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INDEX

WIDEM's Strategic Objectives

- Creation and validation of an innovative and rigorous methodology to design wheelsets

- Endurance strength design approach for wheels and axles which will lead to an optimisation of wheelset geometry, a reduction of un-sprung masses and an extension of maintenance intervals while meeting increasing safety and service requirements

- A new wheelset maintenance strategy based on more accurately defined inspection periods through the use of new NDT devices for railway (Compensated Resonance System)

- Optimise the design and maintenance of wheelsets, to reduce Life Cycle Cost. Wheelset loads will be measured and used to develop design guides for new axles and optimise testing regimes for existing axles

- The ultimate goal is to increase the competitiveness, capacity and availability of European railway products in the wheelsets area

General project information

WIDEM is a partly EU funded research project (Specific Targeted Research Project - STREP), the other half being funded by the consortium partners The project started in January 2005 and will end in December 2007 for a total duration of 36 months. WIDEM is coordinated by Lucchini with the assistance of UNIFE. There are 10 consortium partners

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Introduction

The economic efficiency and competitiveness of the rail transportation mode depends on safety, availability and maintenance of its individual highly loaded components such as railway wheelsets.

The WIDEM research project, partially funded by European Community in the 6th Framework Program, aims to improve efficiency and competitiveness through a fundamental re-examination of wheelset design, which in turn will facilitate improved maintenance practices.

Combining inputs from reliable service measurement of wheel-rail forces carried out by means of an innovative instrumented wheelset and extensive assessment of actual material properties, an original endurance strength design concept is developed and validated through a comprehensive testing programme on full scale wheelset prototypes.

A flexible multi-body numerical tool is also proposed to address high dynamic loading conditions in presence of wheel/rail discontinuities like wheel flats or switches. In this way possible exceptional loads linked to possible geometrical irregularities ere considered in the evaluation of the life load spectra.

Additionally, the project addresses NDT (non-destructive testing) techniques applying methods to evaluate the crack size probability of detection (POD).

Such information together with results from full-scale crack propagation tests and measured load spectra will be the basis for setting up a schedule for NDT periodicity inspection.

The research work will lead to the definition of wheelset design and testing procedures and maintenance methods to be implemented into existing standards.

This newsletter gives an overview of the progress since the project start at the beginning of 2005.

Background information

The WIDEM project is in principle a re-examination of the basic information necessary to design and validate a railway wheelset and to manage the maintenance parameters that in some way are related its design criteria.

The idea of starting this project was stimulated by the application of the new European design Standards.

As the verification of full scale fatigue limits of wheels and axles become mandatory, testing methods and interpretation methods of the results were not defined or in general were not homogeneous throughout the European Laboratories.

The technical information that can be found in the new European Standards comes from the previous UIC norms; for example, in the case of axles, is based on the so called A1N steel grade extensively tested in the past 70's by SNCF laboratories.

Over the past years these norms were surely proven to be safe when using this kind of steel grade.

In the last 20 years many new vehicles were put into service with higher and higher speeds. Vehicle weight reduction, become a must for the majority of the European train manufacturers.

Already in the 80's in Italy, the former Fiat Ferroviaria (now part of Alstom Transport) started together with Lucchini to use an alloy steel grade (30NiCrMoV12) for the new axle of the first Italian Tilting Train.

In this case design methods based on the manufacturers' internal experience were used to handle this material.

Also in this case the applied design was proven to be safe by years of service.

The new European Standards enable the use of materials different from E1N, but not so much of the latest experience and knowledge in using new material and in designing new advanced vehicles was considered when writing these norms.

For the above mentioned reasons, today, from a formal point of view, it becomes difficult for the designer to define more precise load spectra and material characteristics that can be accepted by an authority responsible to approve the qualification of a new component.

Impacts of the Project objectives on Industry - Point of view of the System integrators

Objective

The objective of this paper is to define the impact of WIDEM on the system integrator side.

The expected benefits which can be obtained are a reduction of the wheelset mass of 20% and an increase of the periodicity of the ultrasonic inspection from 300.000 to 450.000km. Are these results useful for the system integrator? The impact is to be considered at construction, operation and maintenance level.

State of the art

For the integrator the first issue concerning wheelset is safety :

The existing referential wheelset standards in European Community is more or less issued from reports of ERRI B136.

These design rules are all issued from the experience of the railways administrations however there is no direct notion of reliability in the global axle assessments, design rules are based on a pass or fail criteria, although reliability notions are present in the admissible stresses for the axle. It means that a non compliance with a criteria is a non acceptance of the corresponding product.

For example for axle:

− A method to determine the efforts applied on the axle, corresponding torques according rolling stock parameters.

− Recommendation on the axle :

▪ geometry of the axle shape.

▪ Press fitted interface requirement.

− Value of admissible stress for one material and a method for these values determination.

It means that a new global method of wheelset design shall be compared accurately and validated according to the existing referential. It is one main interest of WIDEM project to give a global method of designing and maintaining a wheelset.

Link to safety are based on compliance with the state of the art standards and not to forget, the certification and acceptance procedure throughout EC is an important thing for integrator because rolling stock have to be interoperable and developments are less and less focused on one customer.

Up to now acceptance procedure are not the same according the operator EU. It is based obviously on a reference of common standards, however some points are completed by operator technical specifications. It means that for the same application wheelset are different according countries on one hand and certification costs are important on other hand.

For the system integrator, the second issue is rolling stock cost according to customer technical specification of performance. The cost is obviously the cost of the rolling stock itself however also the impact on the system i.e. operation and maintenance.

<u>Wheelset mass saving interest</u>

The saving of mass is and important issue for system integrator, the assessment of the project is :

−   at constant safety we save 200kg.

(what does "at constant safety" means exactly today! Because we have now no safety criteria in term of failure probability).

This mass has an influence at two levels : overall masses of the rolling stock (axleload) and unsprung masses.

<u>Overall mass of rolling stock</u>**.**

Wheelset has a medium impact on the axleload and the mass saving can be used by system integrator on different ways. We will take an example of a 15t axleload vehicle 200kg per wheelset represents a mass saving of 1,3%. Three possibilities is offered to the integrator :

−   to decrease axleload of the rolling stock which is interesting for the life cycle cost of rolling stock and tracks.

−   to increase payload staying with the same axleload which is interesting for the operators.

−   to decrease the rolling stock cost by avoiding to use expensive light material instead of conventional steel mainly in the carbody interior or sometimes light alloy parts in the bogie.

<u>Cost of the vehicle</u>

Concerning the cost of the wheelset mass saving should have a positive impact however difficult to evaluate.

An important point for the system integrator is written in the state of the art. The wheelset standardisation can be applied at several levels : interoperability interface, acceptance criteria and certification, parts interface and parts all these aspects particularly at component level standardisation is a driver for reducing construction cost.

<u>Life cycle cost</u>

This cost is shared in two parts infrastructure and operation.

<u>Infrastructure, track damaging criteria</u>

The track damage is function on one hand of the vertical forces on the track generated the rolling stock which are related to axle load.

Axle load in vertical direction

Guiding forces in the wheel rail contact plane.

Wheel wear is related to the energy dissipated in the contact patch, usually expressed as the product of the creep force (T) and the creepage (γ). The creepage is mostly depending on :

−   the position of the wheel in the track (yaw angle and offset) which is related to the links between axleboxes and bogie frame).

−   the wheel and rail profile.

– the wheel rail friction coefficient.

If we consider a given configuration of primary suspension, wheel rail profile and friction coefficient, a parametric analysis in quasistatic curving in 300m curve shows that variation of 10% or –10% of non suspended mass (in this case 1446 Kg) doesn't gives any significant results for guiding forces and track shift forces. See table 8.1.2

Vehicle configuration	Guiding force variation in %	Track shift force variation in %	Profile wear variation in %
Reference	1	1,00	1,00
Unsprung mass +10%	1,05	1,01	1,01
Unsprung mass –10%	0,95	1,00	0,99
Cx & Cy new*	1,14	1,05	1,05
Unsprung mass +10%	1,18	1,06	1,05
Unsprung mass –10%	1,07	1,04	1,04

Table 8.1.2

* Cx and Cy are primary longitudinal and lateral stiffness.

Life cycle cost, operation cost.

Wheel wear

Wheel wear as seen in the next paragraph this 10% gives only small variation of this index. A variation of the primary longitudinal and lateral stiffness has a far more important impact.

One important point concerning wheel life cycle cost is the wear radius of the wheel which is generally between 30 and 40mm (50mm in extreme case). The mass saving can be used to increase admissible wheel wear radius only if low part gage constraint and other integration constraint concerning transmission and braking … are taken into consideration in the vehicle design.

Maintenance parts

For rolling stock maintenance the cost and reduction of parts number is an important issue.

Modbogie subproject had treated partially this topic on maintenance parts standardisation which includes wheelset and gives some recommendations for Interoperable high speed train and locomotive applications.

Braking

The impact of braking energy given by a mass decrease of 200kg per axle is existing however seems to be low in term of friction wear and life duration even if the mass considered is rotating.
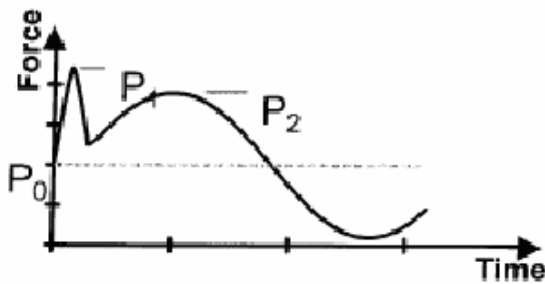
Energy

Concerning energy consumption, to find relevant information is difficult. One Figures, written in a paper of British railway review "Modern Railways May 2008: Vol65 N°716 p59, comes from one operator Ian Walmsley who is Engineering Development Manager at Porterbrook . The following evaluation was : "*the energy needed to carry around one tonne of train mass for 100 miles is about 3,4kilowatt hours. This translate to about £200 per year to which we need to add the track access charge which is another £576 per tonne and per year*"

Unsprung mass saving.

Track damaging criteria

The main damage to the track is the dynamic effect of the unsprung mass which is named the "hammer blow" effect and cause large impact forces. These forces occurs in vertical when there is a track local defect or a flat on the wheel surface and in lateral at discrete events when there is a change of direction (switches crossing,.

On a theoretical point of view this point was treated formerly by British Rail with a simplified vertical model named P2.

P0 is the static load of the wheel, P1 the first peak which appears in the gradient discontinuity is the wheel rail effort taking into consideration the herzian stiffness and P2 the second peak taking into consideration the track stiffness including rail, sleepers and ballast.

$$P_2 = P_0 + 2\alpha V \sqrt{\frac{m_u}{m_u + m_t}} \times \left(1 - \frac{c_t \pi}{4\sqrt{k_t(m_u + m_t)}}\right) \times \sqrt{k_t m_u}$$
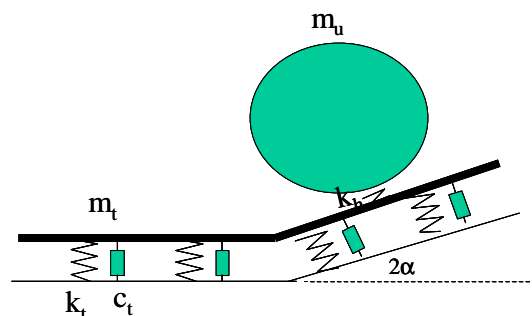
Where

2α = the total joint angle (radians)

V = the vehicle speed (m/s)

k_H = the Hertzian contact stiffness (N/m)

m_u = the vehicle unsprung mass (kg/wheel)

m_t = the effective track mass (kg)

c_t = the effective track damping (Ns/m)

k_t = the effective track stiffness (N/m).

For the lateral impact the same approach exists.

$$F = \left(1 - \frac{\pi c}{2}\right)\alpha V \sqrt{k_t m_u}$$

Where

α = the kink angle (radians) (change of direction)

V = the vehicle speed (m/s)

m_u = the vehicle unsprung mass (kg)

k_t = the lateral track stiffness (N/m)

c = the ratio to critical of the track damping

In both model the effort is depending on the square root of the unsprung mass.

In the same vehicle and track configuration, if we consider variation of + or –10% of unsprung mass, we have roughly +/-5%. This value has no direct signification in term of cost. The important aspect after these simple theoretical consideration is the impact on the wheel and track wear.

These aspects are related to the global system in which vehicle track interface in given conditions of operation are in study especially in UK. Vehicle track interface strategic model have been developed to evaluate the global impact on wear and rail contact fatigue (RCF). These studies will without any doubt have an impact on track access charge in the next years.

<u>Increase of US inspection periodicity</u>

Maintenance

The impact of WIDEM is to increase the periodicity of axle US inspection. The result is to an increase of the periodicity of the ultrasonic inspection from 300.000 to 450.000km.

This inspection in workshop need at minimum :

− to disconnect device fixed on the axlebox end cover,

− to dismount axlebox end cover, remove seals .., axle end equipment device WSP and axle end cup on one or two sides of the axle depending on the case,

− to make the US inspection,

− to remount the parts and change the seals and reconnect the device.

This operation need for a trainset of approximately an average of 16 man hours and a one day trainset immobilisation in shop.

In addition, to increase the periodicity of US inspection brings more flexibility to maintenance and allow to optimise it by doing other operations.

WP1 The accuracy in measuring wheel-rail dynamic loads

Main task

Measuring wheel-rail dynamic loads is today a very approximate exercise because of: inadequate technology of the instrumented wheelset (telemetry, data processing and self powering) static calibration of the measuring system which does not reflect the actual service conditions.

The WIDEM project has developed an innovative measuring wheelset made of up to date wireless data processing and transmission technology. A dynamic calibration is performed by using a unique roller rig on which running conditions near to reality can be simulated.

A mathematical calibration approach enables to turn the measured strains into vertical, lateral and longitudinal force components by optimising a transfer matrix.

The final result is the possibility of improving and verifying the actual accuracy of the measuring system, together with a robust telemetry data transmission system.

Main achievements

In this Work-package two different instrumented wheesets were prepared, calibrated on the Lucchini roller rig BU300. One wheelset was an Alstom Pendolino ETR480 trailer wheelset and the other one was a 30ton freight whelset.
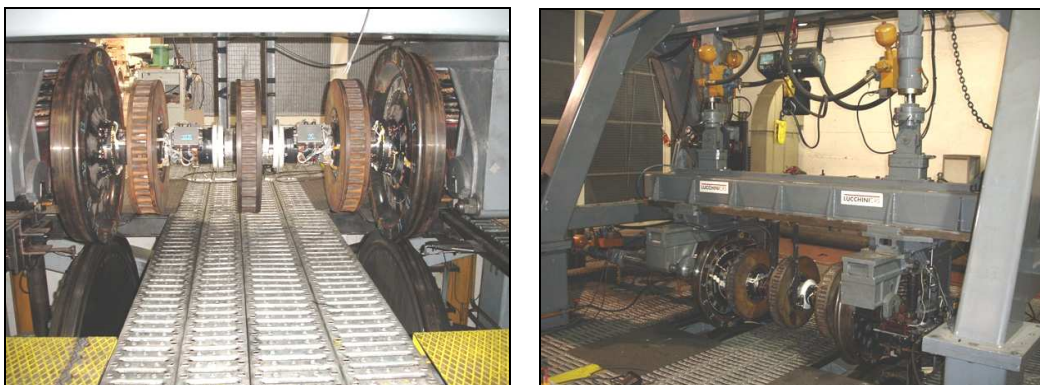
POLIMI and Lucchini, have developed a new real-time measurement methodology of wheel – rail contact forces based on the acquisition of axle deformations having a bandwidth of about 70Hz.

Specifically for the Pendolino wheelset, Alstom installed on the wheel webs a measuring system for the evaluation of lateral forces acting on each wheel.

The measuring system consists in a particular application of the existing measuring system (already used by Alstom for several years) that should improve the accuracy of the measurement.

All together there are 30 strain gauges channels acquired by a telemetry system. Together with a traditional analogue-multichannel telemetry, an innovative one based on digital transmission is developed to improve data transmission robustness.

The innovative calibration procedure applied with the roller rig enable to optimize the accuracy of the measurement system reducing errors related for example to the variation of the wheel / rail contact point.

BU300, the Lucchini full-scale wheelset test rig with

the Czech Pendolino instrumented wheelset during calibration tests.

WP2 Wheel-Rail load test campaigns

Main Tasks

The main task was to collect load data for two different vehicles to be used as a basis for the definition of load spectra.. The results are intended to become the basis for defining a common standard method for the definition of wheelsets load spectra to be used in the design and in the service-NDT periodicity evaluation.
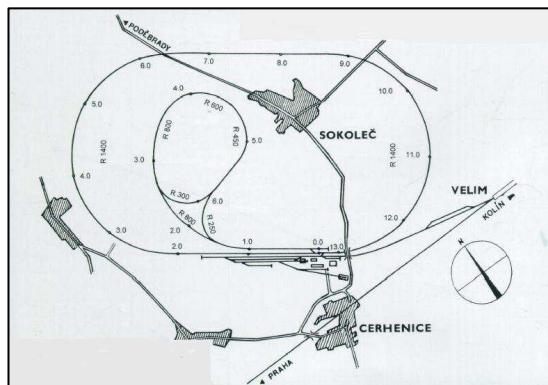
Main achievements

The first innovative instrumented wheelset developed in WP1 was mounted on a Czech Pendolino vehicle and load measurements together with accelerations, speed and GPS coordinates were recorded on various Czech railway routes across the country. Additionally, specific tests were performed on the VUZ railway circuit based in Velim. Here, loads were measured in presence of switches, rail defects and artificial wheel flats made on the instrumented wheelset.

VUZ was involved in the organization of the in service tests with the Czech Pendolino Trainset along the Czech railway track and their unique railway testing circuit.

To evaluate the corresponding load increase due to geometrical irregularities of the wheel, artificial defects on wheels rolling surface were produced.

Czech Pendolino trainset

VUZ railway test circuit – Velim

Wheel / rail load and acceleration

Switch profile measurements measurements during passage over switch

The second test campaign will be performed in Sweden on the MTAB heavy haul vehicles from Kiruna to Narwik. With its current fleet of locomotives and cars, MTAB has a mine-to-harbour freight capacity of more than 23 million tonnes per year. This corresponds to about 7,000 fully loaded ore trains per year. Advancements in rolling-stock technology mean that the chain of ore logistics can be utilised with greater efficiency, with locomotives that can haul longer, heavier trains. The objective of reducing transport costs is achieved by investing in new locomotives and cars with a 30-tonne axle load. The second instrumented instrumented wheelset was mounted on one of these vehicles to measure load spectra in these rather quite extreme conditions.
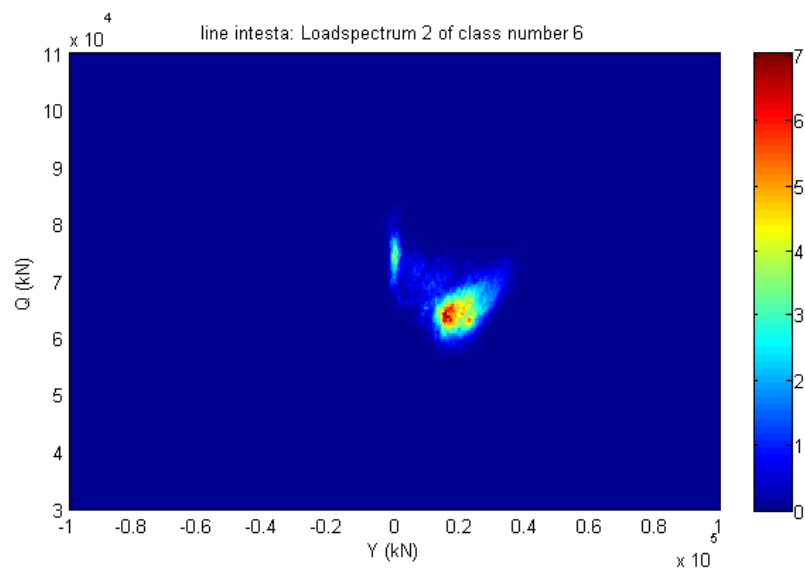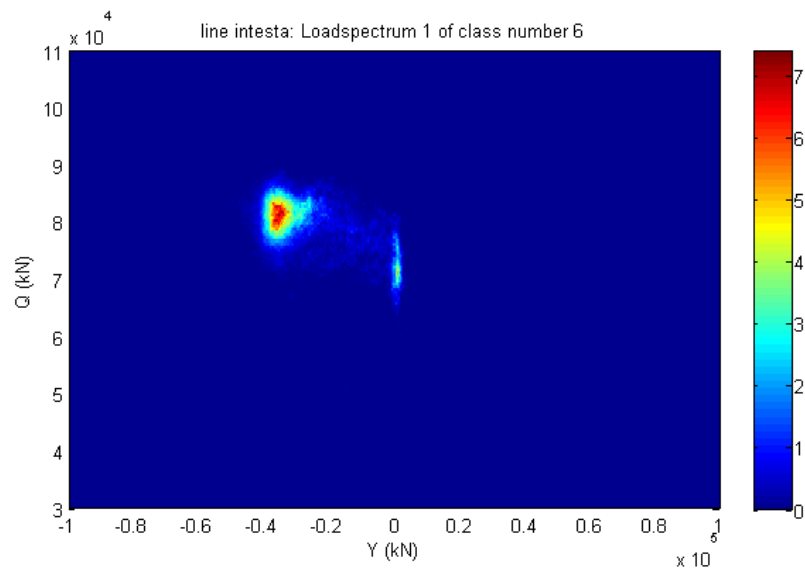

One of MTAB cars with 30 tonne axle load

Following the measurement campaigns, a specific software was developed to extract the measured strains on the axle and calculate the contact forces on the wheel (normal, longitudinal and lateral forces) and in a second step, to detect in the measured signals when the vehicle was in a curve and when it was in a straight line with the help of the gyroscope signal.

The software is able to calculate the radius of the curves with the value of the yaw speed and the vehicle velocity. With these elements in hand, the software can cut the signal following depending on the kind of running condition (curves left or right, radius and non-compensated acceleration; straight lines of different speed; presence of defects of different speed).

For each running condition, the software is then able to compute load spectra. The load spectra is a distribution of the number of wheel rotations that the wheel undergoes for different vertical/lateral load combination and is presented as a matrix of values where the vales are the wheels rotations and the indices correspond to vertical and lateral load level. An example of load spectra is given on the figure below. It comes from measurement on the Pendolino train for a right curve with a radius between 300 and 600 m and non-compensated acceleration between 1 and 1.5 m/s². The picture above is the load spectrum on the left wheel and the picture below is the load spectrum on the right wheel.

This information is then used in the new design method of railway wheels.

line intesta: Loadspectrum 1 of class number 6

line intesta: Loadspectrum 2 of class number 6

Example of load spectra for a right curve on the Pendolino train (right wheel above, left wheel below)

WP3 Improving Flexible Multibody Models to understand the vehicle track interaction

Main tasks

In this workpackage, POLIMI further developed their Flexible Multibody Vehicle model which is now able take into account the deformability of both the wheelsets and the bogies as well as the carbody and the track.

While the deformability of wheelsets, bogies and carbody is taken into account through a modal superposition approach, the deformability of the track is accounted for through a FEA model of the railroad.

Together with concentrated defects, the passage of switches represents the most challenging service condition for the wheelset, in terms of peak values of wheel-rail contact forces. Therefore, the correct simulation of these running conditions assumes critical importance in order to reproduce correctly the extreme values of the load spectra.

Also, these are the loading conditions that show the highest sensibility to track flexibility.

From a more general point of view, this modelling work aims to establish the effect of wheel and rail defects on wheel-rail contact forces, in terms of dynamic amplification factors expressed as function of a specific geometrical parameter describing the defect and as a function of speed.

Tests performed on the Alstom tilting train will be the basis for the validation of this kind of modelling.

Finally, validated Flexible Multibody Vehicle models should become a tool to evaluate corrections to be applied to nominal load spectra to be used in the design of a wheelset which includes possible high loads that can be found during the life time of this component.

Main achievements

The Flexible Multibody Vehicle model was validate through the measurement performed during the test campaigns and is now able to simulate both straight/curved track running and the transit over concentrated defects and/or switches thus allowing to determine load spectra of the contact forces in any working condition.

The model was then used to determine load spectra of the contact forces in working conditions that were not possible to be measured during the experimental campaign; in this way it was possible to estimate load spectras for the design that could be representative of the complete life of the wheelset.
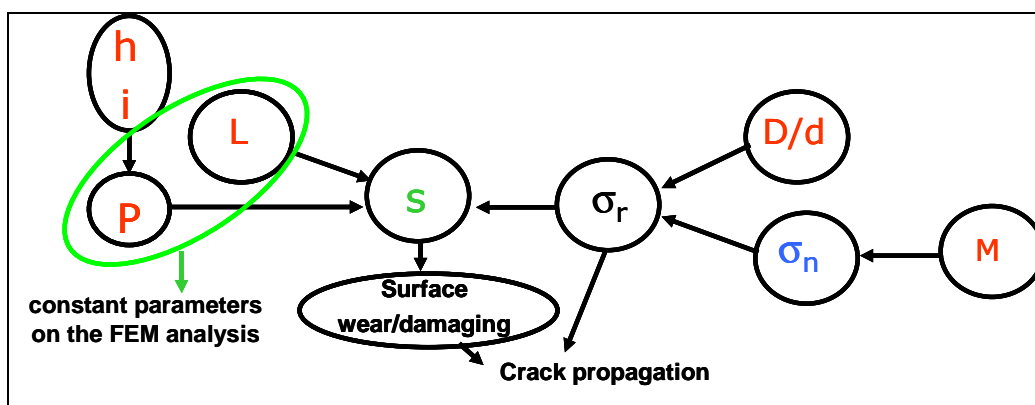
WP4 The assessment of material properties

Main tasks

the main task was to define a precise procedure to perform full scale fatigue tests on wheel and axles. The reason for this was that different laboratories throughout Europe perform tests in different ways and results are the not always comparable.

Testing experience form the past years plus a benchmark with other laboratories has enabled the definition of all the relevant parameters referred to the component geometry, the measurement of the load, and the statistical evaluation method of the test results.

From a research point of view much work is ongoing to describe better the fretting fatigue phenomena which depends on many parameters that are not carefully considered in the norms: hub thickness (h), interference (i), contact pressure (P), slip (s), axle seat length (L), axle diameter ratio (D/d), axle bending moment (M), nominal longitudinal stress (σ_n), real longitudinal stress due to bending moment (σ_r).

The following scheme shows how these parameters are related.

Lucchini fatigue test rig for axles

Example of fretting fatigue crack

Main achievements

The possibility of combining full scale experimental fatigue tests results together with FEM models representing the actual longitudinal stresses and micro-slips between hub and seat can enabled the definition of a design criteria against fretting fatigue.

By changing the main geometrical configuration (D/d), different configuration limits of σ_r and s can be found and from there a theoretical area of permissible (σ_r, s) couples could be defined.

This work was performed for A1N and A4T and 30NiCrMoV12 steel grades.

Full scale tests were brought over on the Lucchini test rigs to find the fatigue limit at 10^7 cycles for different diameter ratios with the aim of validating the above described fretting fatigue model and of defining the "D/d border": below this value cracks will appear on the axle seat, above this value cracks will appear on the body fillet. Such value will increase with the fatigue resistance of the steel grade so that it will be appropriate to define the optimal D/d for each kind of material.

In addition to the above work, a further characterization of the material enabled the definition of the Wöhler curves. to enable the application of typical endurance design methods based on Miner counting methods.

WP5 Development and validation of a new design method for wheelset

Main tasks

With the aim of optimising wheelset geometry, a new design procedure was defined. Taking advantage of new inputs such as life-representative load spectra and actual material fatigue data, first stresses will be calculated according to standard principles and then fatigue cycles accumulation theories will be added according to Endurance Design Concepts.

Main achievements

This endurance design procedure, based on load spectra and the material Wohler curves, is an alternative method to the standard method defined by UIC510.5.

The design procedure makes use of a FEM model of a wheel to which load spectra are applied.

The load spectra is a statistical distribution of vertical and lateral load combination acting on a wheel; the values of the distribution are the number of wheel rotation cycles.

A load spectra is defined for each running condition that are basically 4: straight running, flange curving (outer wheel), no flange curving (inner wheel), switch crossing.

The FEM model defines the relationship between single unit loads applied on the wheel tread and the stress in the various wheel nodes.

The application of the new procedure shows that it is possible to reduce the wheel weight of at lest 10% .

It should be underlined that the load spectra used in the calculation is representative of the Czech railway lines and of the Alsto Czec Pendolino trainset.

For a more general application of the procedure to different railway lines, the load spectra calculated for each load case can be reassembled considering the new distribution of straight line and curving running conditions.

WP6 The probability of detecting cracks in wheelsets

Introduction

Metallographic analysis made on fatigue cracks from tested axles, show that the initiation is generally from internal defects with a dimension of 20 – 100 μm.

Kitagawa-Takahashi diagrams experimentally determined by means of fatigue tests on artificially micro-notched specimens, show that the fatigue limit are strictly dependent on the dimension of defects.

On the other hand, NDT inspections made during the manufacturing process or in service are not able to identify defects or cracks smaller then 1mm. For this reason NDT inspections are required with a certain periodicity throughout the life service of a wheelset.

The possibility to define the reliability of different tests (Ultrasonic, Magnetic or Eddy currents) is the first information that is needed in a procedure to define the optimal inspection interval for an in service vehicle.

Two very different questions can be raised at this point:

What is the largest crack that the NDT equipment will not be able to see; on the basis of this dimension, crack propagation criteria are applied to determine the remaining life.

What is the probability of not detecting an existing crack and how this probability can be compared with the cost limits put on railway accidents. This probability will decrease by increasing the inspection periodicity or by improving the inspection method.
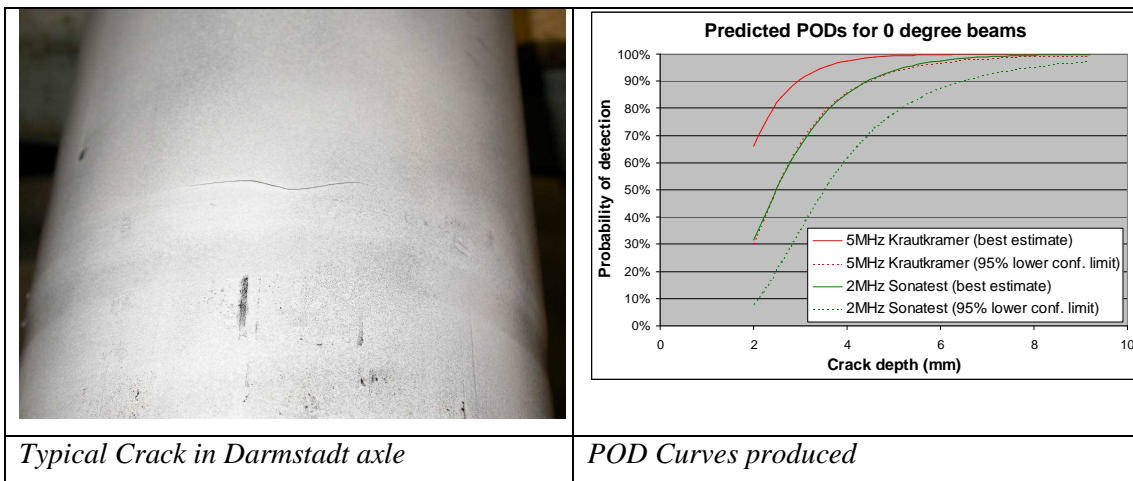
Main Task

The main task is to establish the POD for different inspection methods. and evaluate possible new tecniques like the compensated resonance inspection method.

Main Achievements

TWI produced POD curves by performing inspection tests on both fatigue tested axles and real in-service cracked axles. Collection of the latter was very difficult, fortunately because it's a very rare event However, axles from service have been collected in the UK and in Germany. Other axles with flaws have been produced in the Lucchini fatigue test rig.

The verified methods were AC, Potential Drop, Phased Array Ultrasonics and Time of flight ultrasonics to size the cracks and then the use of representative on site inspections to establish the probability of detection.

An example of the MPI indication of the crack and a POD curves are given in following figures.

Predicted PODs for 0 degree beams

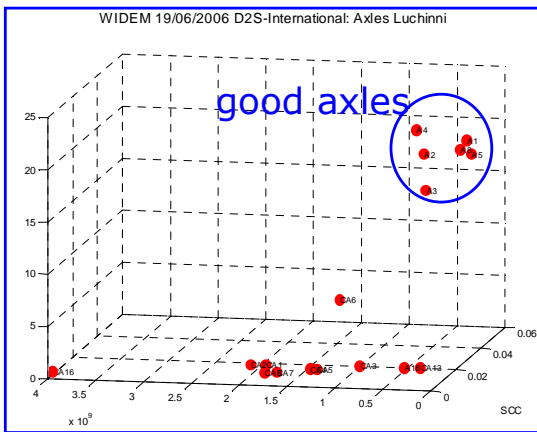|	
Typical Crack in Darmstadt axle	*POD Curves produced*

The main trials for the solid axles and the trials on the Lucchini axles are planned for autumn 2006.

D2S implemented a through a simple vibration test setup with artificial excitation and a complex analysis of the collected data in the high frequency range (10-150 kHz) are able to detect changes in the vibratory response of the structure and to correlate these changes to the presence of cracks.

D2S has integrated the ARTEMIS instrument within the scope of the project. It includes the artificial excitation, the measurement tool and the analysis methods based upon vibrational behaviour.

The ARTEMIS has been used to successfully identify cracked wheelset axles. The instrument has large capabilities for defective parts detection in following sectors: aerospace, oil, energy and transportation.

WIDEM 19/06/2006 D2S-International: Axles Luchinni

good axles

WP7 The periodicity for in service NDT inspection

Main Task

The determination of the optimal inspection periodicity is quite a new subject for the railway components.

This is the final work package in the project and requires data from all the other work packages.

The WIDEM project aims to put together all the information that are necessary to perform this evaluation.

These include a knowledge of the actual load spectra that the wheelset experiences and the material crack propagation properties.

The original idea for determination of the periodicity is to use a crack growth curve together with the probability of detection of defects/cracks. The hypothesis made, is that when NDT inspections are made in service, in some critical place a small crack exists; but the dimension is such that it can't be seen by the NDT equipment.

From this hypothetical undetected largest dimension, the crack propagation model is applied as a function of the load spectra and the number of cycles at which the crack will become critical is calculated. The Crack Propagation Software would be the well known NASGROW.

This value would be used to set the first inspection time, and other points set so that there would be multiple opportunities to detect the crack before failure.

The work performed in WIDEM was basically the experimental determination of all the material parameters necessary for using the NASGROW software plus the adaptation of the crack propagation model to take into account the rotating bending that increases the propagation speed and modifies the crack shape. Finally the full scale rotating bending test rigs were used also to validate the model by applying variable amplitude loading.

Fracture mechanics experimental tests have been carried out and used to define a stochastic propagation model able to take into account the scatter band of experimental results in the estimation of propagation lives. A set of FEM analyses were then made in order to define the differences, in terms of the constraint at the crack tip, between axles and traditional fracture mechanics specimens. A different set of FEM analyses were carried out in order to characterise the SIF (stress intensity factor) solutions for typical axles notches subjected to rotating bending. The future steps concern the introduction in the SIF solutions of the influence of press-fittings and the incorporation of all the obtained results in a crack propagation software.

Axle rack initiated by a micro notch during full-scale propagation test.	*Typical scatter in A1N experimental threshold data*	*SIF solutions for typical axles notches.*

The main material information needed for the periodicity model are the Paris curve with its constants (C, n, ΔKth), and the crack shape development. These are evaluated experimentally through constant loading – rotating bending full scale tests; the cracks were initiated by micro-notches.

With the same test rig it was be possible then to validate the propagation through variable load spectra measured in service.

An alternative point of view, is that an acceptable level of axle failures is to be set, and work backwards from this to the necessary inspection periodicity.

It is possible to implement this idea using reliability methods and setting a given probability of failure. The proposed reliability software is STRUREL, a well recognised software used for structural reliability estimation.

The following graphs show how the two models can be displayed.

Proposed method of setting the inspection periodicity	*Using probability of failure to determine inspection interval*

Main Achievements

Significant work has been completed in deriving crack growth rate parameters under both plane and rotating bending conditions. Finite element analysis have been conducted to aid selection of appropriate stress intensity factors and crack shape development including complex effects such as the presence of the seats in the axle.

The use of a reliability approach to establish periodicity for a given probability of failure is a new development for axle design.

Data on loading spectra from other work packages was processed into a format appropriate for the probabilistic model. Consideration of the acceptable target reliability based on historical axle failure data was made and also the potential impact of human error was examined.

Plan for using and disseminating the knowledge

Section 1 - Exploitable knowledge and its use					
Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
1. Vibrations based method to find defects	Testing devise	Industrial Product Inspection	2010	N/A	D2S
Instrumented wheelset with high passband	Instrumented wheelset	1. Railway Vehicle homologation and Diagnostics 2. Track homologation and Diagnostics	2007	A system patent is planned for 2006	Polimi, Lucchini
Flexible multibody vehicle model	Flexible multibody vehicle model	1. Railway vehicle design and homologation 2. Railway runnability Analysis	2007		Polimi
Wheelset load spectra	Wheelset load spectra	Wheelset design and homologation	2008		Polimi, Lucchini
Endurance design procedure	Endurance design procedure	Railway vehicle design and homologation	2008		Lucchini
Crack propagation algorithm for railway axles	Crack propagation algorithm for railway axles	Wheelset inspection intervals	2008		POLIMI
Probability of Detection Curves		Rail		N/A (will become public via RSSB)	TWI
Methodology for inspection periodicity)		Rail	From 2009		TWI/Polimio
NDT periodicity determination method	NDT periodicity determination method	Railway vehicle design and homologation	2008		Polimi, Lucchini, TWI
Material properties for classical fatigue phenomena at A1N and A4T	assessment procedure	Design purposes, Mechanical engineering	2008		LBF, Lucchini
Material properties for fretting fatigue phenomena at A1N and A4T	assessment procedure	Design purposes	2008		LBF, Lucchini
Procedure for numerical		Design purposes,	2008		LBF

evaluation of fretting fatigue		Mechanical engineering, Evaluation processes			

Section 2 – Dissemination of knowledge					
Planned/actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
M12-M24 ongoing	Updating project website with new info www.widem.org	General public	global		all
M12 – M24	Regular technical updates through various UNIFE committees, the Innovation and Harmonisation committee	Supply – industry/ UNIFE members	Mainly EU	65 UNIFE member companies	UNIFE
M12 – M24	Direct e-mailing of monthly newsletter, including updates on WIDEM	UNIFE members + business contacts	Global	500	UNIFE
June 2007	IHHA (congress on Heavy Haul) Kiruna Sweden		Global	500	All
September 2007	IWC Prague		Global	500	Lucchini, all
	Exhibition	NDT Professionals	USA	1000	D2S
Sept 2007	British Institute of NDT Annual Conference	NDT	UK	200	TWI
Nov 2007	Meeting at UIC Paris	Rail Specialists	Europe	10	Lucchini/Polimi/TWI
November 2007	7th ASTM/ESIS Conference on Fatigue and Fracture	Academic and structural integrity technicians	World		Polimi
November 2007	Engineering Fracture Mechanics Journal	Academic and structural integrity technicians	World		Polimi/ GKSS
December 2007	Journal of Rail ans Rapid Transit	Academic and structural integrity technicians	World		Polimi
October 2008	Workshop on fracture mechanics at the Politecnico di Milano.	Industry/ research	Global	2000	LBF, PoliMi, Lucchini
Oct 2008	EIS Conference (Milan)	Structural Integrity	Europe	50	TWI/Polimi

Late 2008	RSSB Website	Public	UK	Unknown	TWI
July 2009	12th Int. Conference on Fracture	Academic and structural integrity technicians	World		
2010	International Wheelset Congress	Industry/ research	Global	500	Lucchini

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Public Deliverables of the WIDEM Project can be downloaded from the WIDEM web site:

www.widem.org