation from on-track tests.

In ref [N3] vehicles with $V_{adm} \leq 60$ km/h are granted dispensation from dynamics assessment. This does not apply to vehicles with very high axle load.

For heavy haul vehicles the dynamic performance is important. Also tare condition need to be tested due to the in general very large possible span in axle load between different loading conditions.

7.2 Type of measuring method and on-track test extent

7.2.1 Choice of assessment method

Apply ref [N3] 7.2, annex T2, T3 and annex U with the following modification:

The base conditions for a simplified test method described in Section 7.2.2 cannot be applied.

Annex T3 is used to check if the model is appropriate to be used in the simulations for the new or modified vehicle and/or the modified operational conditions

When applying ref [N3] the outcome may be one of five. Depending on this outcome the assessment/measuring method shall be selected according to Table 1.

Outcome when applying ref [N3]	***Method to be used***
Test exemption	Test exemption
Simulations (complete or in parts)	Simulations (complete or in parts)
Simplified test method using accelerometers only	A stability check shall be done for tare load.[1]
Simplified method using H-force measurements	Normal method (instrumented wheelsets)
Normal method	Normal method (instrumented wheelsets)

Table 1 Selection of assessment / measuring method

Measurement results from using load measuring wheelsets may also be used to gain load spectra for other parts of the vehicle e.g. wheels and axles.

[1] *Also for the laden vehicle it is recommended to check acceleration and strain values to avoid fatigue issues in the future.*

In case the outcome is to use simulations, this outcome may be replaced with normal method. If simulations are used, ref [N3], annex T shall be applied.
In the case the test extent is to carry out a stability test only, test cannot be exempted from, but in this case it is enough to use a simplified method with accelerometers only.
In the case the outcome is to carry out a simplified test the maximum allowed cant deficiency is limited to the following value:

$$I_{adm,\max} = \frac{(2b)^2}{2{,}3H}\left(\frac{Q_{qst,\lim}}{Q_0} - 1\right)$$

7.2.2 Test zones, choice of test extent

The test zones are defined in Table 2.

Test zone 2 will often be completely encompassed by test zone 3. In this case test zone 2 may be disregarded from.

The test extent is based on testing on the entire Malmbanan/Ofotbanen plus the line Luleå - Boden. The selection of sections shall be aimed and preferably all sections encompassed shall be used in the evaluation. Excluded sections shall be accounted for and the exclusion be motivated in the test report.

For stability testing an analysis of the geometric contact conditions between wheel and rail shall be carried out with the aim to test the vehicle under dimensioning conditions on Malmbanan/Ofotbanen. The analysis shall be included in or appended to the test report.

No limit values do yet exist for test zone 3b but evaluated values shall be reported.

	Test zone				
	Stability	**1**	**2**	**3a**	**3b**[2]
Description	Tangent track and very large curve radius		Large radius curves	Curves	
Objective	Running stability assessment	Testing for V_{adm}	Testing for simultaneous V_{adm} and I_{adm}	Testing for I_{adm} in tight curving and severe contact conditions	
R	$R \geq 50\,000$ m		-	250 m $\leq R \leq$ 650 m	
V	Max(V_{adm}+10 km/h;1,1*V_{adm})		$V_{adm} \leq V \leq 1,1*V_{adm}$[3]	$V \leq 1,1*V_{adm}$	
I	-40 mm $\leq I \leq$ 40 mm		Lower interval limit: 0 Upper interval limit: MAX(I_{adm}+10 mm ; 1,1·I_{adm})		Lower interval limit: I_{adm}-90 mm Upper interval limit: 0
Tolerance	±5 km/h		±5 km/h ; ±0,05·I_{adm}		
Wheel/rail friction	Dry	Dry rails in at least 80% of track sections			
L_{ts}	100 m			70 m for R<400 m 100 m for R≥400 m	
$n_{ts,min}$	25				

Table 2 Test zones and track sections

[2] In case the lower interval limit for I is larger than or equal to 0, test zone 3b can be disregarded.
[3] For multiple regression also lower speed may be included

7.3 Performing dynamic test

Apply ref [N3], Section 7.3.2 modified for test zones according to Table 2.
Apply ref [N3], Sections 7.3.3 and 7.3.4.

7.4 Measured quantities and measuring points

Apply ref [N3], Section 7.4.

7.5 Assessment quantities and limit values

Apply ref [N3], Section 7.5 with the following deviations:

Apply the limit values of ref [N3], Table 4 with the following deviations.

7.5.1 Running safety – stability

When using the normal measuring method or simulations and for loading conditions where the axle load is higher than 25 ton the stability limit value is:

$$\Sigma Y_{j,rms,\lim} = \frac{\Sigma Y_{2m,\max,\lim}}{2}$$

7.5.2 Quasistatic guiding force

The limit value for the quasi-static guiding force is:

$$Y_{qst,\lim} = \begin{cases} 60\,\text{kN for } P_{0j} \leq 25\text{ t} \\ (4 \cdot P_{0j,\max} - 40)\,\text{kN for } 25\text{ t} < P_{0j,\max} \leq 30\text{ t} \\ 80\,\text{kN for } P_{0j,\max} > 30\text{ t} \end{cases}$$

In case it can be shown that the rail geometric shape is such that it is impossible to achieve radial steering at the curve radius in question, or if other extreme environmental factors not influenced by the vehicle properties make the guiding forces high and if the vehicle is of a design permitting radial steering, such test sections may be excluded from the evaluation. This must be commented on and shown in the report and the body[4] reviewing the vehicle must specifically comment on this in the review report.

7.5.3 Quasistatic wheel force

The limit value for the quasi-static wheel force is:

$$Q_{qst,\lim} = \begin{cases} 155\,\text{kN for } 22{,}5\text{ t} < P_{0j} \leq 27{,}9\text{ t} \\ 1{,}133 \cdot Q_0\ \text{kN for } P_{0j,\max} > 27{,}9\text{ t} \end{cases}$$

7.5.4 Maximum wheel force

The limit value for the maximum wheel force is:

[4] With body is meant a designated body (DeBo) or other body authorised by the National Safety Authorities involved.

$$Q_{\max,\lim} = \begin{cases} \mathrm{Min}\left(Q_0 + 90;210\right)\mathrm{kN}\ \mathrm{for}\ 22{,}5\ \mathrm{t} < P_{0j} \leq 27{,}9\ \mathrm{t} \\ 1{,}133 \cdot Q_0 + 55\ \mathrm{kN}\ \mathrm{for}\ P_{0j,\max} > 27{,}9\ \mathrm{t} \end{cases}$$

7.6 Test evaluation

Apply ref [N3], Section 7.6 with the following deviations:
For each assessment quantity and test zone given in Table 2 the estimated maximum value of the sample $Y(PA)_{max}$ is calculated applying a statistical method which is either:

- One-dimensional as described in ref [N3] , Annex R.4 (only applicable for Y_{qst}),
- two-dimensional as described in ref [N3] , Annex R.5 (only applicable for test zones 2, 3a and 3b) or
- a multiple regression as described in ref [N3] , Annex R.6 and relevant parts of ref [N3], Table 2.

In case a one-dimensional method is used:
The curve radius range shall be between 250 and 400 m and the mean radius must be explicitly stated in the report. The sections used shall represent the sections present at Malmbanan/Ofotbanen. Usually all sections where measurements were taken shall be included in the analysis. There may be reasons for excluding sections. It shall be stated in the report, if any sections were excluded from the analysis and why. A list of such excluded sections shall be given in the report including information about radius, speed, cant deficiency, the four track geometric quality values and in the case of test zone 1 sections, the equivalent conicity.
In case a two-dimensional method is used:
Maximum values shall be assessed at the lower interval limit and at the upper interval limit as defined in Table 2. The highest of the two values shall be compared with and comply with the limit value.
The quasistatic guiding force is evaluated to the curvature (the inverted curve radius) and shall be evaluated at $\rho = 1/300$ [m^{-1}].
The quasistatic wheel force shall be evaluated at $1.00 \cdot I_{adm}$.
In case a multiple regression is used:
Every track section used for the multiple regression shall fulfil the following requirements:

- Speed: $0.50 \cdot V_{adm} \leq V \leq 1.10 \cdot V_{adm} + 5$ km/h (test zones 1 and 2)
- Cant deficiency: 40 mm $\leq I \leq 1.15 \cdot I_{adm}$ (test zone 2)
- Cant deficiency: as given in lower and upper evaluation limits of Table 2 (test zone 3)
- Curve radius: 250 m $\leq R \leq$ 650 m (test zone 3)
- Track quality: no specific requirement

In addition, the following requirements shall be met:

- On test zone 1: $V \geq 1{,}05 \cdot V_{adm}$ on ≥ 5 sections
- On test zone 2: $V \geq V_{adm}$ - 5 km/h and $I \geq 1{,}05 \cdot I_{adm}$ on ≥ 5 sections
- On test zone 3: $I \geq 1{,}05 \cdot I_{adm}$ and $R \leq 300$ m on ≥ 3 sections

The target values to be used are given in Table 3 of the present document.

Speed	V = MAX(V_{adm}+10 km/h;1,10·V_{adm}) (on test zone 1) $V = V_{adm}$ (on test zone 2)
Cant deficiency	I = 1,10·I_{adm} (for maximum values on test zone 2) $I = I_{adm}$ (for quasistatic values on test zone 2) Whatever gives the highest value of the following[5]: MIN(I_{adm}-90 mm ; 0,75·I_{adm}) (on test zone 3) MAX(I_{adm}+10 mm ; 1,1·I_{adm}) (for maximum values on test zone 3) I_{adm} (for quasistatic values on test zone 3)
Curve radius	R = 300 m (on test zone 3a and 3b)
Track quality	Class C as defined in ref [N12], sec 8.2 with values defined in sec 8.3, however assuming a track quality class higher than the Vadm for the vehicle in question. [6].

Table 3 Target values when using a multiple regression

7.7 Documentation

Apply ref [N3], Section 7.7.

[5] If the lower value of the cant deficiency is used it is allowed to modify the target value for the speed accordingly

[6] As an example, if V_{adm} for the vehicle to be tested is 80 km/h then the value for longitudinal level and alignment shall be taken for TQC C for speed class 80 < $V \leq$ 120 km/h

8 Characteristics of Malmbanan/Ofotbanen

The information presented in this section is partly a snapshot in time (2013). Neither Jernbaneverket nor Trafikverket can be held liable whatsoever for the given information. This entire section is informative and contains no requirements.

8.1 General

Malmbanan/Ofotbanen runs from Boden via Gällivare, Kiruna, Riksgränsen to Narvik. The line from Riksgränsen to Narvik runs on the Norwegian side named Ofotbanen and the remaining line in Sweden is named Malmbanan. The line between Luleå and Boden (about 30 km) does not strictly belong to Malmbanan, though connecting heavy haul traffic from Malmbanan to the harbour in Luleå.

The total length of Malmbanan/Ofotbanen is approximately 500 km.

The climatic conditions are characterised by very cold winters and cool summers on the Malmbanan and mild winters and cool summers on the western part of Ofotbanen. The average gradient from Riksgränsen to Narvik is 15‰ over about 40 km with a maximum gradient of 17,6‰.

The rails on Ofotbanen are mostly 54E3 inclined 1:20 but the rail head is re-profiled to 1:30. On some sections 60E1 have been installed. The sleepers are wooden sleepers with a sleeper spacing of 520 mm. A continuous upgrading takes place to install concrete sleepers with a spacing of 520 mm combined with rail 60E1.

The rails on Malmbanan are mostly 60E1. The sleepers are mostly concrete sleepers with a spacing of 600 mm.

The rails in curves are head hardened.

Ofotbanen is 42 km and the rest is Malmbanan.

Malmbanan/Ofotbanen accommodates passenger traffic, freight traffic with an axle load up to 22,5 ton as well as heavy haul traffic with axle loads up to 30 ton. Maintenance rules and speed profiles are set according to a combination of requirements from these various modes of operation.

8.2 Curvature

The two lines Malmbanan and Ofotbanen are distinctly different in character. Ofotbanen runs through a mountain area with many sharp curves, where the typical curves radius is around 300-400 m. The transition curves are generally short. On Malmbanan a curve radius around 600 m is very common but also larger radii with many and long straight track sections are common. The curvature distributions are shown in Table 4 (Ofotbanen) and Table 5 (Malmbanan).

Curve radius	*Percentage*	*Track length [km]*
R < 300 m	*1 %*	*0,42*
300 m ≤ R < 400 m	*32 %*	*13,44*
400 m ≤ R < 500 m	*7 %*	*2,94*
500 m ≤ R < 600 m	*3 %*	*1,26*
600 m ≤ R < 800 m	*6 %*	*2,52*
800 m ≤ R < 1000 m	*1 %*	*0,42*
R ≥ 1000 m	*6 %*	*2,52*
Straight track	*21 %*	*8,82*
Transition curves	*23 %*	*9,66*

Table 4 Distribution of curvature on Ofotbanen

Curve radius	*Percentage*	*Track length [km]*
R < 250 m	*0%*	*0,00*
250 m ≤ R < 400 m	*0,6%*	*2,40*
400 m ≤ R < 650 m	*11%*	*46,55*
650 m ≤ R < 2500 m	*13%*	*55,77*
R > 2500 m	*0,9%*	*3,85*
Straight track	*50%*	*215,44*
Transition curves	*25%*	*107,46*

Table 5 Distribution of curvature on Malmbanan

8.3 Cant and cant deficiency

For traffic on Malmbanan / Ofotbanen it may thus be suitable to consider the values of combinations of V_{adm} and I_{adm} in Table 6. These values are based on a curve radius of 300 m on Ofotbanen with a cant of 100 mm and a curve radius of 600 m on Malmbanan with a cant of 75 mm. Local deviations from these values exist.

Vadm [km/h]	*Iadm [mm] (O)*	*Iadm [mm] (M)*
50	*0*	*-25*
60	*40*	*0*
70	*90*	*20*
80	*-*	*50*
100	*-*	*120*

Table 6 Representative values of speed and cant deficiency on Ofotbanen (O) and Malmbanan (M).

8.4 Track geometry quality

For rules that applies for track quality maintenance on Malmbanan/Ofotbanen, see ref [N11] for Malmbanan and refs [N13], [N14] and [N15] for Ofotbanen.

The actual characteristics (2013) are as given in sections 8.4.1 (Malmbanan) and 8.4.2 (Ofotbanen) below. The values are given as standard deviations for wavelength range D1 (3 to 25 m) according to ref [N12]. The section length is 200 m as a sliding window.

Existing speed classes governing the track maintenance on Malmbanan/Ofotbanen are:

$V \leq 80$ km/h,

$80 < V \leq 120$ km/h and

$120 < V \leq 160$ km/h.

In the cumulative distributions below these speed classes have not been separated.

8.4.1 Malmbanan

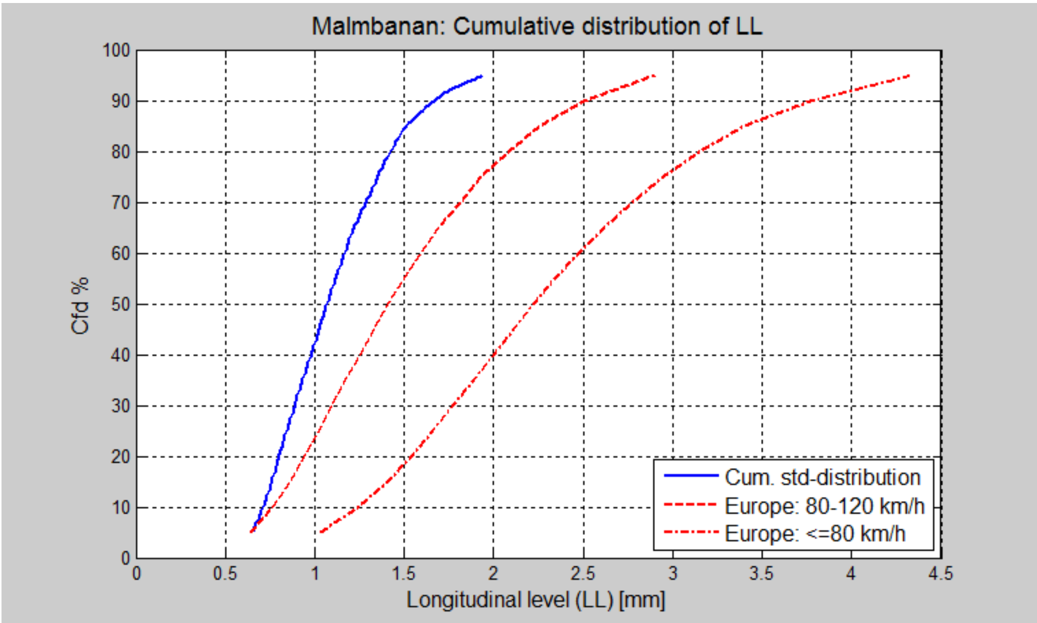

Figure 1 ***Cumulative distribution for the longitudinal level on Malmbanan. Standard deviation, wavelength interval 3-25 m, track section length sliding window 200 m.***

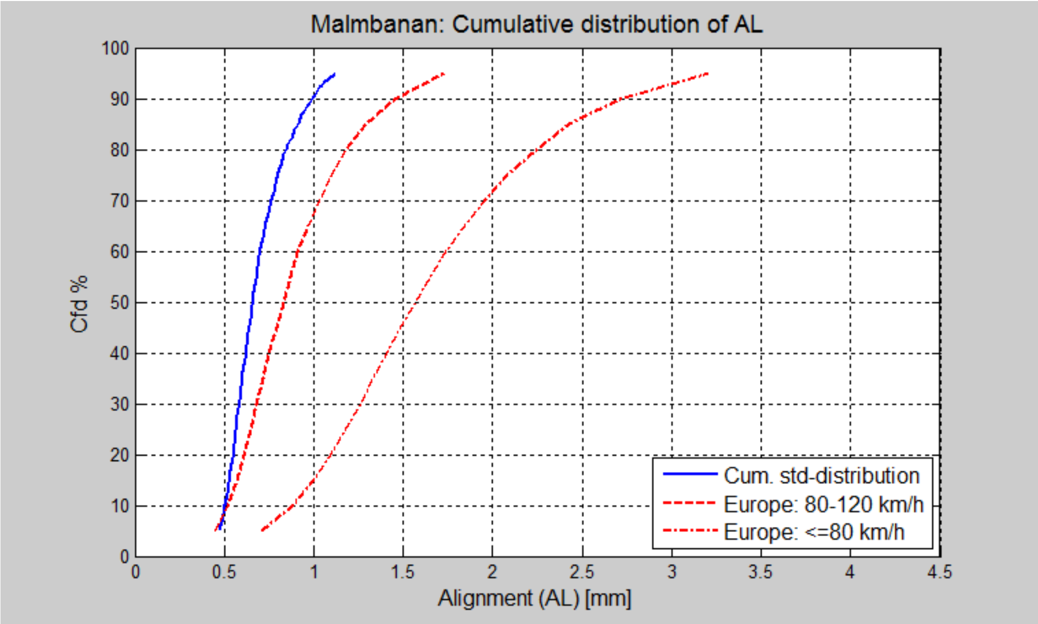

Figure 2 ***Cumulative distribution for the alignment on Malmbanan. Standard deviation, wavelength interval 3-25 m, track section length sliding window 200 m.***

8.4.2 Ofotbanen

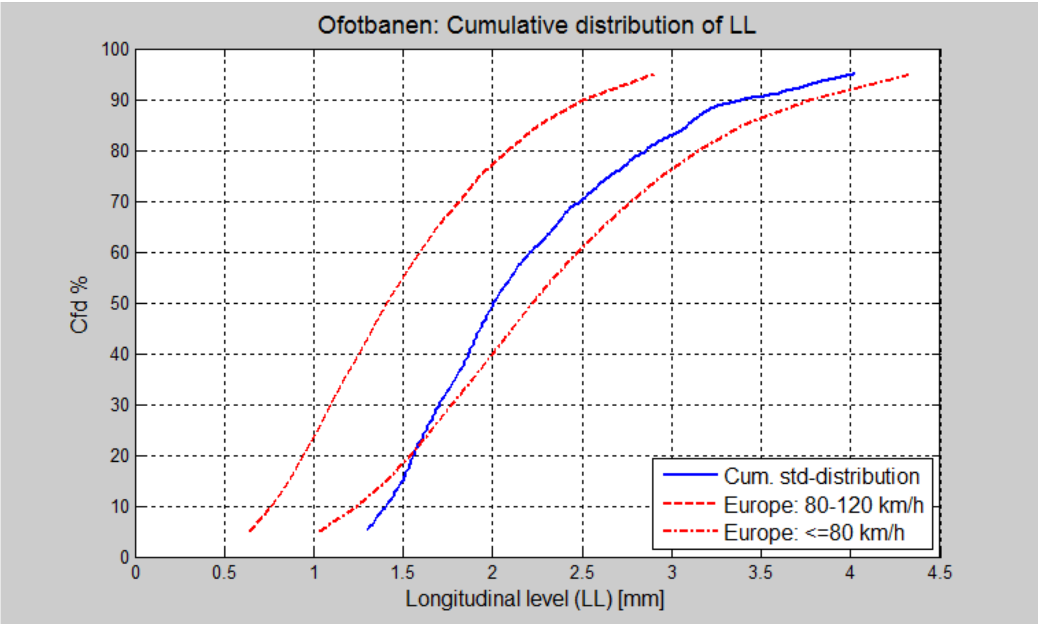

Figure 3 ***Cumulative distribution for the longitudinal level on Ofotbanen. Standard deviation, wavelength interval 3-25 m, track section length sliding window 200 m.***

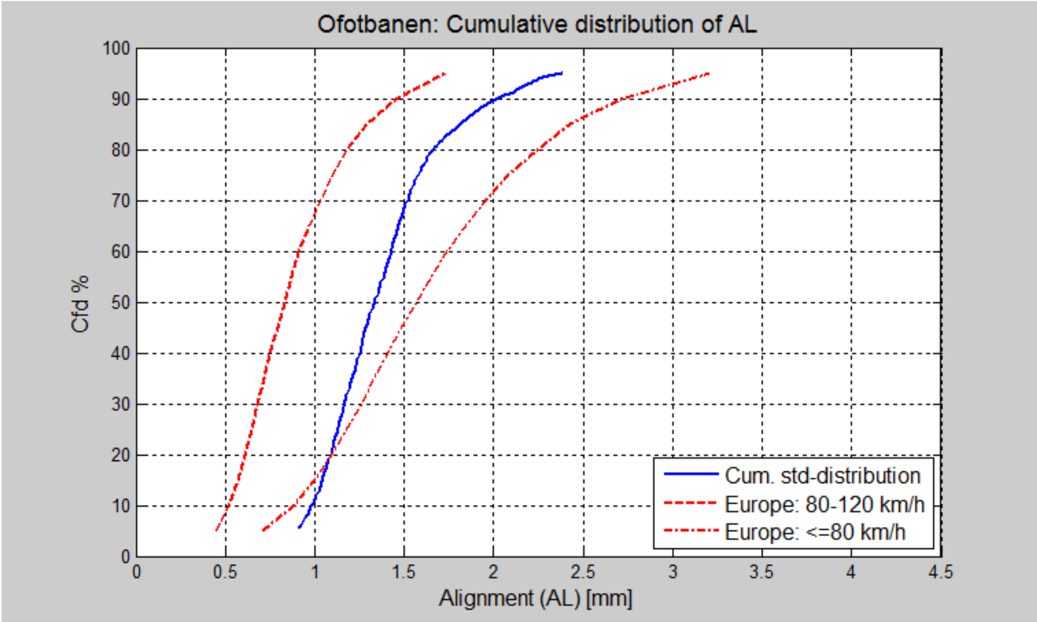

Figure 4 Cumulative distribution for the alignment on Ofotbanen. Standard deviation, wavelength interval 3-25 m, track section length sliding window 200 m.

8.5 Equivalent conicity

The equivalent conicity on Malmbanan/Ofotbanen is generally low. Analysis have been carried out 2012 using wheel profiles WPL9, S1002 with flange thickness 32.5 mm and EPS with flange thickness 32.5 mm (see Figure 5)

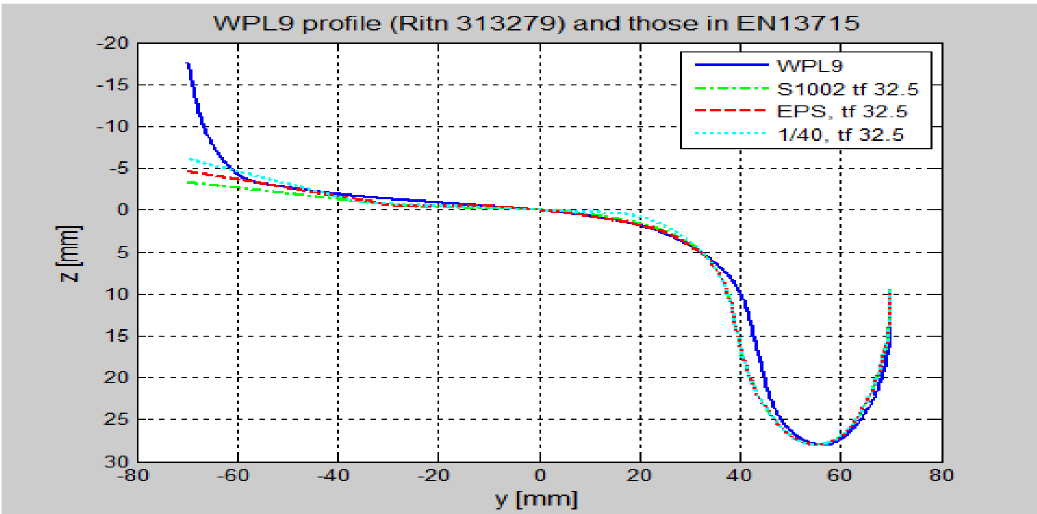

Figure 5 Wheel profiles

The 3 mm value of the equivalent conicity all of these profiles rarely exceeds 0,20. For an example of equivalent conicity, new WPL9 on worn rail, see Figure 6.

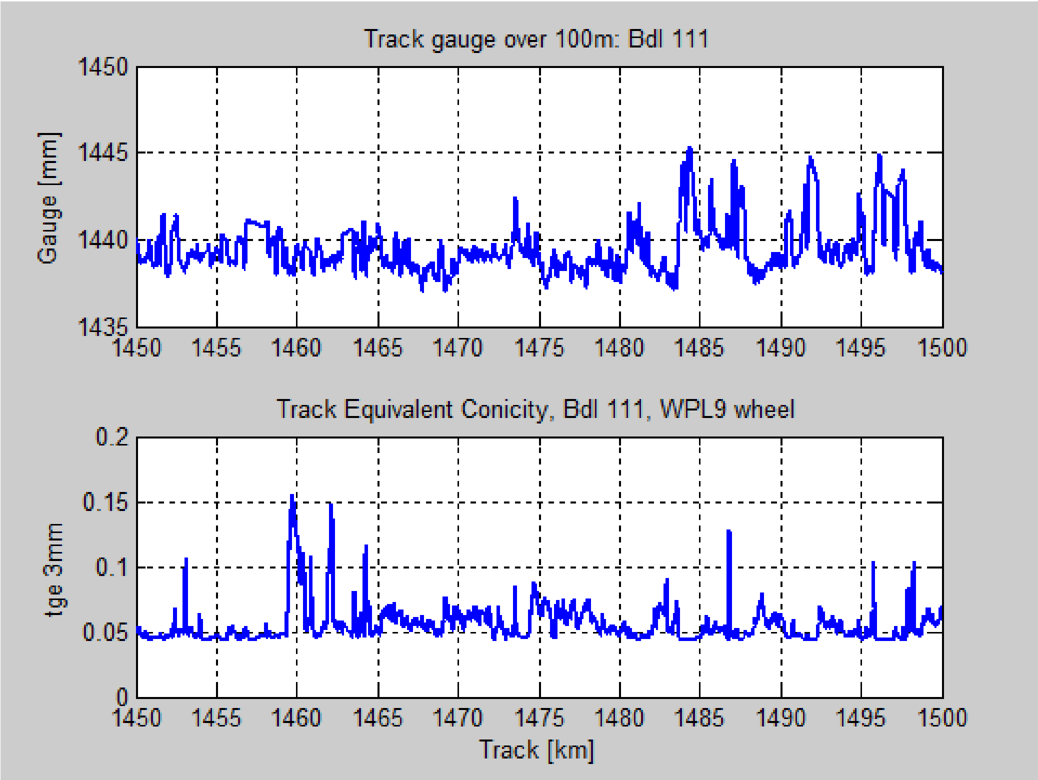

Figure 6 ***Example of equivalent conicity on Malmbanan, 3 mm values, WPL9 wheel profile on worn rail profiles.***