Project no. TIP5-CT-2006-031415

INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D4.3.1
Initial Definition of Conditions for Testing Matrix of Rail Steels and Welds

Due date of deliverable: 2007-08-31

Actual submission date: 2007-06-27

Start date of project: 2006-09-01 Duration: 36 months

Organisation name of lead contractor for this deliverable: Deutsche Bahn AG

Rev.: Final, agreed 2007-05-30
revised again 2007-06-20

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
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CO	Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Chalmers	Chalmers University of Technology, Göteborg
DB	Deutsche Bahn Technik/Beschaffung
TUD	Technical University Delft
UoN	University of Newcastle
VAS	Voest Alpine Schienen GmbH
RCF	Rolling contact fatigue

1. Executive Summary

This paper has been written in order to define and reconcile the test matrix of the INNOTRACK work-package 4.3 ‘Innovative laboratory tests of rail steels and joints’.

The tests shall be performed due to data obtained from site observations of railway operators. On the basis of these data a programme for specific laboratory tests will be established in order to validate the site observation results under different service conditions such as speed, axle loads, angle of attack etc.

Service conditions for laboratory tests (i.e. wheel-rail test rig or twin disk tests) will be derived from the above mentioned experiences and will be compared to the experimental capabilities of the project partners. The conduction of the tests is based on the experience of each project partner from other projects. Their transferability to rail material testing is a known risk of the work package.

The testing capabilities of the project partners are described as Annexes 1 to 4

Annex	*Originator*	*Objective*
1:	UoN	Description of twin disk rail material testing
2:	VAS	Description of test rig rail material testing
3:	DB	Description of rail on roller tests
4:	Chalmers, TUD	Subsequent numerical calculations, regarding rail degradation

The tests will be performed with original rail and wheel material. The grades, forces and other parameters of the tests have been reconciled within the workgroup. It is intended that the test conditions of the different partner’s tests should have common effects at RCF.

For proving this, numerical simulations provided by the other project partners will be used in the progression of the WP 4.3.

The combination ‘operational demands vs. experimental capabilities’ form the WP 4.3 test matrix as the main result of this deliverable.

2. Definition of the test matrix

2.1 Preliminary remarks

It is the aim of WP 4.3 to test and p rovide a rail material laboratory test that better reflects the expected performance of rail steels in service.

The reasons for laboratory tests are

1. The cost and the time requirem ent for site trials restrict their number and their repeatability. Consequently, there is a nee d to undertake controlled tests in the laboratory that will e nable extrapolation of the observed site results to a greater range of duty conditions.
2. Although the current CEN standard on rail steels (EN13674-1) has all basic material property tests their direct relevance to in service performance remains a subject of debate, especially regarding RCF which is one of the key rail degradation effects now. As the programme focuses on LCC reduction, laboratory tests could provide a link between metallurgy and rail-wheel contact mechanics that would affect future rail steel developments in order do reduce rail maintenance cost.

Regarding the 2nd aspect the initial discussion within the workgroup focused on the size of RCF cracks to be investigated in the work package. The project partners clarified that the experimental investigation and modelling are targeted in the area most useful for a technical stable railway operation.

The experimental basis for laboratory tests, such as

- Full scale wheel-rail roller rig
- Rail roller rig
- Twin -disc test
- Torsion tests

will be supplied by the project partners UoN, VAS, Corus and DB.

Corus wishes to point out that they do not intend to undertake any torsion tests but results from earlier tests undertaken by IRSID (France) could be made available. Experiences in evaluating the test results could be given by the other partners involved Chalmers and TUD.

In order to find a comm on basis for establishing the tests, relating them to service conditions from rail test sites and comparing the data obtained a test matrix had to be agreed within the workgroup.

2.2 Constitution of the test matrix

2.2.1 Conditions derived from railway operation

Wear and Rolling Contact Fatigue (RCF) are two important factors that determine the replacement cycles of rails. Whereas the me chanisms for wear are well u nderstood to be able to m anage the rai lway system to minimize wear, RCF is still not sufficiently understood to have efficient solutions to prevent the formation of RCF. Especially in curves RCF defects like Head Checks (periodic cracks at the gau ge corner of the rail) and Spalling (Head Checks combine and cause material flaking) cause significant problems.

The workgroup decided that the o perational conditions of typical passenger cars moving through a curved track should be the basis for the testing matrix. It was not expected to use extreme co nditions such as high speed or heavy load traffic for the tests because the tests should represent a typical situation at the track.

It is well-known from railway operation that the RCF in curves depends on the curve radius in combination with features of the bogie s which affect the angle o f attack of th e wheel against the ga uge corner. From simulations and other experience it can be assumed that the range of curve radii should be in the order of 500 to 1500 m in order to obtain angles of attack between 0 and 0.25°.

The wheel and rail profiles should be usually shaped 60 E1/E2; 1:40 / S1002. Environmental conditions such as humidity and temperature of the air should be involved as far as possible at the laboratories.

The vertical load should be oriented at a typical axle load of 150 … 200 kN. As VAS prefers a higher load on its test rig in order to obtain fast results a comparison between this and normal conditions is intended. For twin disk or other tests an equivalent pressure has to be simulated.

The material properties are given from representative samples which are under discussion in the workgroup.

2.2.2 Test conditions

The test matrix on the other hand describes which features can be tested by which of the methods. Although every test method will probably fit best for one aspect of wear or RCF, it is intended to define at least one test configuration where the test methods are comparable among each other.

The initial definition of conditions for testing of rail materials and welding methods on different test rigs are being described in the Annexes.

2.2.3 Data obtained (Output) and evaluation of results

Finally an output of the tests is being defined. It consists of a reporting about the tests, initial and intermedial wear and profile measurements and a final metallurgical examination of the material properties.

It was agreed that cracks over 3-4mm in penetrated depth cannot be removed economically e.g. by grinding. Such rails require replacement instead. This is an upper limit on the sizes of interest.

The lower limit was less clearly defined, but could be taken as the size at which cracks can be observed using a replica of the rail or test disc surface, giving a lower limit of 100-200μm.

A subsequent numerical evaluation of the worn profiles, forces etc. seems to be necessary in order to evaluate and compare the pressures and stresses during the tests. The methods of evaluation will be derived from existing models of stress distribution and plastic deformation by the project partners. Details are described in ANNEX 4.

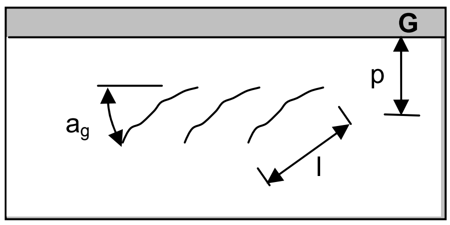
2.3 WP 4.3 test matrix

2.3.1 Inputs

Parameter	Overall test conditions, (derived from operator's observations)	Special test conditions, derived from the capabilities of each test rig		
	(All rigs)	**1. DB Rig C**	**2. VAS RSP**	**3. Twin disc**
A: Fixed conditions				
Rail profile	60 E2	60 E2	60 E2	N/A
Rail Inclination	1:40	1:40 or higher	1:40 or any other	N/A
Wheel Profile	S1002	S1002	S1002	N/A
Wheel Steel	R7	R7 or R8 (R9)	R7 (R8, R9 possible)	R7
Longitudinal Slip	Calculate from speed differential	none Limited		Controllable
Lubrication	Water (needs measuring)	Water	Water	Water/Dry
Lateral load	As per equipment (needs measuring)	low (<10 kN)	40 kN or lower	None
B: Variable conditions				
Vertical Load	up to 22.5 t axle load[1]	80 kN and 150 kN per wheel	200 kN and 150 kN per wheel	Equivalent contact pressure
Angle of attack	variable	0°, 0.25° and/or other (to be confirmed)	0°, 0.25°	0°
Rail steels	260, R350 HT, 400HB	R260, R350 HT (400 HB)	R260, R350 HT, 400HB	260, 350 HT, 400HB

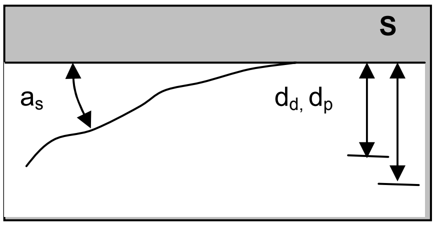
[1] All forces regarding the rolling contact will be given in kN. Only the axle loads of a vehicle or the total loads of a railway line will be given in t, MGT etc. because of older rail way conventions. A number of 10 can be used as approximate conversion factor.

2.3.2 Outputs

Parameter	Requirements for observation	Special requirements for observation at the different test rigs		
	(All rigs)	**1. DB Rig C**	**2. VAS RSP**	**3. Twin disc**
C: Outputs to be documented during testing				
Environmental conditions	Air temperature & humidity	Temperature of contact partners (if possible)		none
Wear rate	Wear measurement	wear vs. no of cycles for both wheel and rail		Mass loss
Profile data	Profile (coordinate) measurement	Profile loss by coordinate measuring machine (rail + wheel)		Diameter loss
RCF	Document the initiation and growth of cracks. A definition of crack initiation is still needed.	numbers of load cycles and cumulative loading Period to initiation Eddy current testing (if applicable).		
Crack parameters [2]	Document the final status of cracks	Photographic documentation, **p** - Position of cracks in mm, i.e. distance between gauge corner G and center of cracks. **a_g** - angle of cracks i.e. angle between gauge corner G and visible direction of cracks **l** – (visible) length of cracks in mm These measures can be seen in top view: 		Photographic documentation
		d -Crack density, i.e. cracks per 10 mm.		

[2] The measurement of the position, sizes and angles of head checks will be defined at the WP meeting in October 2007 on the basis of the "blue book" [1] and other related documents.

2.3.2. Outputs (continued)

Parameter	Requirements for obser-vation	Special requirements for observation at the different test rigs		
	(All rigs)	**1. DB Rig C**	**2. VAS RSP**	**3. Twin disc**
D: Outputs to be documented after metallographical examination				
Results of metallographi-cal examina-tion[3]	Document the structure of cracks and deformation within the rail material	**a_s**- Angle of cracks i.e. angle related to rail surface S. **d_d** - depth of crack penetration d_d in mm i.e. thickness of damaged material **d_p** – characterisation of microhardness and/or plastic defor-mation in mm (if applicable) These measures can be seen in a vertical cross section view:  		
E: Outputs to be evaluated by numerical simulation				
Numerical simulation	Determine the shear stresses and pressures on the basis of the profiles measured	Compare the pressure/shear stresses of the different test rigs Determine the location of maximum pressure/maximum shear stress Determine additional parameters (slip, friction etc.)		
Assessment of available predictive models	Prediction of Wear and RCF initiation and Growth	The tests planned in WP4.3 provide well controlled inputs and closely monitored test conditions and include the contribution of steel composition from the various grades, it is the ideal environment to establish the efficacy of predictive models. Corus will undertake “blind prediction” of the results from these tests using its own developed models. The scientific analysis of the tests to be undertaken by UoN (and possibly by Chalmers and TUD) should also provide some guidance on predictability of wear and RCF under such controlled conditions.		

[3] See previous footnote

3. Next steps

The following table shows the tasks in order to prepare a testing matrix and to perform first test rig measurements. The tasks are appointed within the workgroup in order to prepare, to conduct and to document the tests as well as to compare and evaluate the results of testing.

Work to be done	Who?	When?
Confirm deliverable report D4.3.1, final draft	all	30-05-07
Additional remarks	all	15-06-07
Release report as D4.3.1	DB	End of June
Drafted version of D4.3.2: Establish relevant material properties tests	Corus	End of July
Comments (if nesc.)	all except DB	August 10
Final version of D4.3.2	Corus	End of August
Send data to TUD, Chalmers	DB (VAS). UoN	ASAP
Appoint data exchange for numerical simulations (to be done step by step, DB will answer within 2 weeks)	Chalmers TUD	Report at next meeting
Perform preliminary test at DB full scale test rig (has already been done in April 07)	DB	Report end of August
Perform 1st test series at full scale (VAS)	VAS	Autumn 07
Prepare twin disc machine for testing (UoN)	UoN	Ok
Derive similarity conditions for twin disc tests from known mechanical models	UoN Ha	s already been done
Invite to Autumn meeting at 16 Oct. 2007	**Jay J. (Corus) Detlev U. (DB)**	**Early Sept.**
Reconsider established models	all	Next meeting
Report on tests and test machine (if progressed)	VAS, UoN, DB	Next meeting
Appointment on exchange of measurement data	all	Next meeting
Long term planning		
Plan and perform additional test series (if required)	DB/VAS	End 2007
Perform twin disk tests	UoN	End 2007
Compare and evaluate results	Chalmers,TUD	to be defined
Reconsider results, review report	all	Jan. 2008 meeting
Report on test results D4.3.3.	DB/VAS/UoN	March 2008

4. Bibliography

The features of the different test rigs have been described in several publications. They will not be further explained in the annexes.

For the definition of RCF in rails:

1. Rolling Contact Fatigue in Rails; A Guide to Current understanding an practice. Produced by RAIL-TRACK PLC, Issue 1, Heron Press Birmingham, February 2001,

For the twin disk tests (UoN):

2. FLETCHER DI & BEYNON JH, Development of a machine for closely controlled rolling contact fatigue and wear testing, Journal of Testing and Evaluation, 2000, 267-275.

For the VAS full scale test rig:

3. EADIE D, ELVIDGE D, OLDKNOW K, STOCK R, POINTNER P, KALOUSEK J & KLAUSER P, The effects of top of rail friction modifier on wear and rolling contact fatigue: full scale rail-wheel test rig evaluation, analysis and modelling, CM2006 – Proceeding 7th international conference on contact mechanics and wear of rail/wheel systems, pp 411 – 419, 2006.

For the DB full scale test rigs:

4. ULLRICH D & LUKE M, Simulating rolling-contact fatigue and wear on a wheel/rail simulation test rig, WCRR 2001 – Proceedings 5th World Congress on Railway Research, Cologne, Germany, 2001.
5. ULLRICH D, MAEDLER K & ZOLL A, Testing of wheel/rail technologies on test rigs and in operational trials, RTR - Railway Technical Review 04/2005, pp 29-33.
6. Test Report DB 05-P-0037-TZF93-FE-0631_E, Validation of crack initialisation (head checks) on the RASP wheel/rail test rig Work package 4.1 in "NOVUM – Rail Track Performance" (DEUFRAKO Project), 2005.

5. Annexes

5.1 ANNEX 1: Description of twin disk rail material testing (UoN)

Contributed by Francis Franklin UoN

5.1.1 SUROS Twin-Disc Machine

The SUROS twin-disc machine has been designed to simulate a wheel in rolling/sliding contact with a rail. The disc diameter is typically about 47mm, suitable for machining disc specimens from real rail and wheel sections [2]. The rail disc is driven at fixed speed by the lathe, and the wheel disc is driven by an A/C motor; the speed of the wheel disc, and thus the relative (longitudinal) slip, can therefore by controlled precisely. During testing, and eddy-current probe is used to check for cracks.

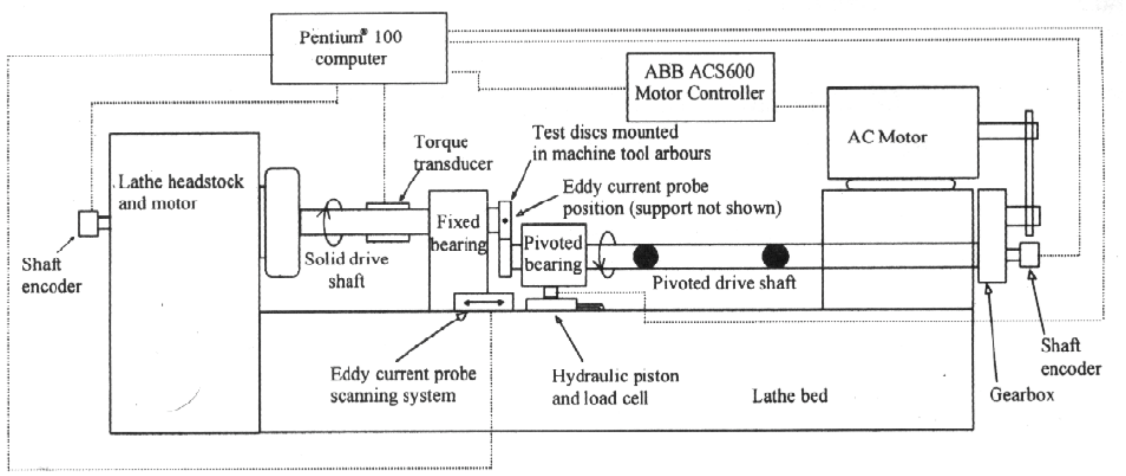


Figure A1-1: Schematic of SUROS twin-disc machine.

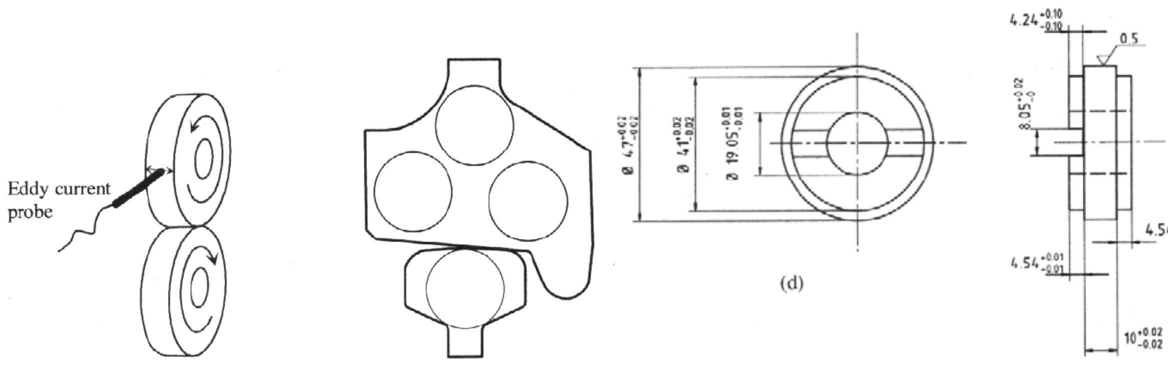


Figure A1-2: Left: Disc specimens are cut from rail and wheel sections. Right: Usual dimensions are 47mm diameter and 10mm track (running) width.

5.1.2 Proposed Tests

It is proposed to test three different rail materials (260, 350HT, 400HT – or other, as agreed by WP4.3 partners). Short sections of rail of these types will be required for manufacture of twin-disc specimens.

For each of the three selected rail steels, three twin-disc tests will be performed (i.e., a total of nine tests):

1. 5000 cycles dry (i.e., without water or other lubrication).
2. 5000 cycles dry, followed by 10000 cycles with water lubrication.
3. 10000-15000 cycles dry. (Subject to change, following analysis of earlier tests.)

Tests will be performed at contact pressure1500MPa and slip -1% (to simulate a driving wheel), conditions which have been used extensively with the SUROS machine in the past.

5.2 ANNEX 2: Description of test rig rail material testing (VAS)

Contributed by Richard Stock, VAS

5.2.1 Full scale test rig

Experimental work will be carried out on a full scale rail wheel test rig at voestalpine. This equipment was developed to provide a quick and reproducible test capability of rail wear and RCF [3].

Figure A2-1: Full scale test rig of voestalpine Schienen GmbH

A 1.5m piece of test rail is attached to a carriage which moves hydraulically underneath a common locomotive or freight wheel. The following loads can be applied to the wheel-rail contact:

- Vertical (N): up to 1.000 kN
- Lateral (Q): up to 100 kN
- Longitudinal (braking or accelerating) (T): up to 35 kN

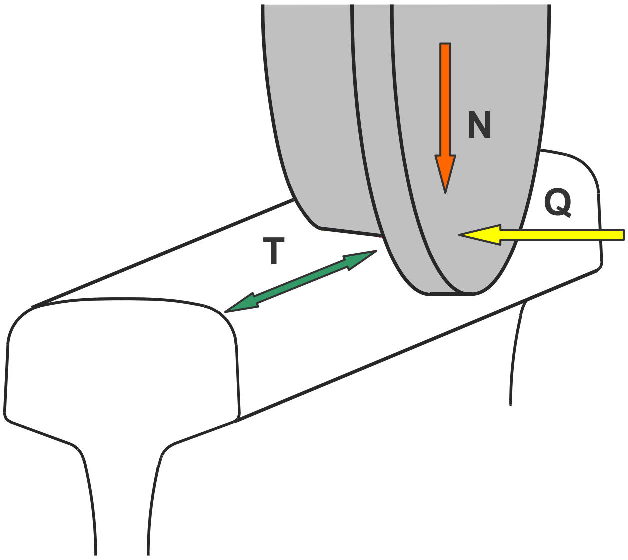


Figure A2-2: Loading conditions - forces

The angle of attack between wheel and rail can be set to either 0, 0.25 or 0.5 degrees. Rail cant is adjustable with a ribbed base plate or wedge to alter wheel-rail contact conditions.

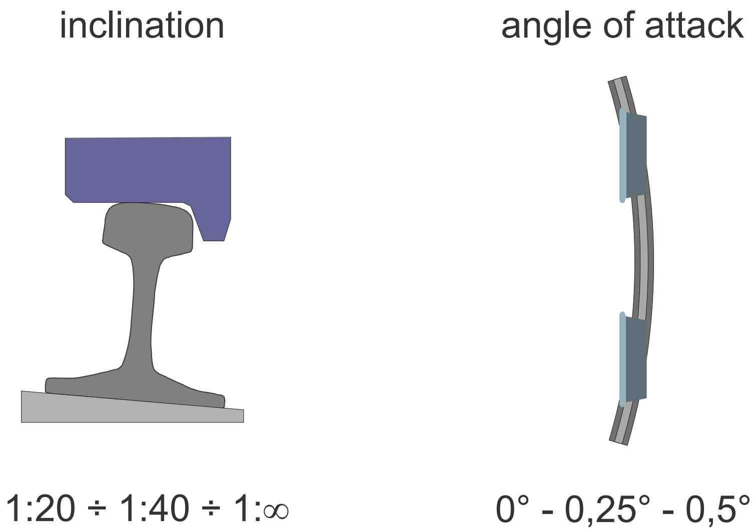


Figure A2-3: position adjustments

The loaded rail length (approx. 1m) is divided into three parts:

- The first 0.2 m in which the hydraulic system is powering up and accelerating the rail carriage (accelerating area).
- The rail test area (0.5 m) with stable load and speed conditions. All rail tests were done on this section (testing area).
- Carriage stopping distance (0.2 m – breaking area).

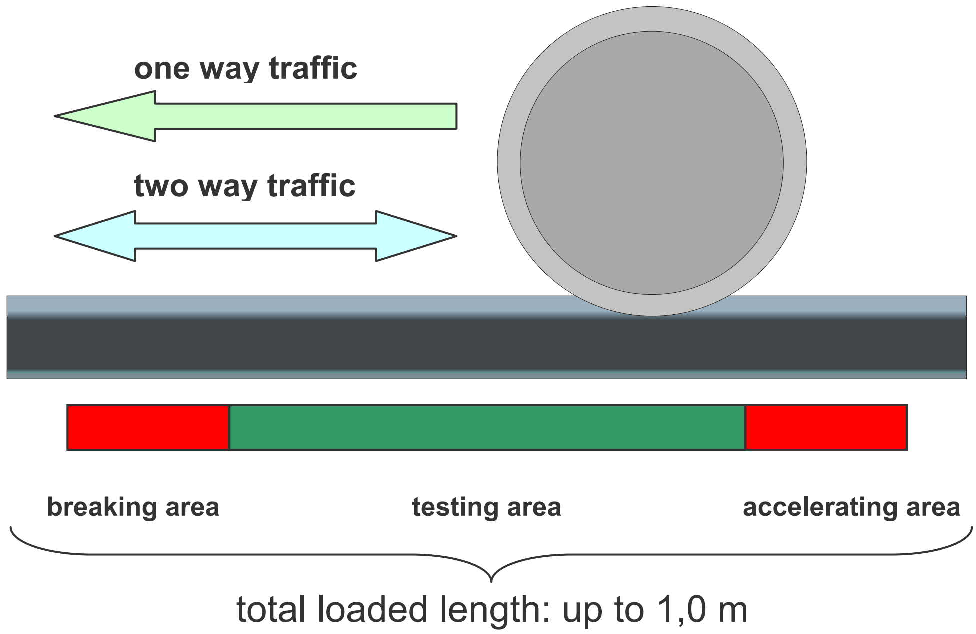


Figure A2-4: motion uni-/bi-directional

The test ri g can simulate uni-di rectional or bi -directional traffic conditions. In this wo rk onl y uni-directio nal running was simulated. For uni-directional running the wheel is lifted up while the rail carriage is returning at the end of a pass, and then gently set down on the rail to start another rolling cycle.

The speed of the test ri g is limited to 1m/s, allowing a maximum of 33,000 wheel pa sses in a 24 h our pe-riod.Forces are mea sured within the hy draulic cylin ders. Rail an d wheel p ositions a re recorded in all three dimensions with displa cement sen sors. Room temp erature an d a ir humidity are recorded d uring e ach test. All measured data is stored in a database for post processing and test evaluation.

5.3 ANNEX 3:
Description of rail on roller tests (DB)

Contributed by Detlev Ullrich, DB

5.3.1 The test rigs used

RCF at rail heads shall be examined at the test rigs C or A of DB under original size (1:1). Both the roller rigs consist of a pair of 2100-mm rail rollers upon which original sized wheelsets can unroll under axle loads up to 300 kN. The geometry of the wheel/rail contact such as angle of contact or lateral displacement can be fitted to the real conditions.

Test rig A is being used for programmable, non-steady-state wheelset simulations. It can be driven up to 310 km/h. Only the rail heads are of R260 steel grade which cannot be exchanged. Therefore other steel grades are not possible to be tested with the rig. Details of the test rig are given in reference [4]. It has been proved in the past that RCF can be observed at the rail heads as well as at the wheel threads (see refs. [5] and [6]).

Test rig B is being used for testing of wheelsets under steady state conditions or at the most slow lateral movements. It has a variable gauge width and can be driven up to 160 km/h. One aim of this work package is to use real rail heads on it and to exchange them later. For doing this the rail heads have to cut from the rail, bend into circular form and mount at the rail rollers. Details of the procedure will be given below, although it is not fully clear whether the assemblage will fit the test conditions.

An overview of the test rigs is given below:

Table A3-1: Technical data of the test rigs

		Test rig A	**Test rig C**
Wheelset	Diameter:	Up to Ø 1250 mm	Up to Ø 1250 mm
	Profile: S1002		S1002
Rail	Rail profile:	e.g. 60 E2 1:40	60 E2
	Diameter	2.100 mm	2.100 mm
	Gauge	1435 mm	variable
	Velocity	Up to 306 km/h (190 mph)	Up to 160 km/h (100 mph)
Servo-hydraulics	Contact force:	2×150 kN	2×150 kN
	Lateral force:	max. 30 kN	max. 100 kN
	Control:	Dynamic, programmable	steady state, slow lateral motion
Others	Lubrication:	Water, oil based lubricants.	Water, oil based lubricants.
	power consumption	-	can be measured
	thermal monitoring	yes	yes
Applications		Rolling contact fatigue and wear at different material Diagnosis of noise and vibrations Testing of bearings Curve squeal and lubrication	crack propagation at axles, threads and related equipment testing of bearings

5.3.2 Scope of testing

It is aimed to simulate head check initiation and growth at a roller rig.

The testing conditions shall be derived from the contact condition of the first wheelset in a bogie at a curve. It is known from the field that head checks occur in curves after sufficient time if the radiu s lies between 600 and 1000 m. Other local situations for the appearance of head checks are known, but testing should be restricted to the above mentioned conditions.

The wheels and rails should have profile shapes S1002/UIC60 1:40. The contact conditions should be characterized according to the test matrix from chapter 2.3.1 by

- vertical force
- angle of attack
- lateral force
- lubricating / moistening the contact point
- material variation

5.3.3 Situation to be tested

When a car moves through a curve the first wheelset of each bogie will form an angle of attack towards the field side as shown in fig. A3-1. Numerical simulations show that the magnitude of the angle of attack depends on the curve radius, the velocity, the wheel base and some other features of the bogie. The angle should vary between 2.5 and 4 mrad for curve radii between 600 and 1000 m.

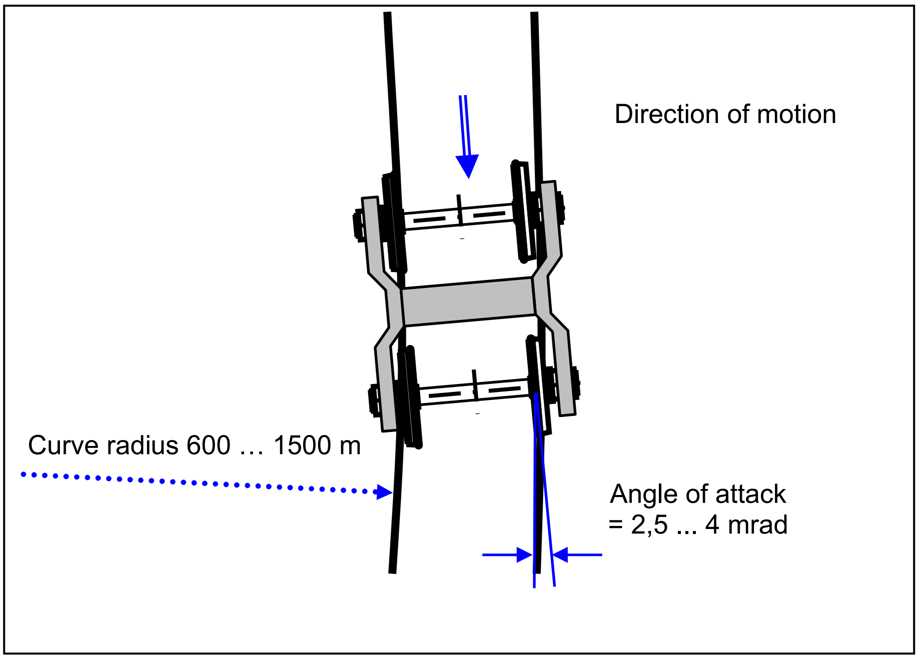


Figure A3-1: Angle of attack of 1st wheelset in a curve (top view)

Vertical and lateral forces may vary as well, depending on the inclination of the track, the suspension of the vehicle etc. It should be noted that only a reference of all these multiple influences can be given by test rig testing, the vertical load will be obtained from the axle load and the lateral force should be neglected.

It can easily be cal culated that test rig tests will provide a huge time la psing effect. Even slow rig m otion of about 1 cycle per second (about 24 km/h) will provide a load of 200 kN per cycle. As a normal DB main line achieves a daily load of 40 kt per day, this load should be reached at the rig within 2000 s or 43 times faster.

5.3.4 Test rig implementation

A wheelset of DB type 220 (used for fast regional traffic) or similar has to be mounted at the rig.

If test rig A is use d both of the wheels/rails have to be newly profiled. Test rig A can be readily used for the test, as the rail material is made of R 260.

If test rig C is being used, both parthers have to be profiled as well, but the wheel flange has to be cut by 12 mm in order to avoid damage at the fix ation of th e rail (f ig A3-2). As the re is no wheel/rail contact at the flange, the contact conditions will not be affected by the cut.

Figure A3-2: Wheel profile with cut flange

If test rig C is being used: Only one rig side is used for the test. The rail roller has to be equipped with a ring of rail materi al, primarily of R 260. It co nsists of two rail pieces which are mounted closely and will be fixed by 30 collets as can be seen in fig. A3-3. The gap between them should be less than 1 mm.

Figure A3-3: Rail head, mounted by collets

As the rail profile is not inclined at test rig C, one wheel bearing has to be lifted by about 50 mm in order to obtain an angle of 1:40 (see fig. A3-4).

The angle of attack will be simulated at the roller rigs by turning the wheelset about the vertical axis against the gauge corner in the rolling direction as shown in Fig. A3-5.

The vertical load will be 100 kN reduced by half the weight of the wheelset (~7 kN).

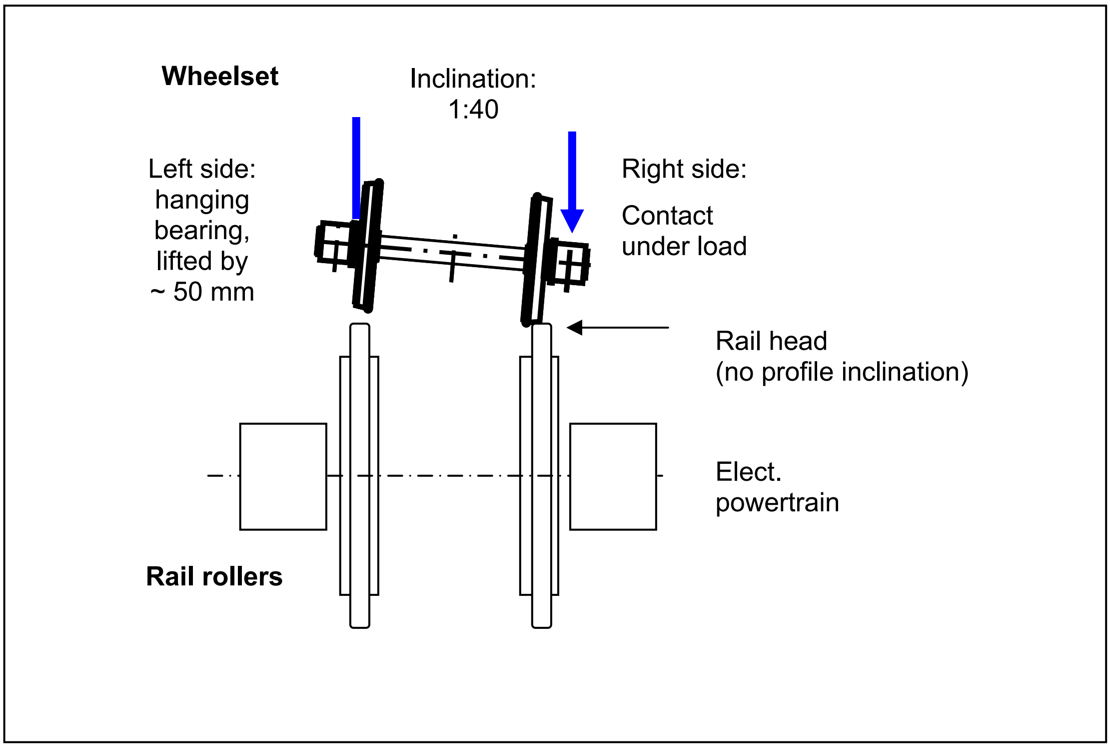


Figure A3-5: Inclined wheelset Rail head, mounted by collets (front view)

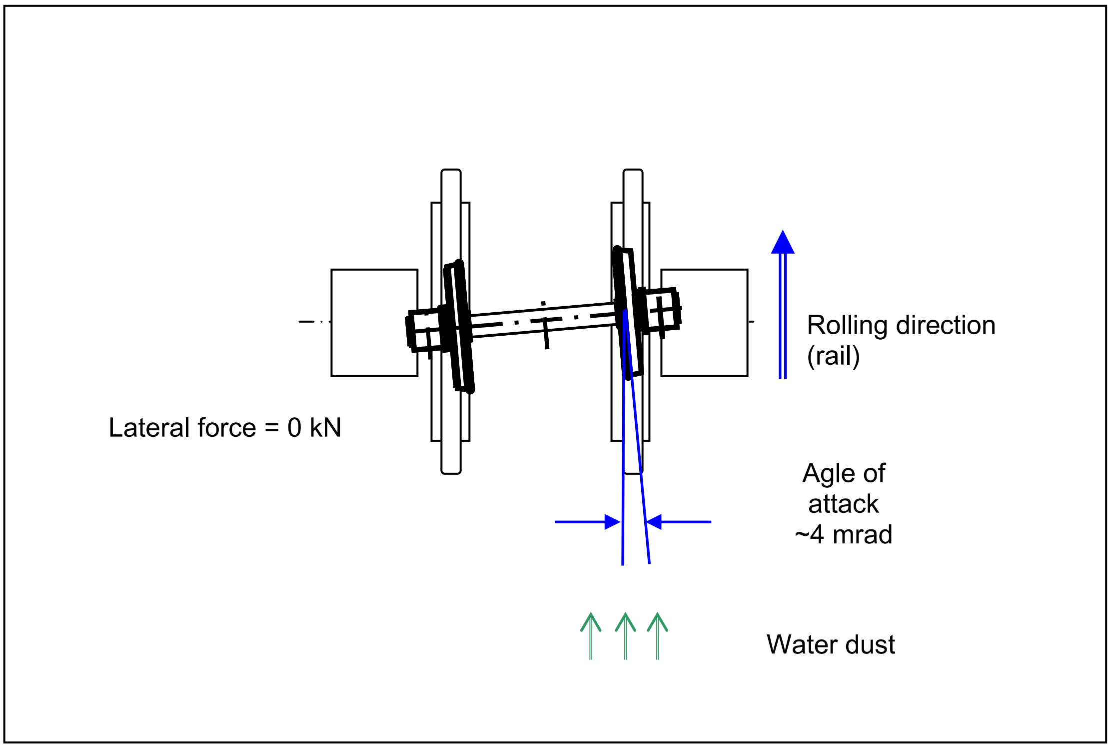


Figure A3-6: Simulation of an angle of attack at the roller rig (top view).

It is known from former roller rig tests that the contact point tends to abrasive wear under laboratory's dry conditions. By using water dust with nearly 100 % humidity near the contact point the friction coefficient could be stabilized, reducing temperature and abrasion. This way RCF, effects could be observed. Therefore it is planned to blow a dust loaded with about 5-10 g Water/min into the contact area (fig A3-7).

The overall setup of test rig C is shown in fig. A3 -8. It is expected that continuous testing of 50 – 100 h should lead to the first RCF effects.

Figure A3-7: Water-air nozzle at the roller rig

Figure A3-8: Wheel/rail positioning at the roller rig (front view).

5.4 ANNEX 4: Subsequent numerical calculations

It is proposed that TUD and Chalmers will perform numerical simulations of the full-scale tests of voestalpine and DB, and of the accompanying twin-disc tests.

5.4.1 Calculation of contact stresses

Contributed by Zili Li, TUD

As the test s will be conducted on a variety of test rigs it is necessary to interpre t and correlate the test results. For the purpose of numerical RCF prediction, the normal and tangential tractions in the contact area at locations where RCF occur need to be known.

TU Delft might perform such calculation under the as sumption of Non-Hert zian steady state rolling in the presence of f riction in elasticity. The model a ssumptions a re th at the tests are well cont rolled in a quasi steady state and that the materials may experience some small plastic deformation in the first thousands of cycles and then harden. For the majority of the contacts that follow, elasticity is a good approximation.

The calculations need the following inputs:

- Measured profiles of each contact couple and the corresponding load cycles. Care should be taken at the gauge corner and gauge face to obtain necessary point density to get the desired accuracy.
- Whe el diameter(s).
- Lateral displacement and angle of attack of the wheelset, if applicable. If combi nation of various lateral displacement and angle of attack are applied, please specify.
- Depending on the te st rig configuration, rail in clination, gauge, wheelset back-to-back distance and chamber angle of the wheel etc may be needed.
- Vertical, longitudinal and lateral wheel loads or a complete data set from which they can be derived. If combin ation of va rious lateral di splacement, an gle of attack and chamb er a ngle a re appli ed, please specify.
- Coefficient of friction (if applicable). This is im portant for accu rate calculation of the tange ntial traction.
- Material properties. By default it will be taken that Young´s modulus E = 210GPa and Poisson´s ratio 0.28. It is preferred to ha ve the materi als st rain-stress cu rves u nder cyclic lo ading to ma ke yield condition evaluation.

Parameter variations seem to be ne cessary. Due to deformation under large load, the real contact locations may for some test rigs deviate from those calculated under the ‘ideal’ rigid body assumption, while data lack for a realisti c deform able body calcul ation. Since what are i nterested are th e traction s at l ocations where RCF occurs, a practical approach will be taken.

Take the DB test rig as an example:

Calculate the "ideal" conta ct con ditions starting from the profile shapes and the position m easured. Th en, apply deviations by 1 and 2 mm laterall y and, say 1 and 2 mrad chamber angle (of the wheel) to it. The deviations must be applied only to the direction given by the forces applied. This would provide a number of up to 9 diffe rent contact situations. Some of them might be obviously implausible. The other ones form an area of uncertainty which should be investigated further by (some of) the test partners.

The following outputs are expected from the abovementioned calculations:

- Normal and tangential traction in the contact area of the different test rigs.
- Location of maximum pressure/maximum shear stress

- Micro-slip

5.4.2 Simulation of material deformation and RCF

Contributed by Elena Kabo, Chalmers

There are several motivations to do such simulations: In relation to task T4.3.1 "Translate site observations into laboratory validations" and task T4.3.2 "Establishing relevant material properties tests" the simulations will show similarities and differences between laboratory tests and in-field operations with respect to predicted rolling contact fatigue impact.

In addition, the simulations will increase the knowledge of the validity and accuracy of models aiming at predicting surface initiated rolling contact fatigue (RCF) of rails.

The simulations will incorporate analyses of voestalpines test-rig, DB's test-rig and twin-disc tests. Plastic deformation of the rail material will be included. Surface initiated RCF will then be predicted from evaluated stresses and strains.

The wheel--rail contact load will be applied either in the form of evaluated contact stresses. If these are not available they will be evaluated from the contact geometries, the relative position between wheel and rail and the acting forces (see 5.4.1).

Needed input will be

> Material response of the rail material in the form of \sigma--\epsilon curves in cyclic loading. These will be used to calibrate an elasto-plastic constitutive model (including non-linear kinematic hardening to allow for the analysis of ratcheting) of the rail steel. Contact pressures, including tractive stresses in longitudinal and lateral directions at load passes
>
> or
>
> Contact forces including tractive forces in longitudinal and lateral directions, and wheel and rail geometries and relative positions between wheel and rail (preferably in the form of an indication of the centre of contact)

In order to evaluate the predictions of the model, the number of cycles to «failure» is needed. To be able to compare the different test set-ups thus requires a common and clear-cut definition of "failure". This may prove difficult. Further, in the twin-disc test the stress and strain gradients in the rail differ from the other two test rigs. This means that crack depths are not directly comparable between the cases.

Further interaction

Based on this outline, the test matrix and TU Delft's proposal for numerical simulations, Chalmers will need to establish details on input, model calibration and output. There is also a need to define the schedule.