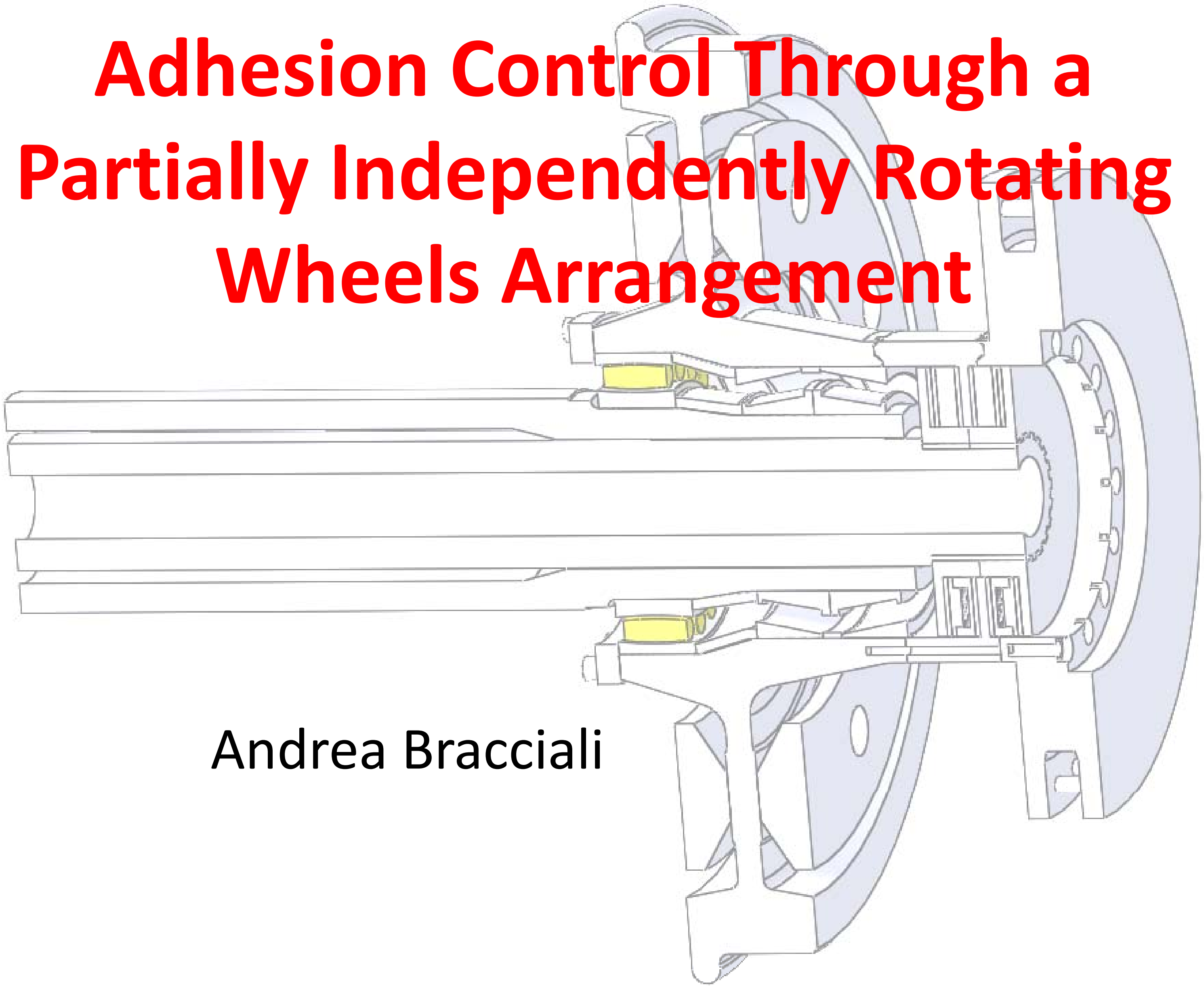
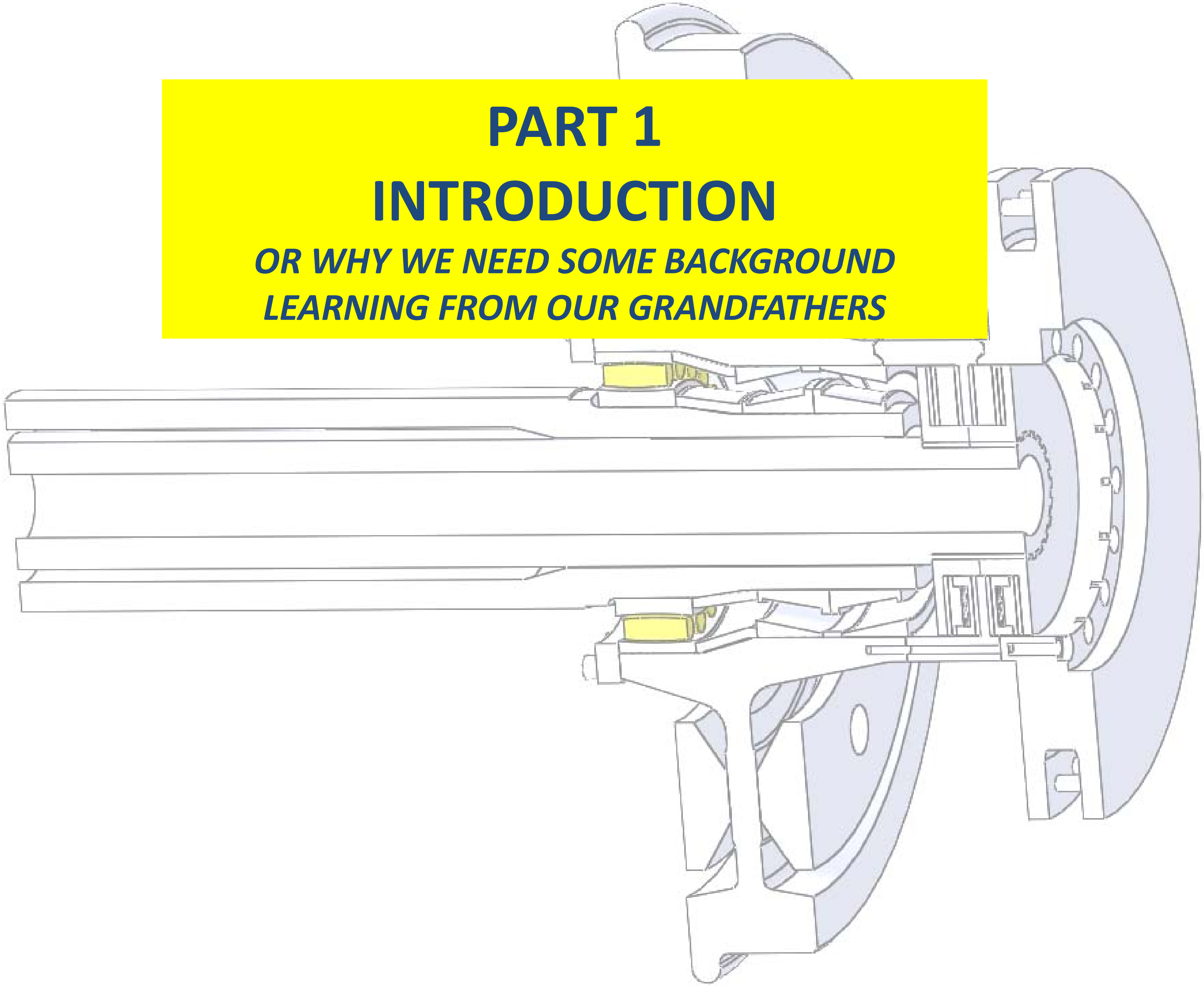
Adhesion Control Through a Partially Independently Rotating Wheels Arrangement



Andrea Bracciali

PART 1
INTRODUCTION

OR WHY WE NEED SOME BACKGROUND
LEARNING FROM OUR GRANDFATHERS

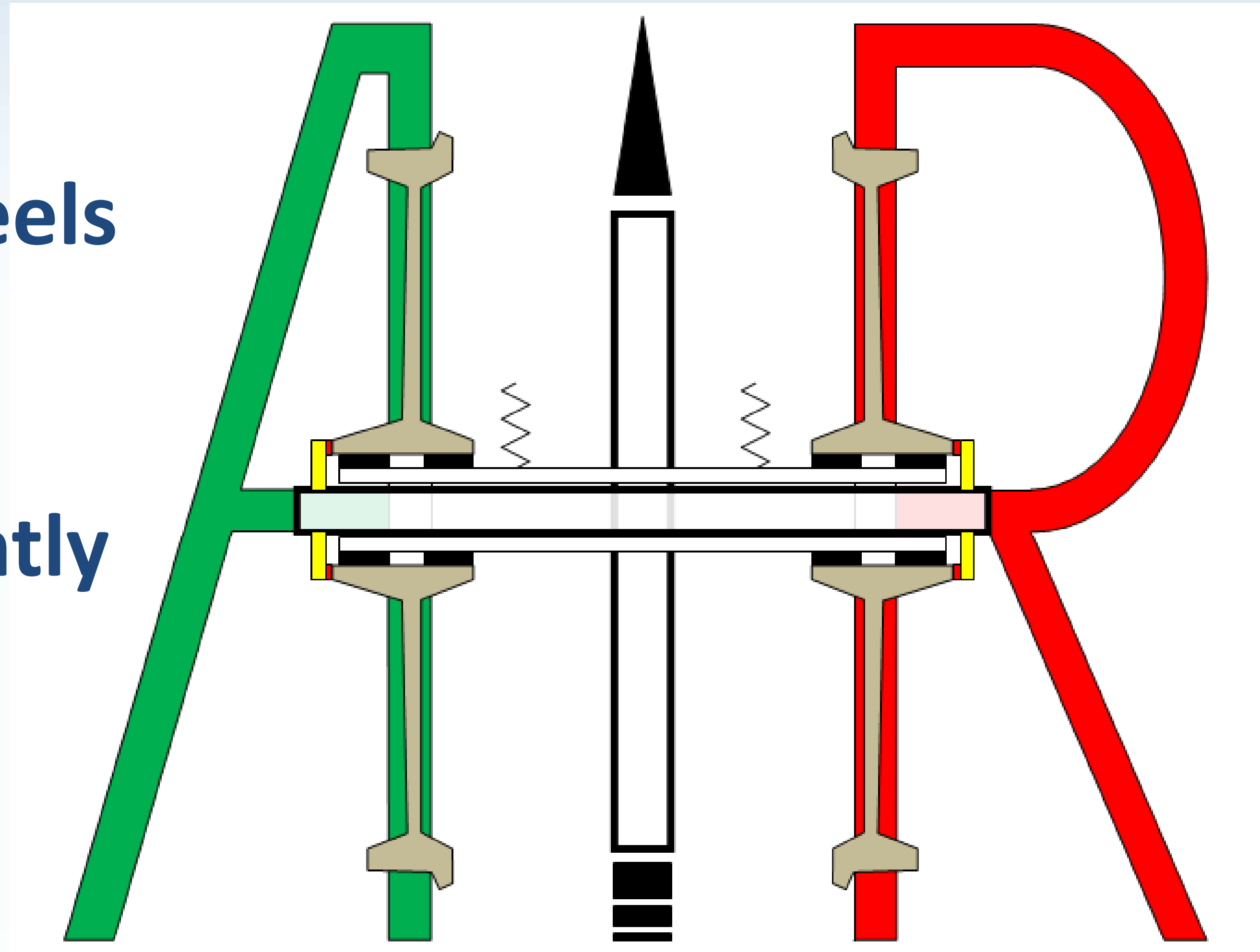


What are you going to listen now?

- Something about the patent (that I own) of a “new” wheelset (*OK, I re-invented the wheel*)
- This is NOT a collaborative research, it’s just my engineering knowledge
- I re-invented the wheel *not* for wheel-rail interface reasons, nevertheless some interesting features can be achieved (a sort of “fallout”)
- For reasons that will be evident later, the design is applicable only to *inside frame bogies* – a.k.a. *inboard bearings*

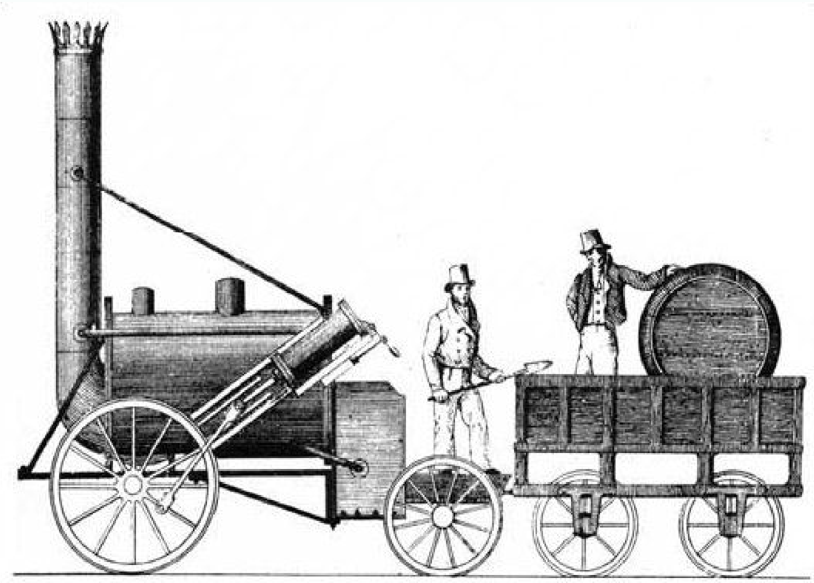
“AIR” Wheelset

A wheelset whose wheels are
Apparently
Independently
Rotating



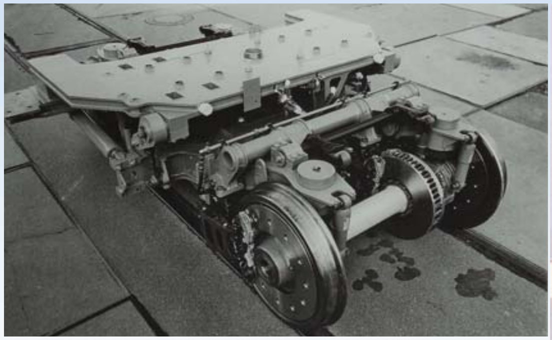
Inboard vs. Outboard bearings (1)

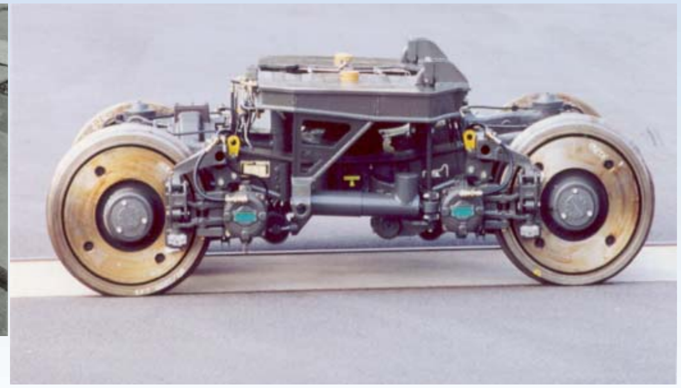
- No major differences for journal bearings (made of two parts)
- Steam locomotives with external cylinders = inboard bearings
- All other vehicles: outboard bearings (maintenance reasons)



Inboard vs. Outboard bearings (2)

The British design B5000 bogie and its successors





Class 5 coach Norway - in service since 2011 - 122 bogies

Class 172 Turbostar UK - in service since 2011 - 186 bogies

Class 220 Voyager UK - in service since 2001 - 288 bogies

Class 222 Meridian UK - in service since 2003 - 303 bogies

A full range of inside frame bogies

Hitachi Intercity Express Programme IEP
Class 800-801
369 + 227 + 270 + 29 bi-mode Hitachi AT300 GWR
(Source: Railway Gazette International, 44-15, Jan 2014)

SF7000 – Siemens
Desiro City Thameslink
1200 cars

FLEXX Eco – Bombardier
ICx Germany - in production - 1390 bogies + options
Crossrail Class 345 - in design - 1170 bogies
Riyadh Metro - in design - 188 bogies
Stockholm C30 - in design - 768 bogies


InnoTrans
LIEBHERR
Rostbratwurst vom Grill
6192

The DB ICx train

Flexx Eco bogie at work: Voyager at Leeds. Paul Bigland

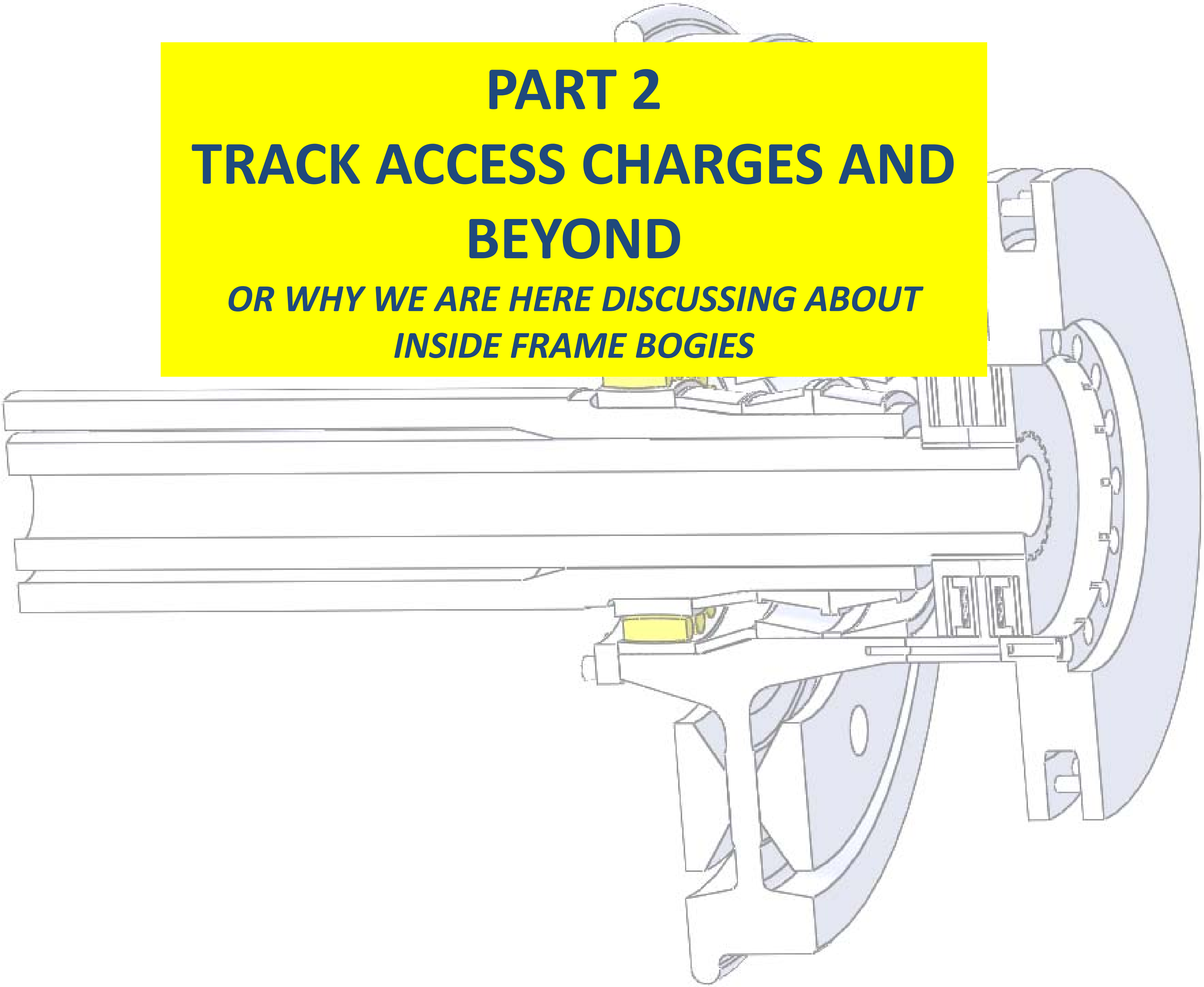
Flexx Eco – home-grown bogie taps international market

A government decision made over 40 years ago has paid off

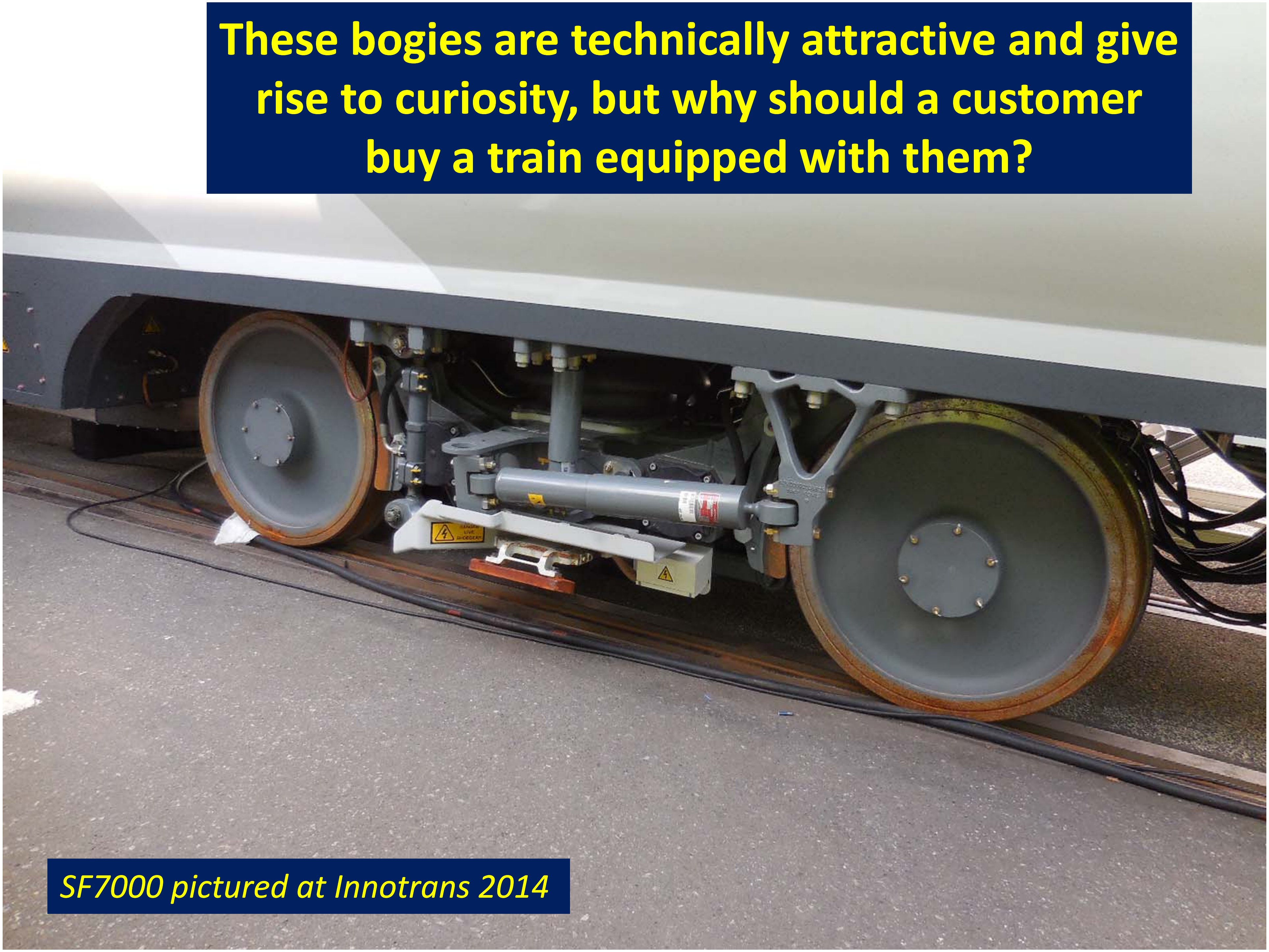
Modern Railways – June 2011

PART 2
TRACK ACCESS CHARGES AND BEYOND

OR WHY WE ARE HERE DISCUSSING ABOUT INSIDE FRAME BOGIES

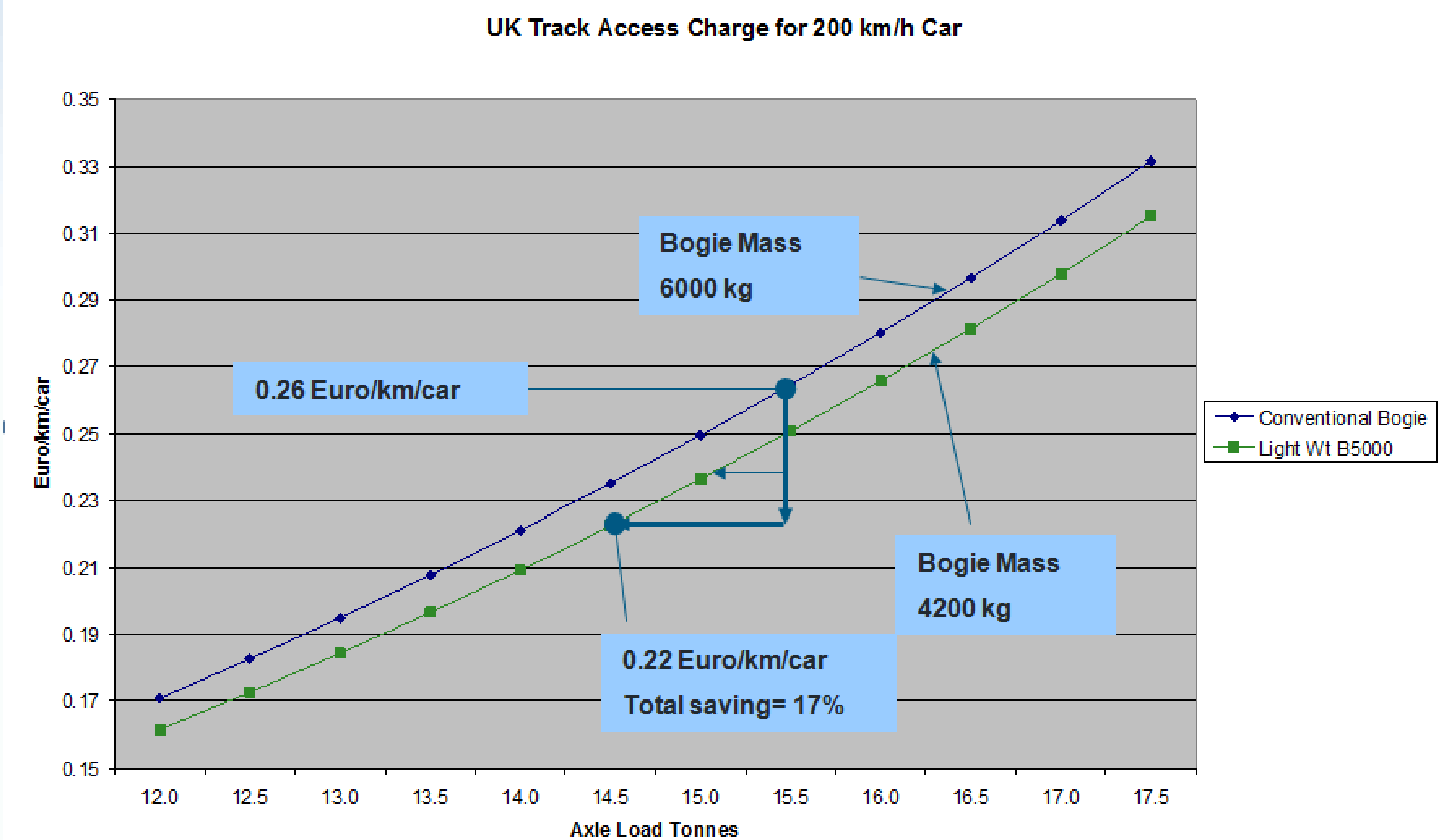


These bogies are technically attractive and give rise to curiosity, but why should a customer buy a train equipped with them?



SF7000 pictured at Innotrans 2014

Benefit of reduced bogie weight on UK track access charge



Source: Eddie Searancke, Benefits of the *FLEXX* Eco Bogie, Innotrans 2008

WRI EU 2015

Other charging schemes

NetworkRail

Relative damage (per axle.mile) = $0.473.e^{0.133A} + 0.015.S.U - 0.009.S - 0.284.U - 0.442$

$T\gamma = (T_x\gamma_x + T_y\gamma_y + T_z\Omega_3)$ $\quad V_n = \frac{1}{A}(T\gamma)$

SBB CFF FFS

$$k_1 \times F_{R_Q} \times Q^m + k_2 \times Q^n + k_3 \times T_{pv} + k_4 \times F_{R_{W_b}} \times W_b + k_5 \times \sqrt{\left(f_{5_1} \times Q^2 + f_{5_2} \times Y^2\right)}$$

TRAFIKVERKET

$$E_{a,z}(R_j,T_a) = k_1 \times T_Z \times \frac{1}{n_Z} \times \sum_{i=1}^{n_Z} Q^3_{tot\_i} + k_2 \times (T_a + T_Z) \times \frac{1}{n_Z} \times \sum_{i=1}^{n_Z} \left[\sqrt{Q^2_{tot\_i} + Y^2_{qst\_i}}\right]^3 + k_{34} \times T_Z \times \frac{\sum_{i=1}^{n_z}[f(F_v \overline{v})i]}{m_Z}$$

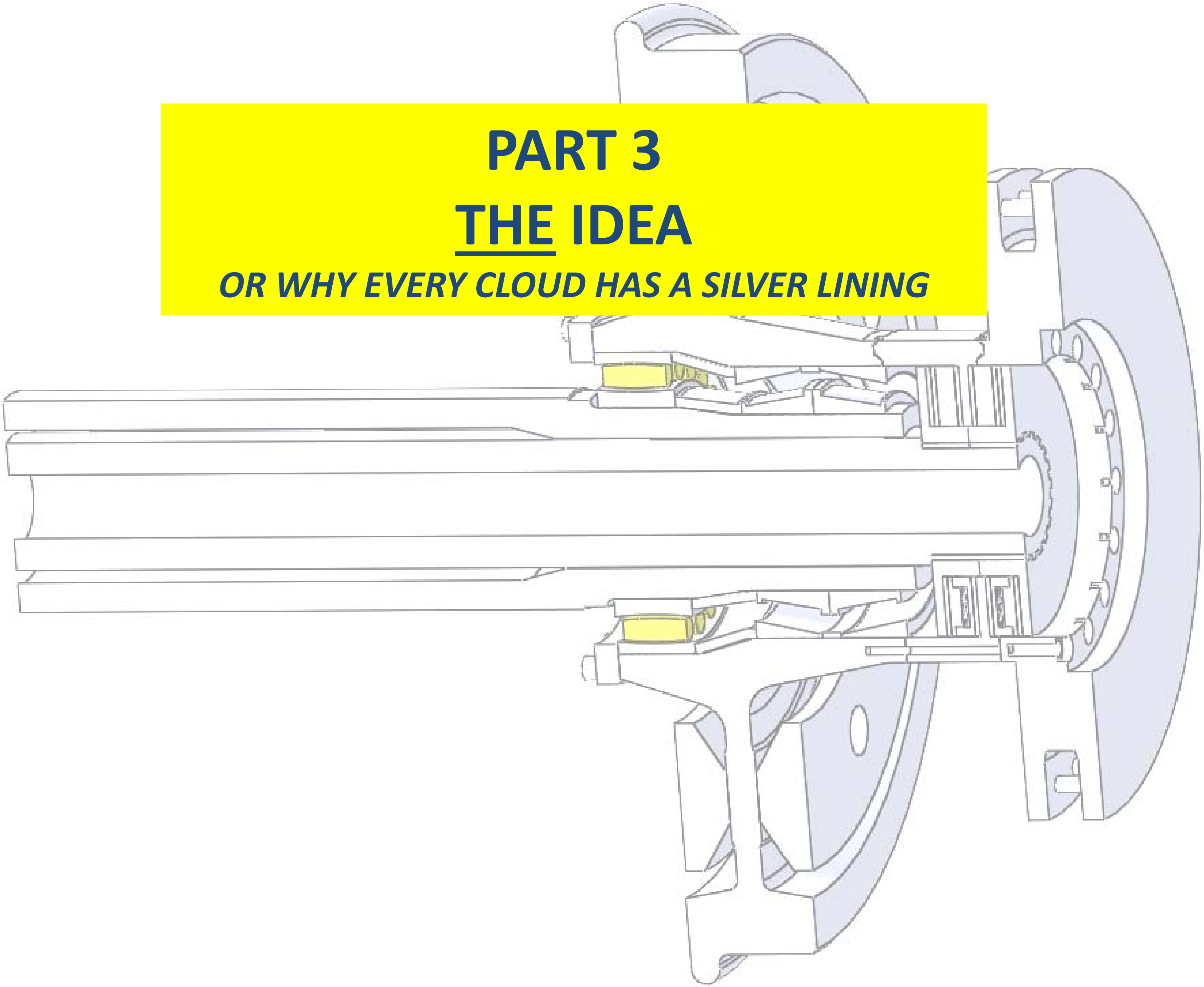
Source: S. Marschnig, Gerechte und transparente Infrastrukturbepreisung - Eine technische Antwort auf eine wirtschaftliche Fragestellung, ÖVG Rad-Schiene-Monitoring, Wien, 2015

THERE MUST BE SOMETHING MORE!

PART 3

THE IDEA

OR WHY EVERY CLOUD HAS A SILVER LINING



EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

FINAL DRAFT
FprEN 15313

July 2015

ICS 45.040

Will supersede EN 15313:2010

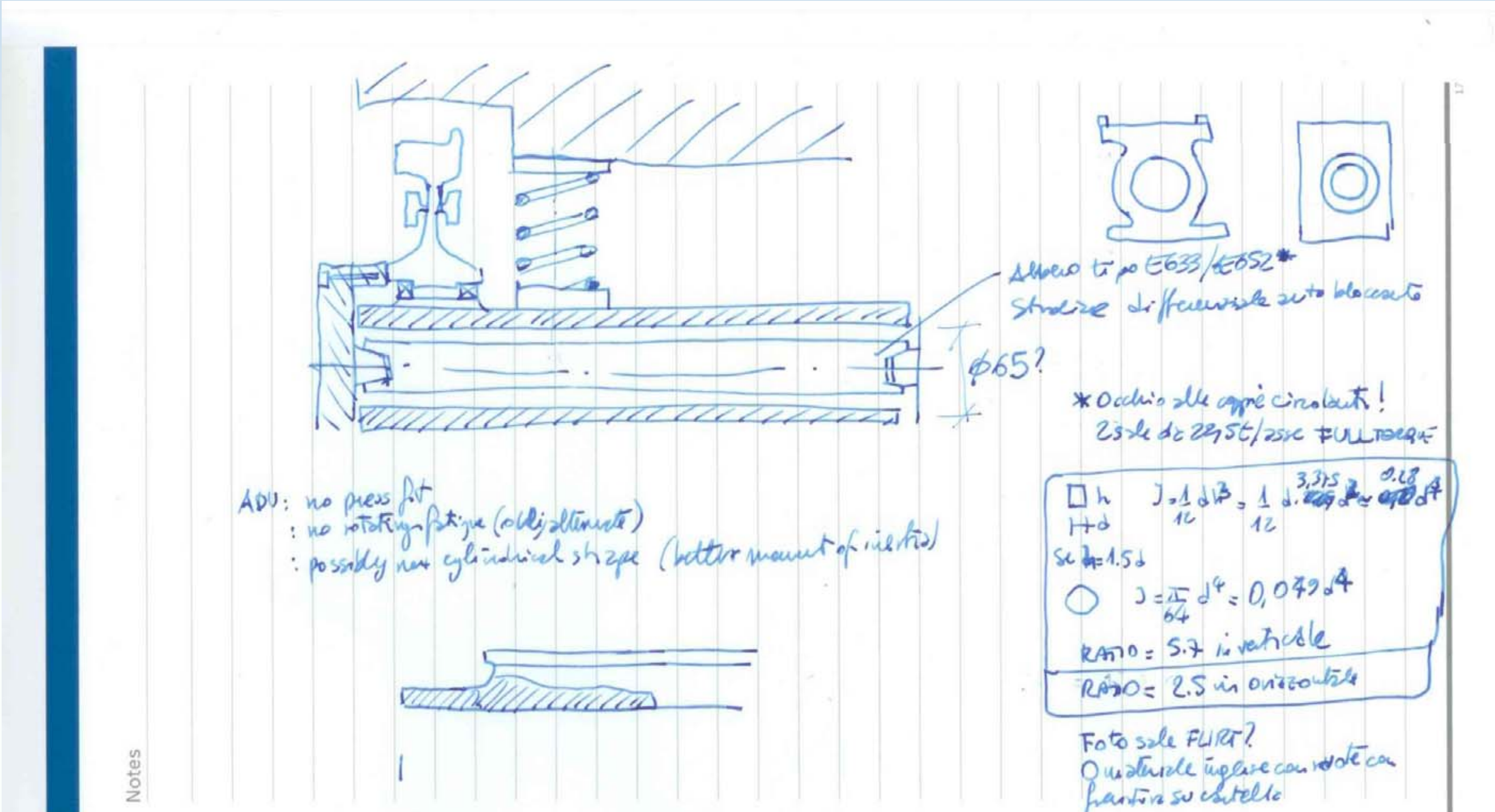
English Version

Railway applications - In-service wheelset operation requirements - In-service and off-vehicle wheelset maintenance

Despite all our efforts, wheels will wear and will damage

What if a customer could change worn / damaged wheels this way?

Anyone who has never made a mistake has never tried anything new



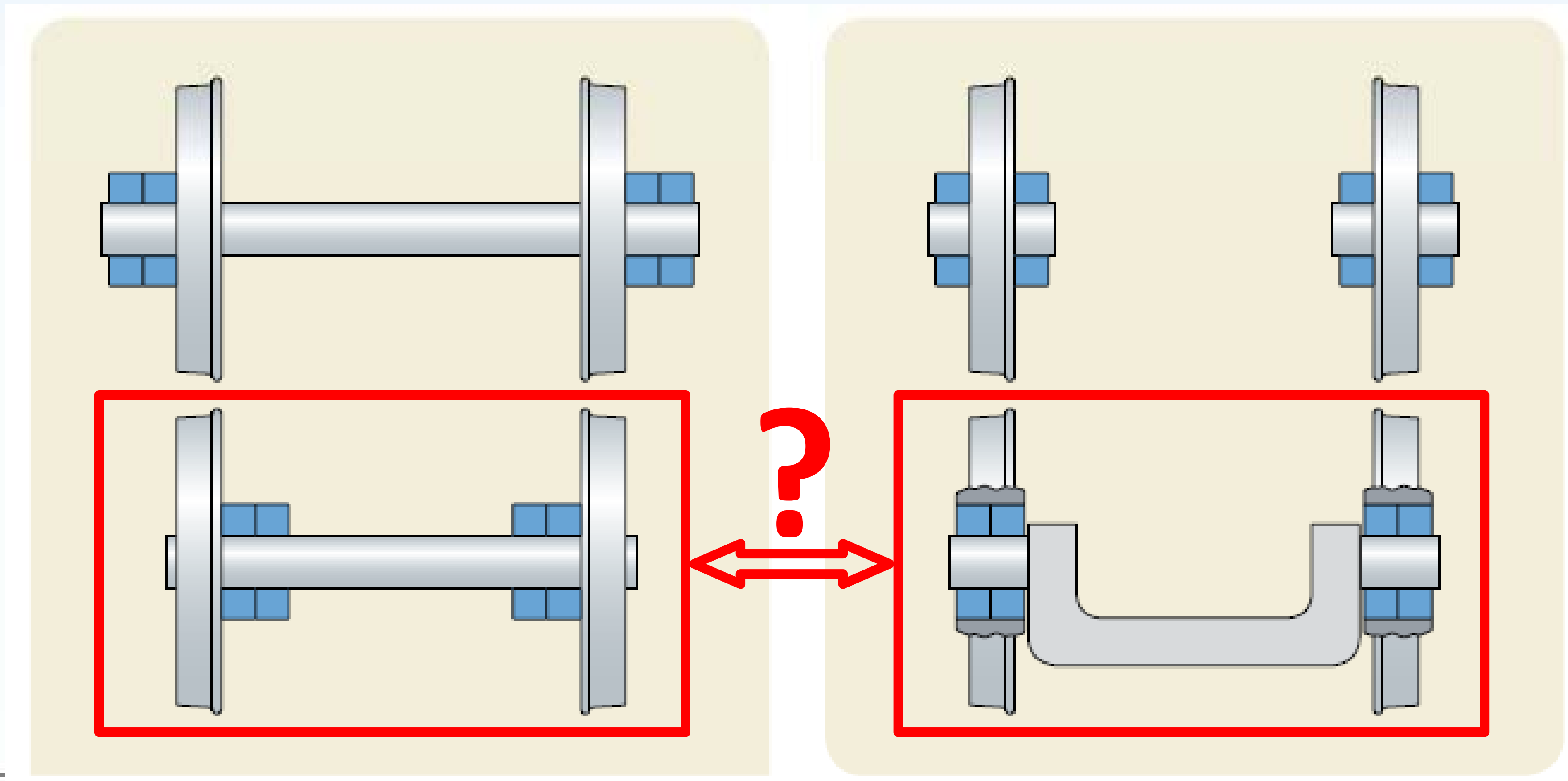
The idea was conceived on March 2010 but was set aside for market reasons

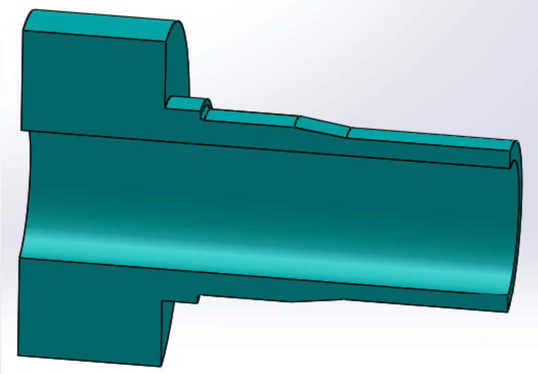
- Italian patent 102014902272121 (FI2014A000154) - 23.06.2014
- International patent PCT/IB2015/051855 - 13.03.2015
- European patent EP15173213.8 - 22.06.2015

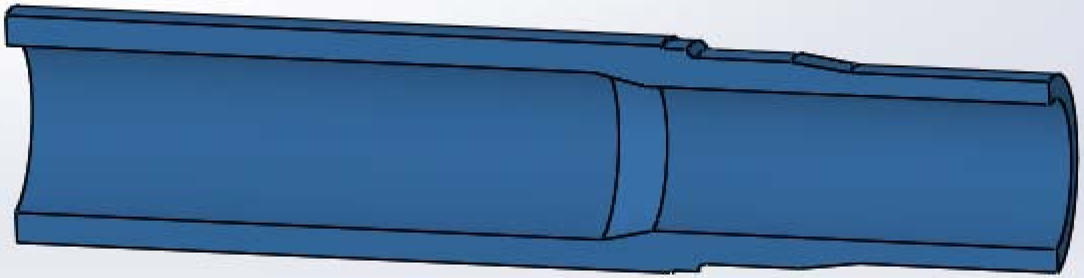
What was I looking for?

1. Something that does not modify both regular checks and underfloor lathe reprofiling procedures
2. The chance to maintain wheelsets in “peripheral” contexts where no carbody lifting or wheelset lowering devices are available
3. The possibility of using standard and low cost simple tools (extractors, shop cranes…)
4. Avoiding *in principle* any possible damage due to wheel pressing on and off
5. *Eliminating* the axle, that gives more than a headache
6. The dream to concentrate all serviceable parts in one component

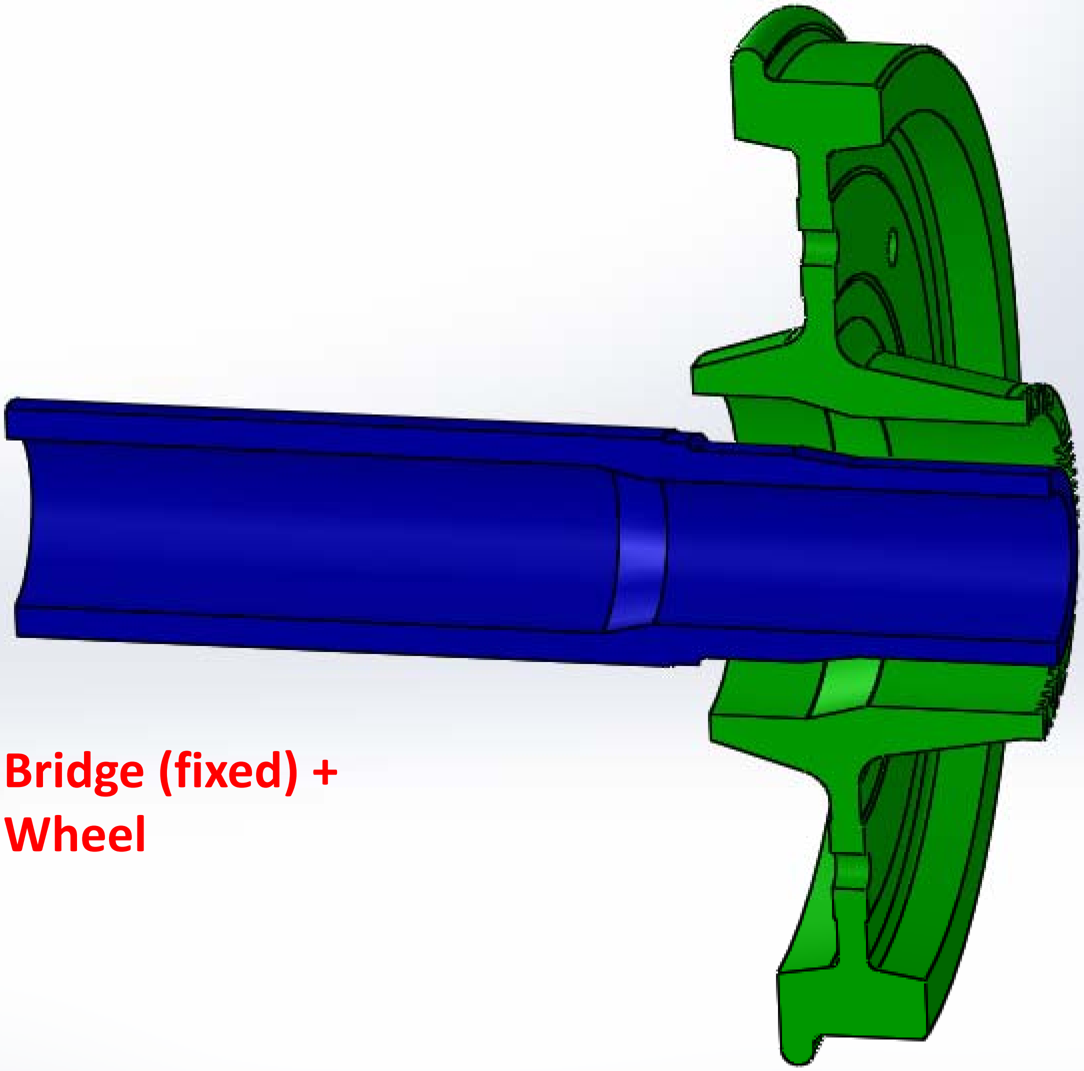
- Different architecture of wheelset and bogies
- The AIR wheelset is *primarily* intended to be used on “railway vehicles” (e.g. not on trams)



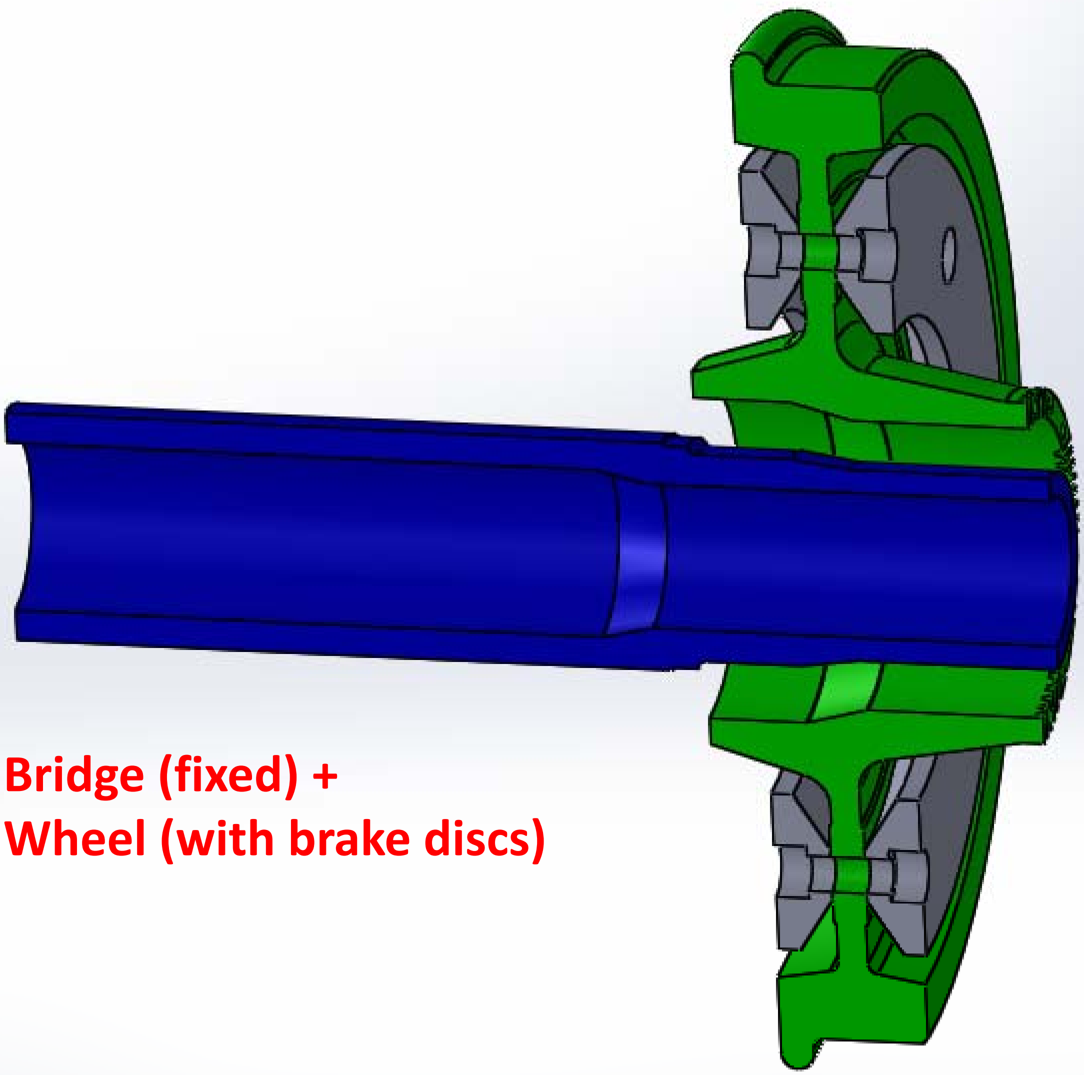




Bridge (fixed)

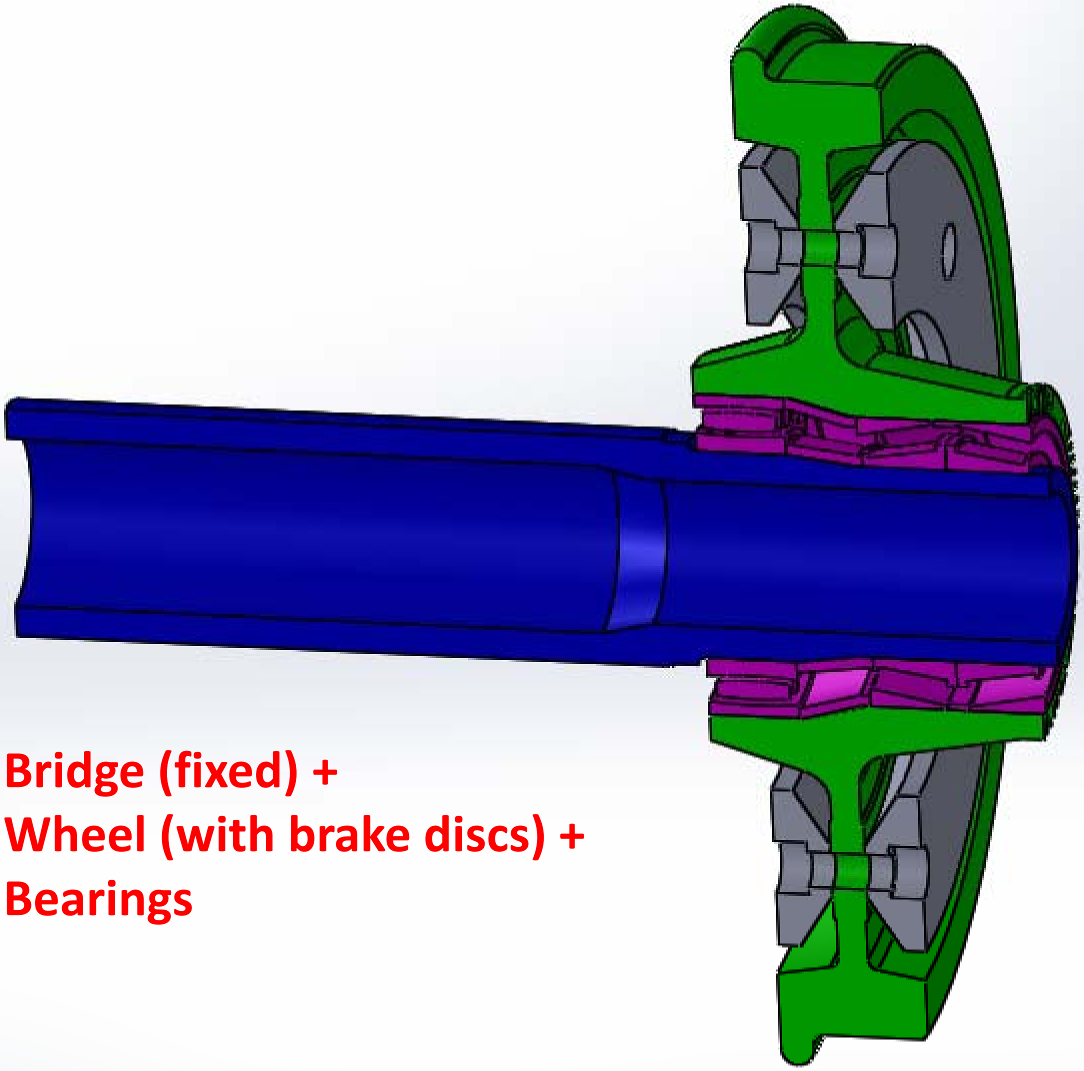


**Bridge (fixed) +
Wheel**



Bridge (fixed) +
Wheel (with brake discs)

WRI EU 2015

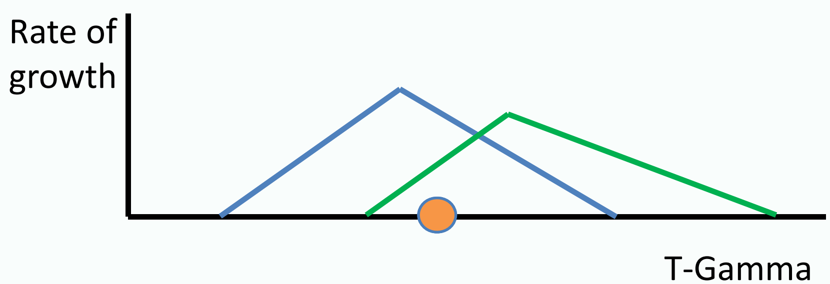


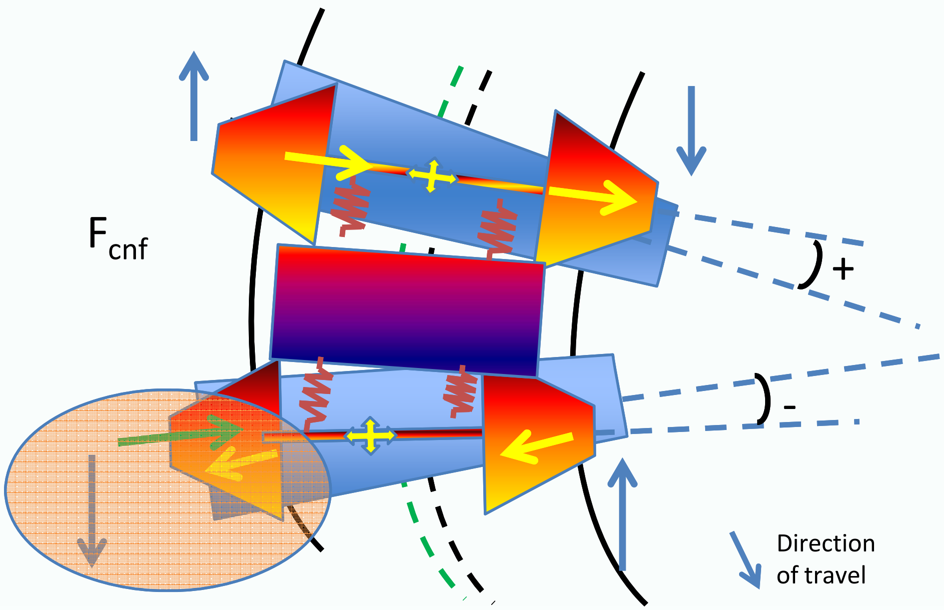
(This is a typical IRW arrangement...)

Bridge (fixed) +
Wheel (with brake discs) +
Bearings

High Rail RCF

- High Rail RCF is caused by excessive T-Gamma on the leading axle whose ***Longitudinal*** force direction promotes RCF
- Corresponding Low Wheel RCF is also generated



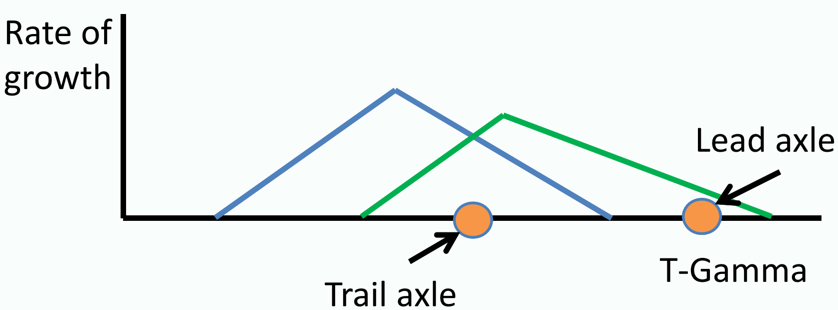


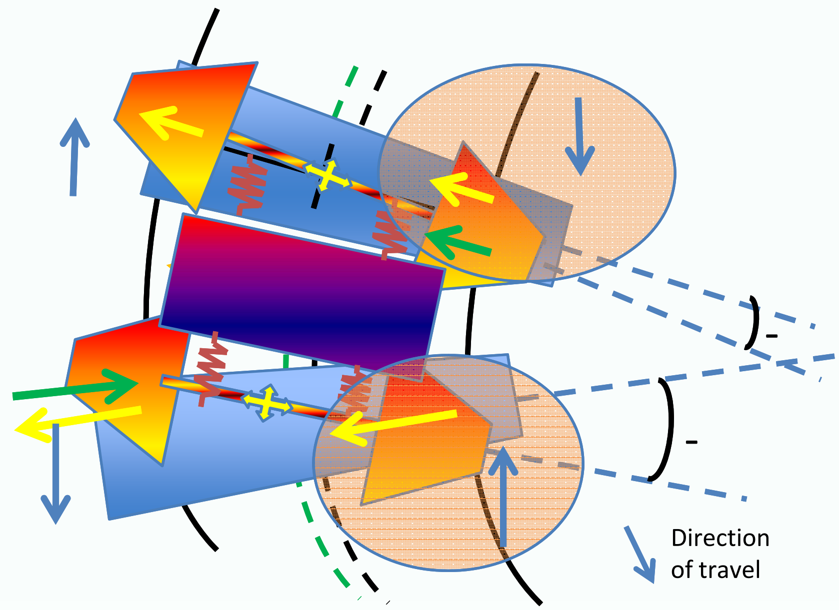
Wheel Forces

Note: Previous slides showed a single Lateral force generated by AOA acting on the axle center rather than the wheels. That was done for graphical simplicity

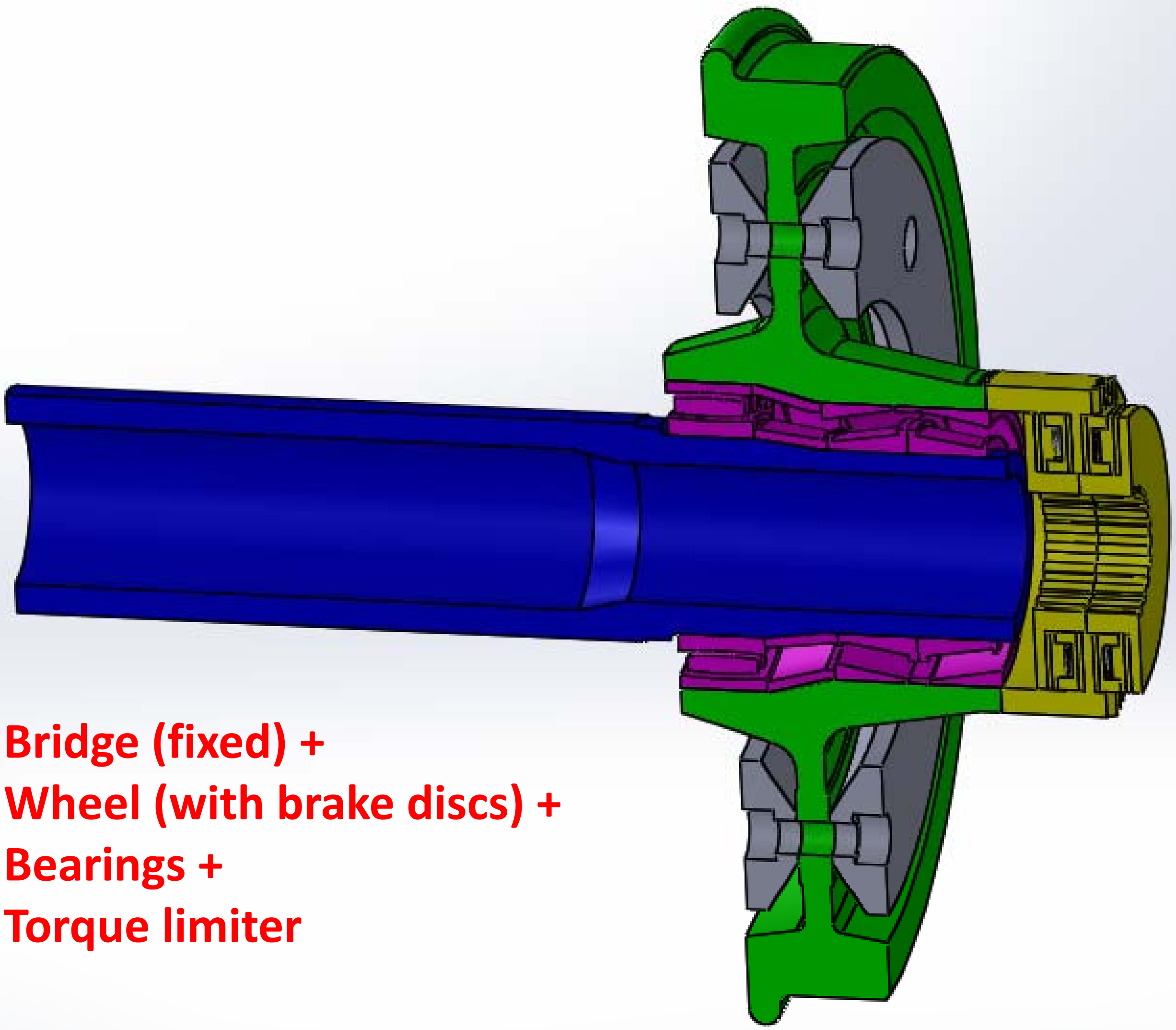
Low Rail RCF

- Low Rail RCF is caused by Excessive T-Gamma:
  - On the leading axle whose ***Longitudinal*** Force direction promotes wear and metal flow
  - On the trailing axle whose ***Longitudinal*** Force direction cause RCF
- It usually occurs with extreme Cant Surplus

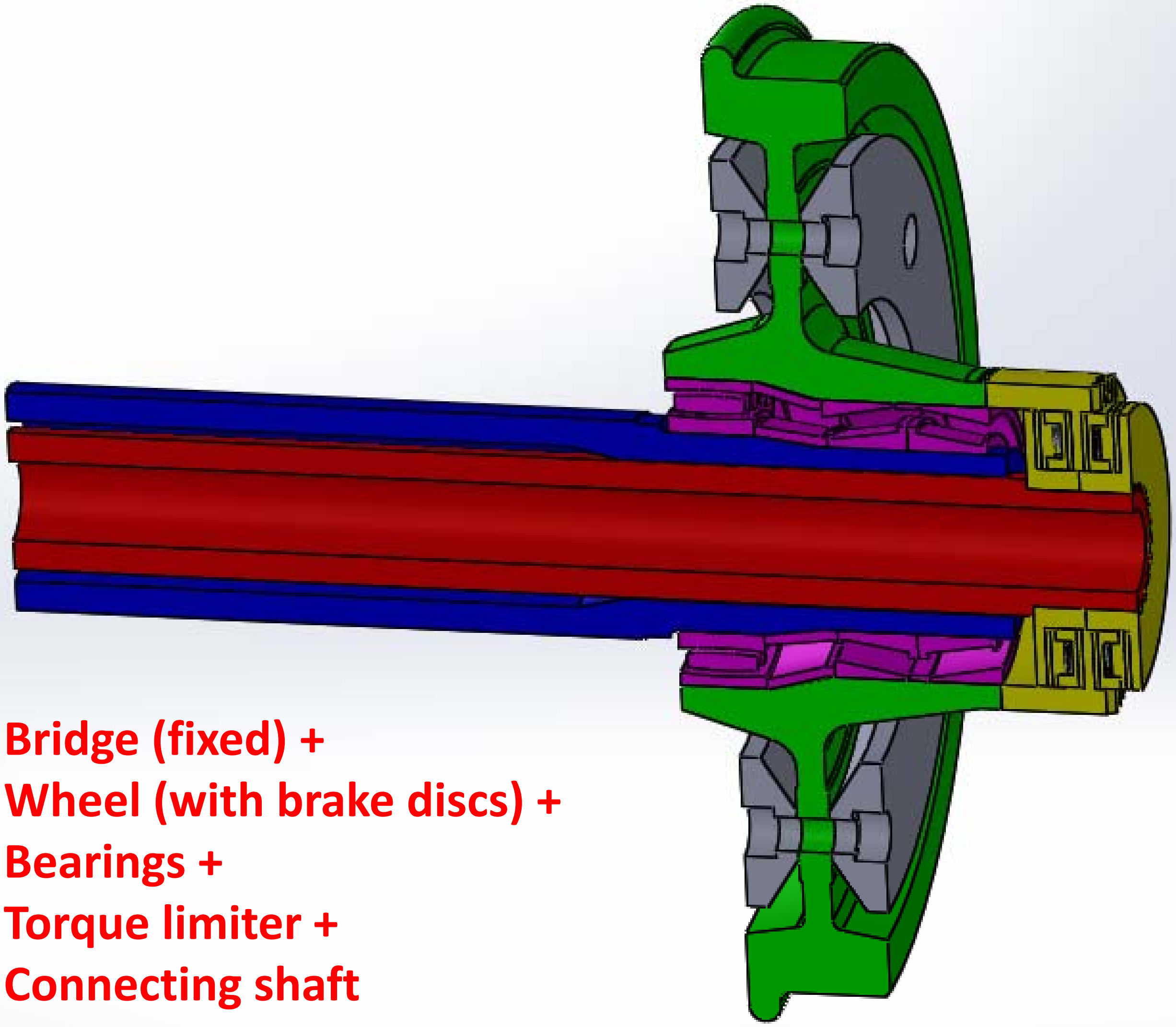




Wheel Forces

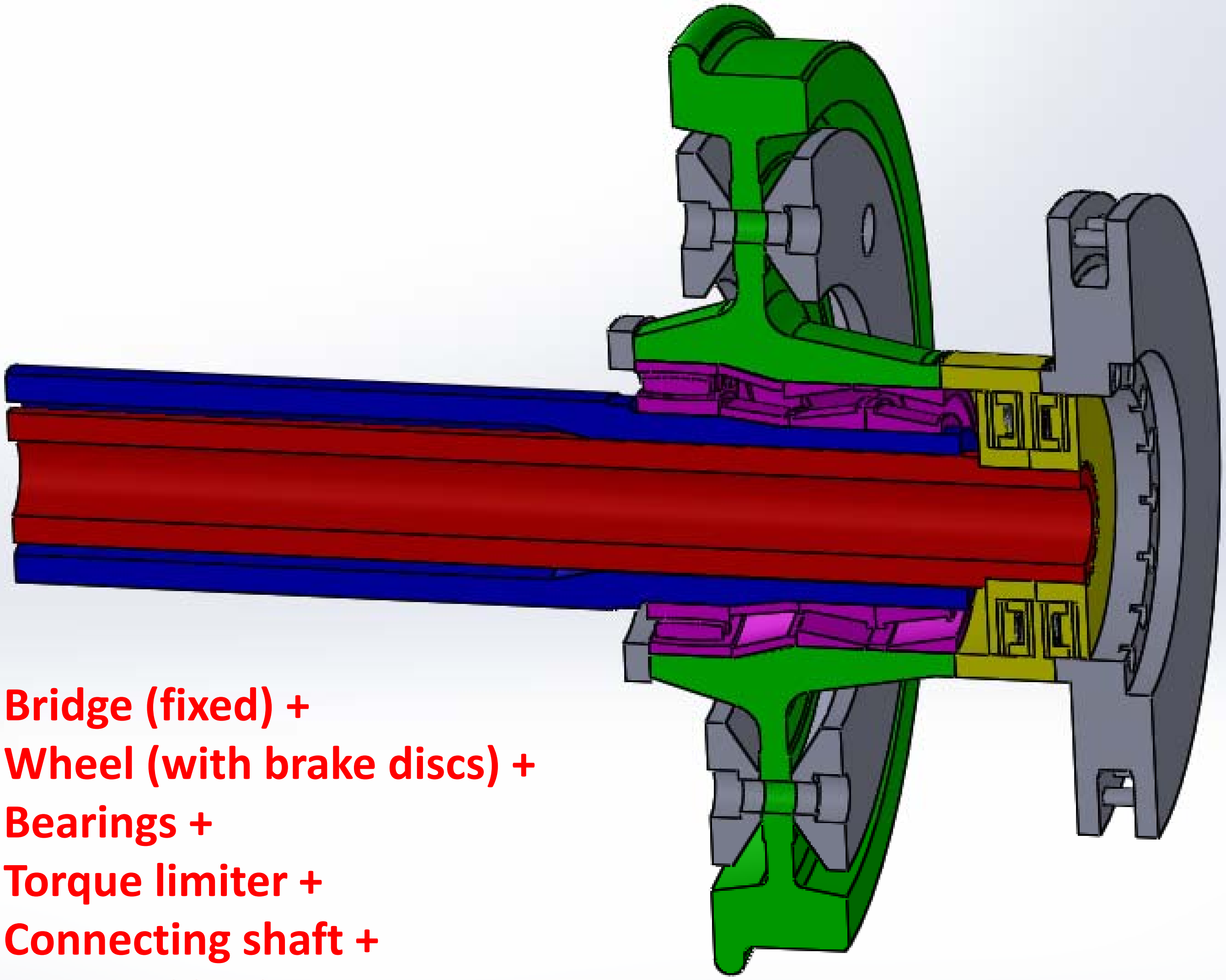


Bridge (fixed) +
Wheel (with brake discs) +
Bearings +
Torque limiter



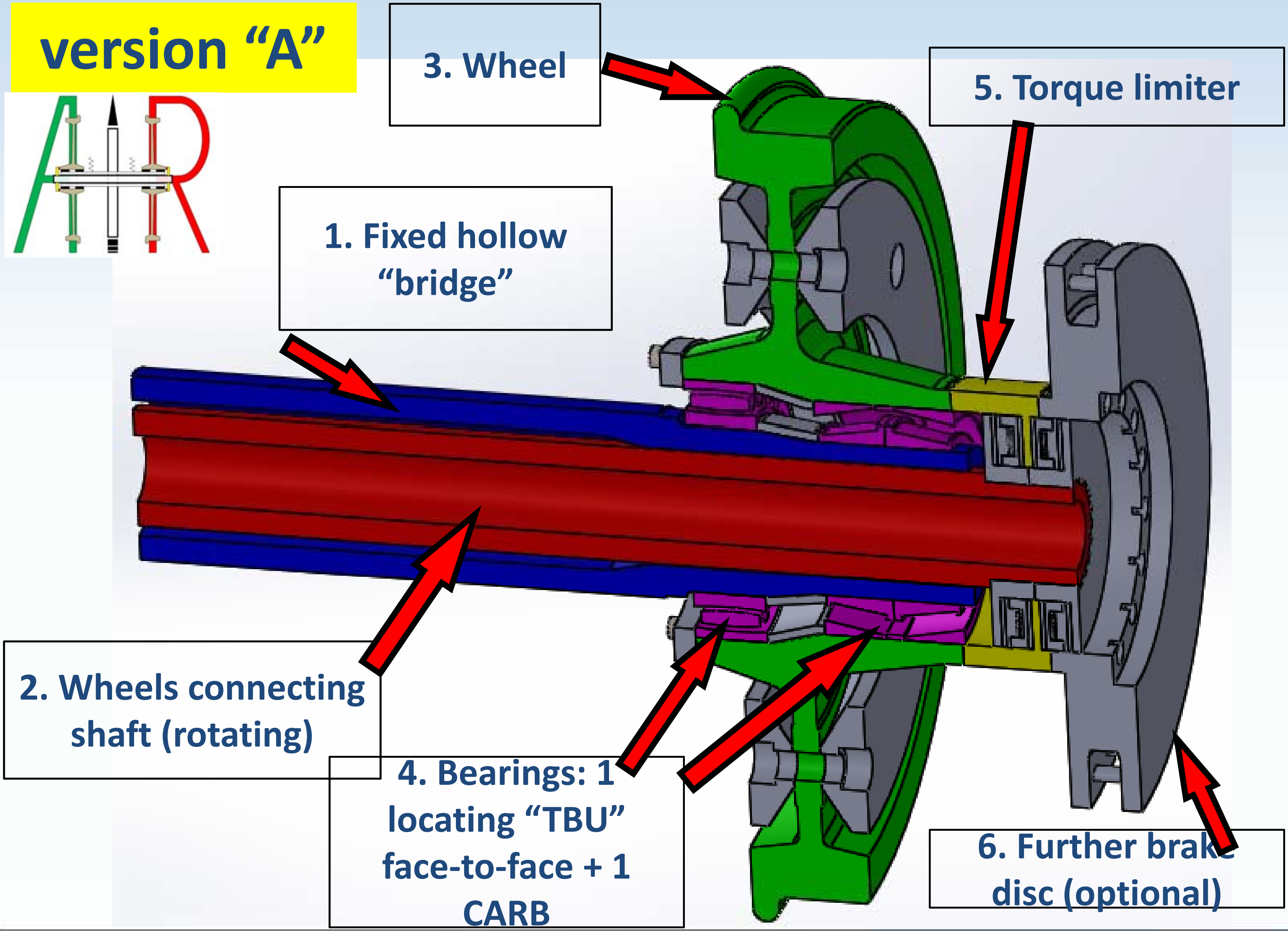
Bridge (fixed) +
Wheel (with brake discs) +
Bearings +
Torque limiter +
Connecting shaft

WRI EU 2015



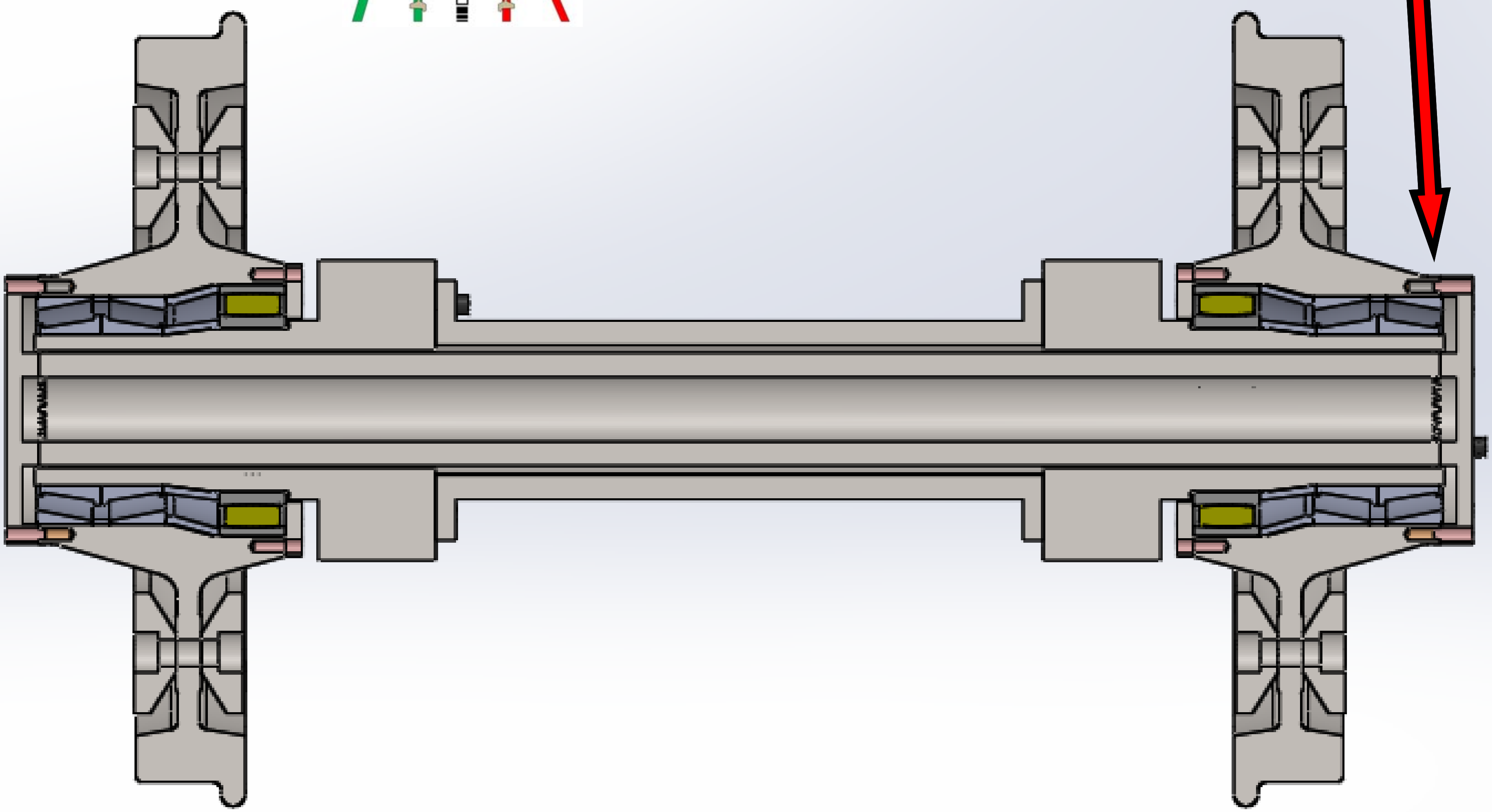
Bridge (fixed) +
Wheel (with brake discs) +
Bearings +
Torque limiter +
Connecting shaft +
Optional brake disc

version "A"


3. Wheel
5. Torque limiter
1. Fixed hollow "bridge"
2. Wheels connecting shaft (rotating)
4. Bearings: 1 locating "TBU" face-to-face + 1 CARB
6. Further brake disc (optional)

version “B”

Rigid joint



Not less important steps

1. CERTIFICATION: compliance to TSIs and EN standards necessary (see ICx for DB case)
2. RUNNING DYNAMICS: Vehicle performance had to be unaffected by the new design
3. BEARINGS: novel solution, sufficient dynamic load rating AND sufficient speed rating must be guaranteed to ensure durability
4. STRUCTURAL ISSUES AND SAFETY: high safety margins (no accidents like Viareggio are tolerated anymore)
5. MANUFACTURING: the new solution must be entirely producible with current manufacturing processes

Apparently Independently Rotating Wheelset - a possible solution for all needs?

A. Bracciali
University of Florence, via Santa Marta 3, 50139, Florence, Italy
AB Consulting sas, via Alli Maccarani 24, 50145, Florence, Italy

ABSTRACT

The paper describes a patented innovative railway wheelset (*AIR Wheelset*) where the wheels are rotating supported by roller bearings and are torsionally connected via a shaft with proper stiffness. This arrangement can dramatically change maintenance operations while keeping optimal running stability at high speed. Better curving characteristics can be obtained by a version where the torque transmitted through the shaft is limited by torque limiters, possibly reducing rail corrugation and improving negotiation of tight curves.

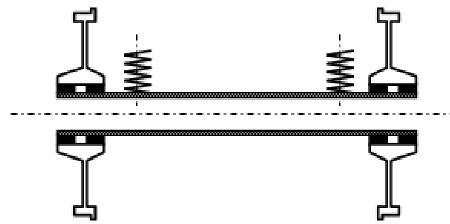
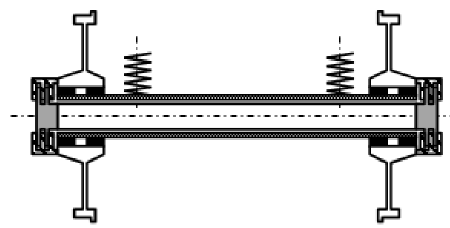
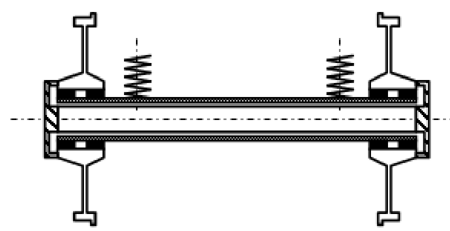
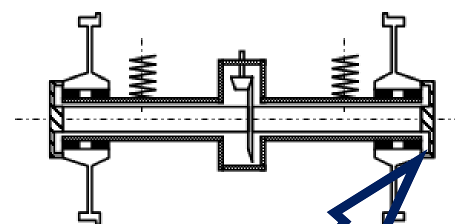
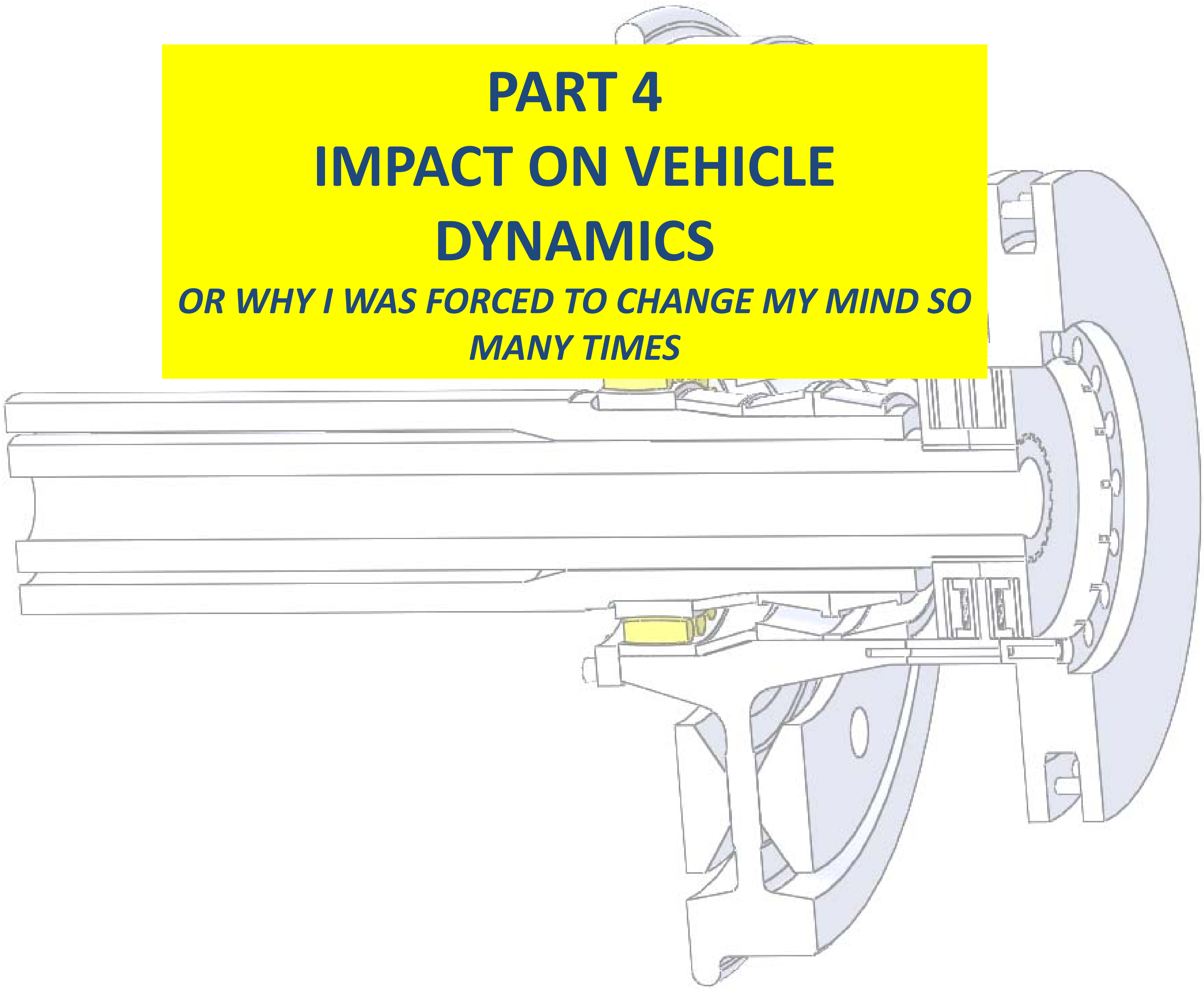
Maximum torque	Trailed *AIR Wheelset*	Motor *AIR Wheelset*
Zero (free)		Not applicable
Limited by a *torque limiter*		Not applicable
Limited by wheel-rail adhesion limit *(rigid coupling)*		

Figure 4. Possible layouts of the *AIR Wheelset* (18). All solutions can be equipped with block brakes and/or up two discs per wheel (maximum four brake discs per wheelset).

No wheel/wheelseat rotational slip ("German problem") possible...

PART 4
IMPACT ON VEHICLE DYNAMICS

OR WHY I WAS FORCED TO CHANGE MY MIND SO MANY TIMES



Handbook

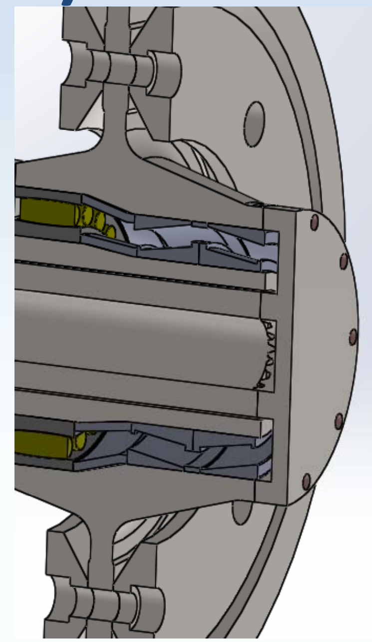
Independently rotating wheels have been frequently proposed as they eliminate the classic hunting problem. Some of the possibilities have been surveyed by Frederich.[135] The essential difference between a conventional wheelset and independent wheels lies in the ability of the two wheels to rotate at different speeds and thus the kinematic oscillation of a conventional wheelset is therefore eliminated. A measure of guidance is then provided by the lateral component of the gravitational stiffness (reduced by the lateral force due to spin creep) which becomes the flange force when the flangeway clearance is taken up, but this leads to slow self-centring action. Extensive experimental experience has shown that, indeed, the kinematic oscillation is absent but

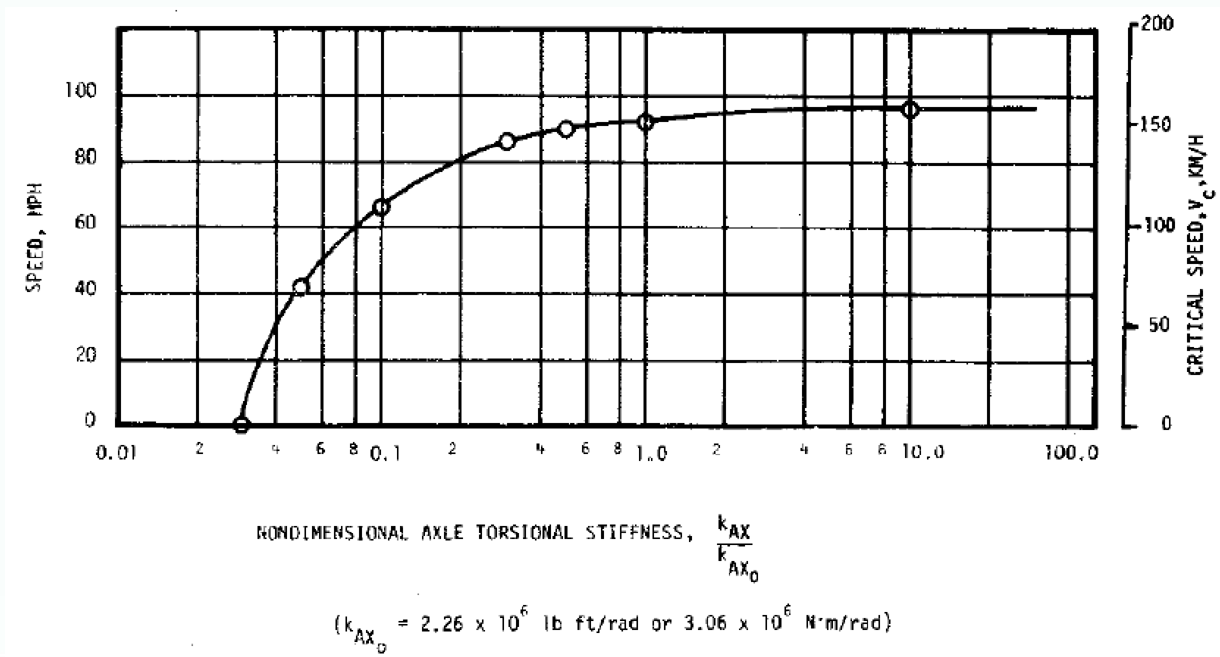
that one or other of the wheels tends to run in continuous flange contact.[136] Good agreement b

A torsional link is needed!

Analysis of version "B" (rigid joints)

- Critical speed decreases with axle torsional stiffness (Doyle, 1977)
- A large axle diameter is needed not only for bending (structural) but also for torsional (dynamics) reasons



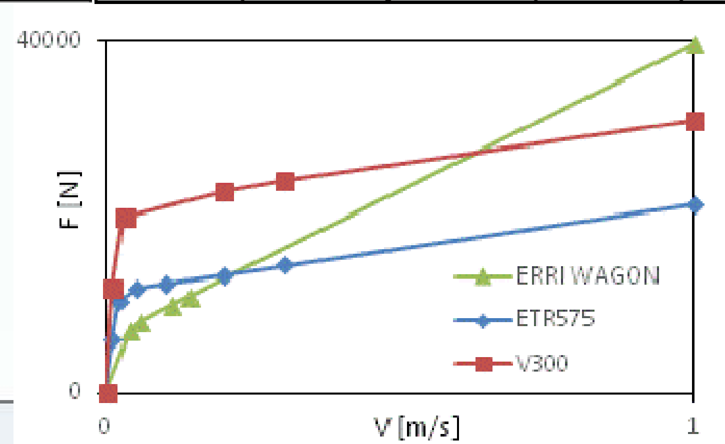


Required shaft stiffness

Fully non-linear running dynamics analysis of the ERRI wagon in the VI-Rail library for a number of shaft sizes:

Axle type	D [mm]	d [mm]	l [mm]	k_t [Nm/deg]	k_t [MNm/rad]	c= original ERRI wagon anti-yaw dampers				
						Flange contact		Non-flange contact		No motion
						$v_{crit,min}$ [m/s]	f_{crit} [Hz]	v_{sway} [m/s]	f_{sway} [Hz]	$v_{stable,max}$ [m/s]
Standard VI-Rail package				∞	∞	90	4.8	/	/	85
0: "Rigid"				10^9	57000	90	4.8	/	/	85
1: Conventional	160	0	1500	59774	3.42	85	4.6	/	/	80
5: Conventional hollow	160	80	1500	56038	3.21	85	4.6	/	/	80
2: Long	160	0	2000	44831	2.57	85	4.6	80	3.8	75
6: Long hollow	160	80	2000	42029	2.41	85	4.6	80	3.3	75
3: Long and thin	140	0	2000	26279	1.51	80	4.4	75-65	3.3-3.1	60
7: Long thin hollow	140	80	2000	23477	1.35	80	4.4	75-65	3.5-2.9	60
4: Long and very thin	120	0	2000	14185	0.81	75	4.2	70-25	3.5-1.7	20
8: Long very thin hollow	120	80	2000	11383	0.65	70	3.7	65-15	3.3-1	10

Luckily this type of instability is of the *primary* type (carbody instability), so using "modern" anti-yaw dampers completely removes the problem → **OK**



For further details on “versions A+B” behaviour…

48.1 RUNNING DYNAMICS OF RAILWAY VEHICLES EQUIPPED WITH TORSIONALLY FLEXIBLE AXLES AND PARTIALLY INDEPENDENTLY ROTATING WHEELS

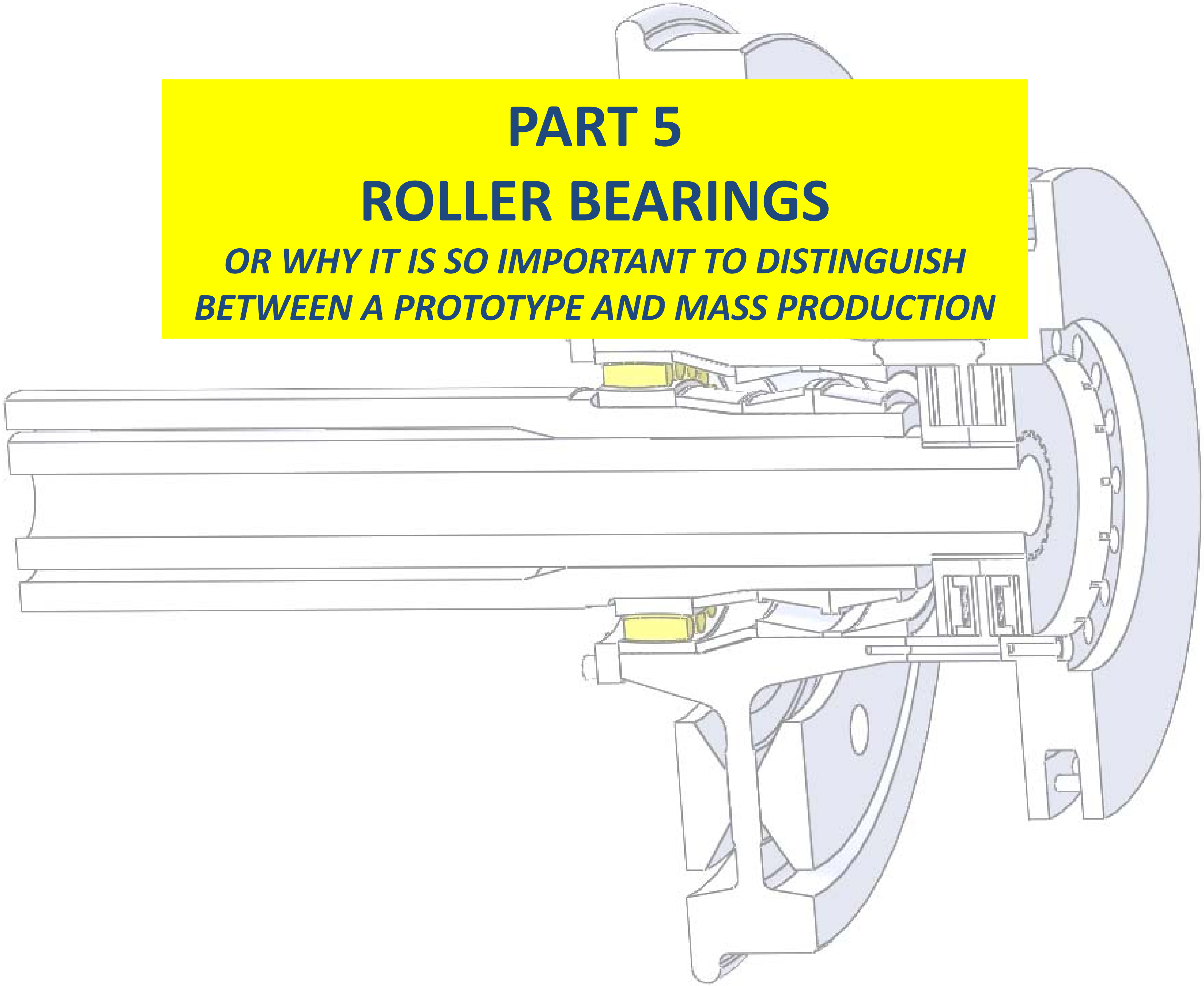
Andrea Bracciali[1], ***Gianluca Megna***[1]
1: University of Florence, Italy

ABSTRACT: The paper discusses the fully non-linear behaviour of railway vehicles whose axles are considered as torsionally flexible. Critical speeds of the ERRI Wagon available in the library of the selected multibody software are investigated with different axle stiffness in order to evaluate any possible reduction in the dynamic characteristics at high speed. All these analyses are applicable to a novel wheelset arrangement where individually supported wheels are connected by a torsionally flexible shaft where the wheels can be easily changed and the axle subjected to rotational bending is replaced by two fixed stub axles. In a further development, the connecting shaft is equipped with a torque limiter. Steering and stability are discussed in order to identify any potential drawbacks in this arrangement.

f=0.4, but I’ll be back on this in a while…

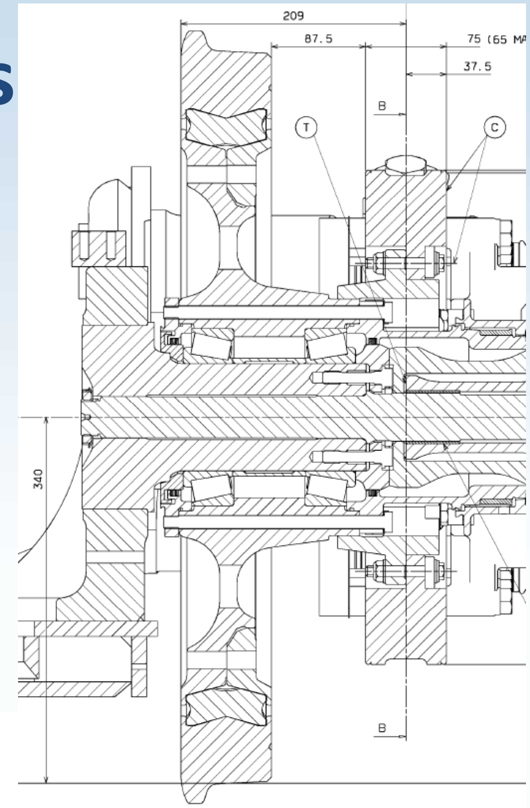
PART 5
ROLLER BEARINGS

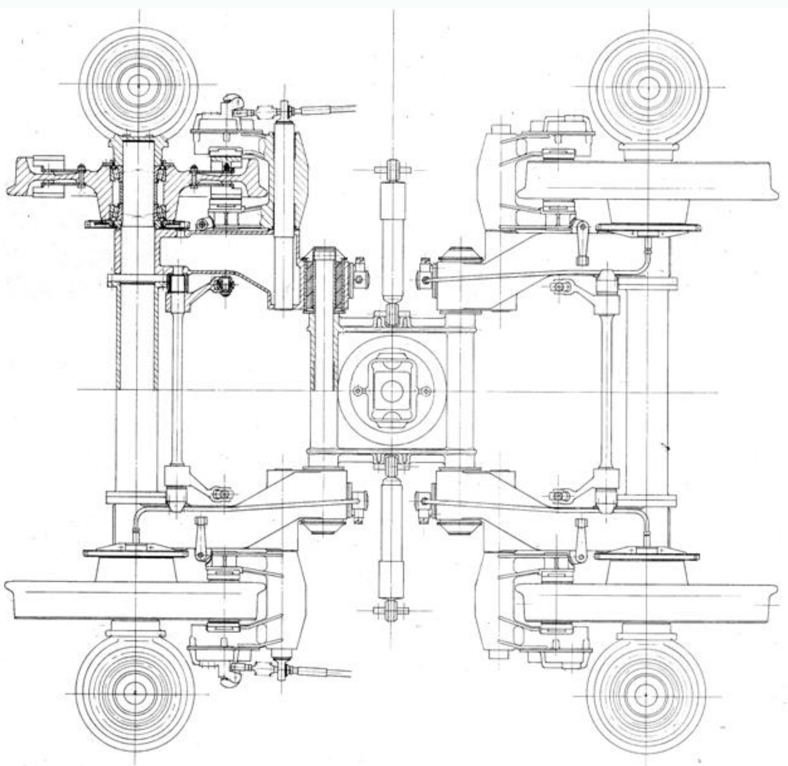
OR WHY IT IS SO IMPORTANT TO DISTINGUISH BETWEEN A PROTOTYPE AND MASS PRODUCTION

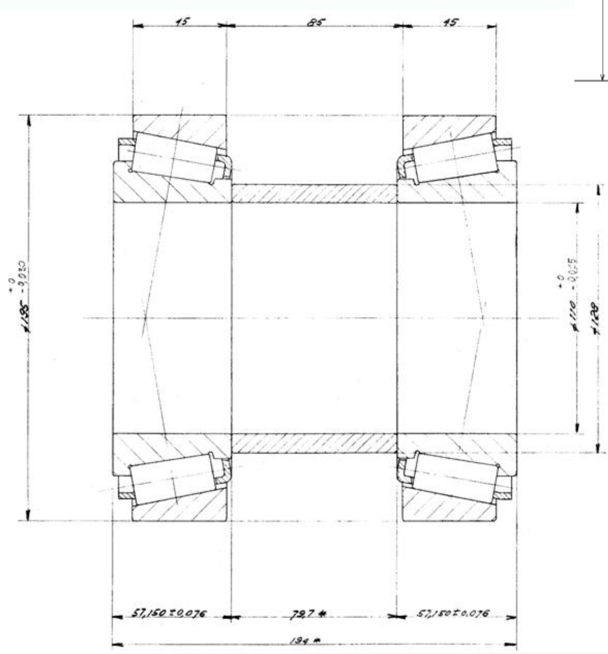


Wheels with bearings

- Only used in practice in low-floor trams
- The experience with a modular and very lightweight passenger car (FIAT CNR) was *totally negative* (Gothard line tests 1992)

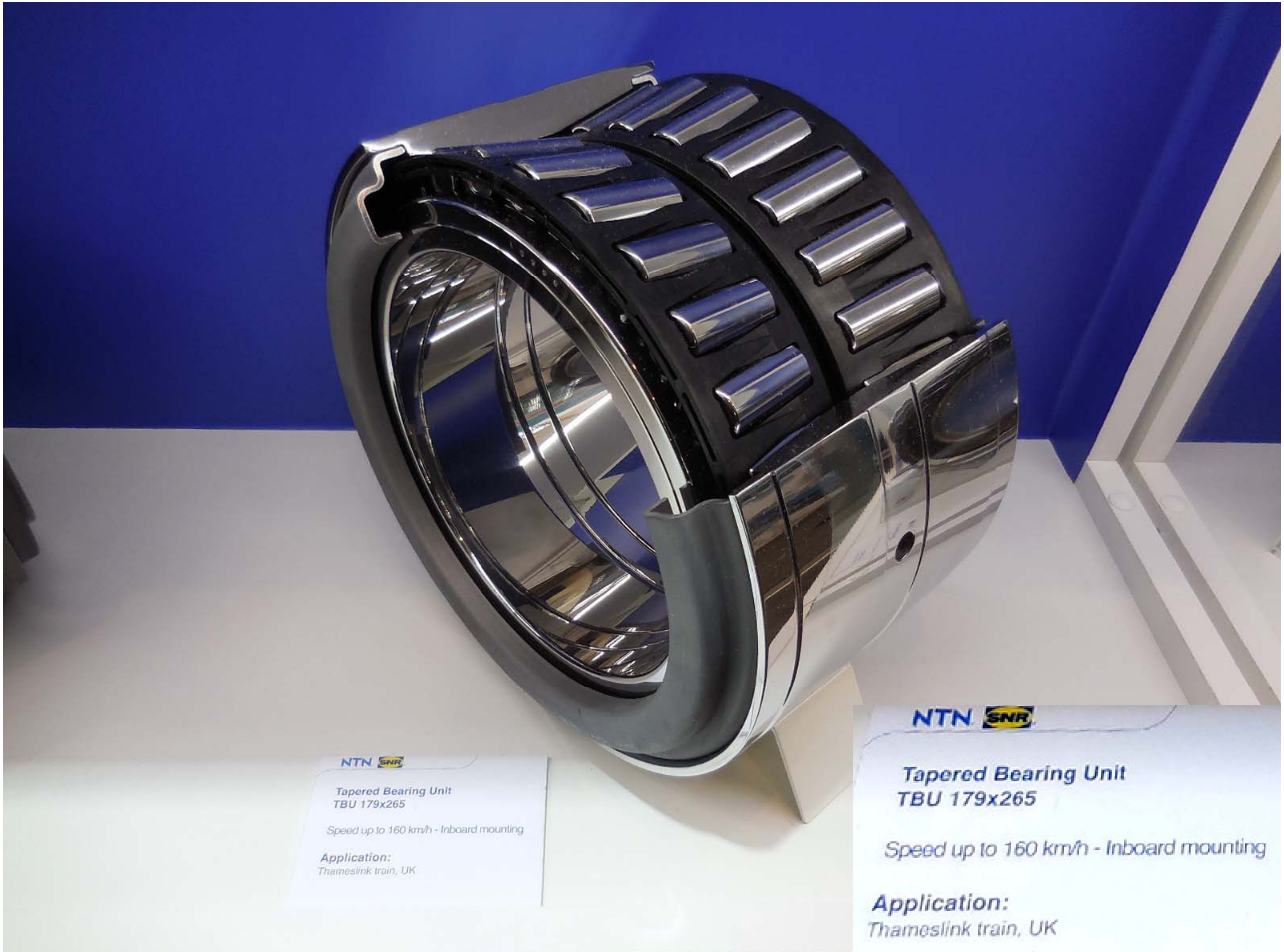


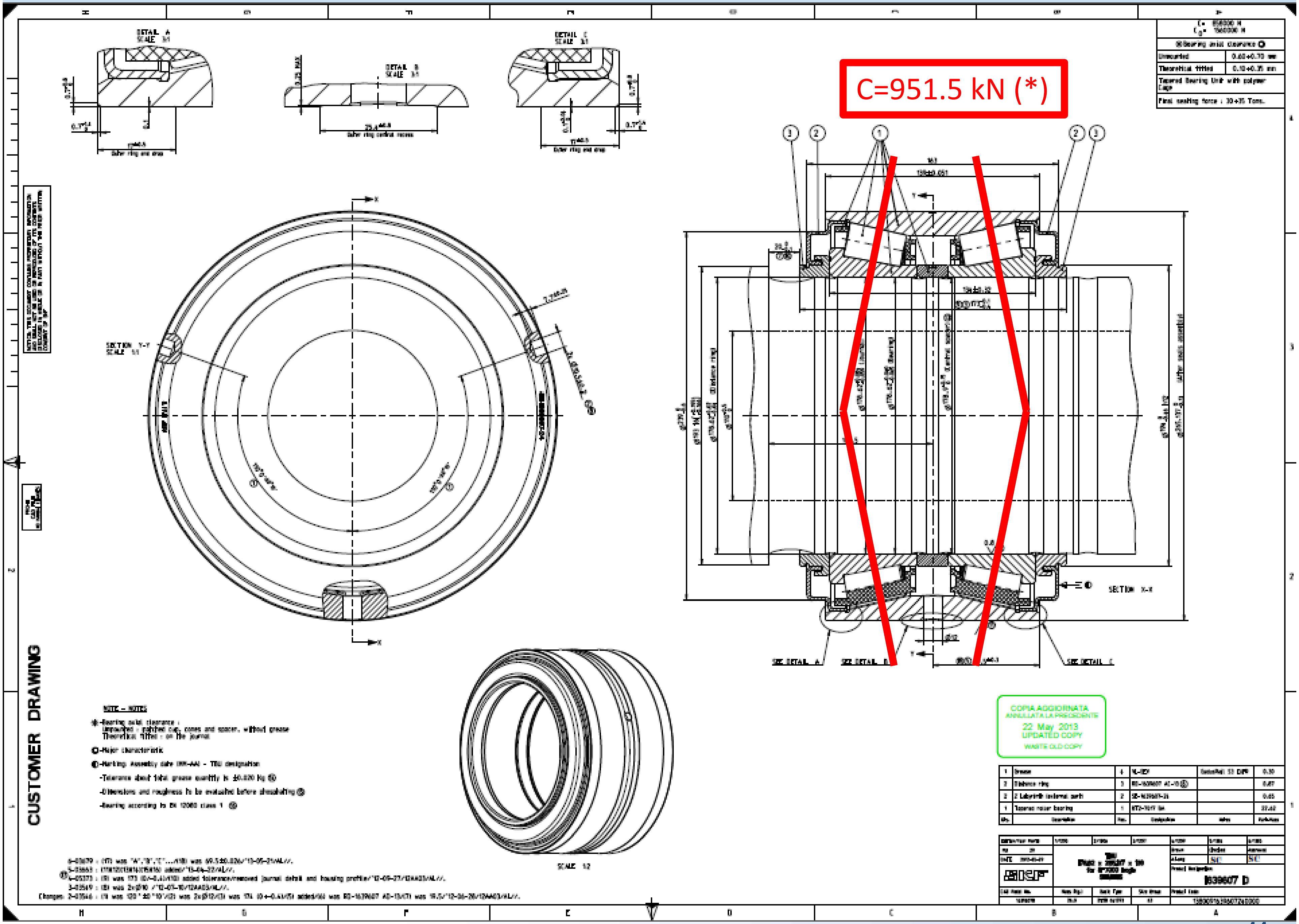




Bearings requirements

1. Large diameter = high dynamic load rating BUT low speed rating
2. Small diameter = high speed rating BUT low dynamic load rating
3. <u>Bearing diameters is driven by seats that are in turn driven by transmission shaft diameter (140 mm)</u>
4. Recently bearings with an internal diameter of 185 mm (FLEXX-Eco) and 178.62 mm (SF7000) were made available. They are classical TBUs with “O” (“back-to-back”) arrangement.

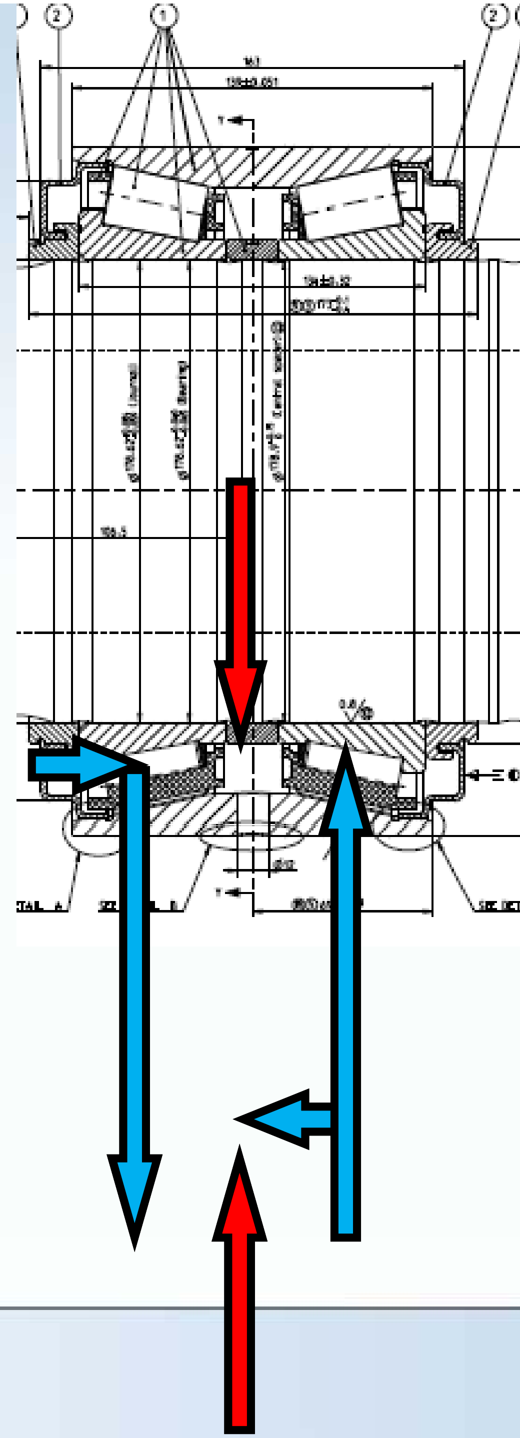

NTN SNR
Tapered Bearing Unit
TBU 179x265
Speed up to 160 km/h - Inboard mounting
Application:
Thameslink train, UK



C=951.5 kN (*)
CUSTOMER DRAWING
SECTION X-X
COPIA AGGIORNATA
ANNULLATA LA PRECEDENTE
22 May 2013
UPDATED COPY
WASTE OLD COPY

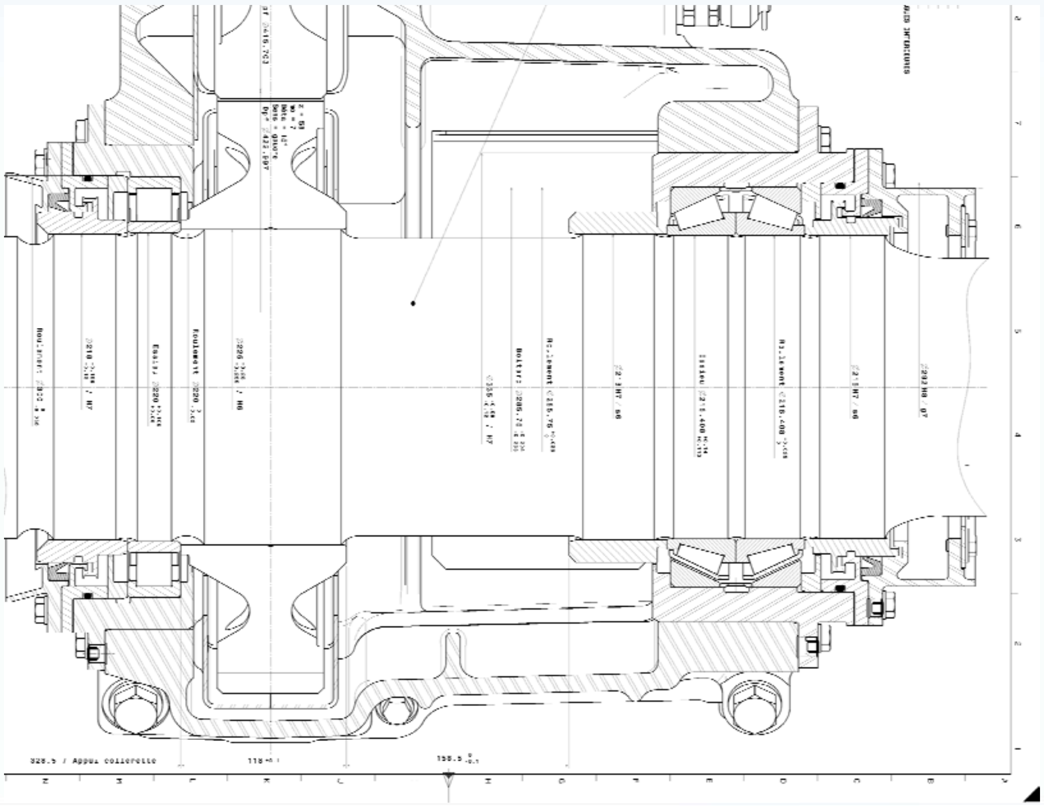
Why TBUs are not sufficient in IRWs solutions

1. Too low dynamic load rating to withstand vertical loads, lateral loads and the resulting torque M_t=Y*r
2. Any combination of two conventional tapered roller bearings would not have enough load rating
3. A different "innovative" solution was needed (note: only standard solutions in machine design were analyzed)
4. Toroidal roller bearings (SKF CARB / FAG TORB) were central in the design (see later)



Typical bearings arrangement

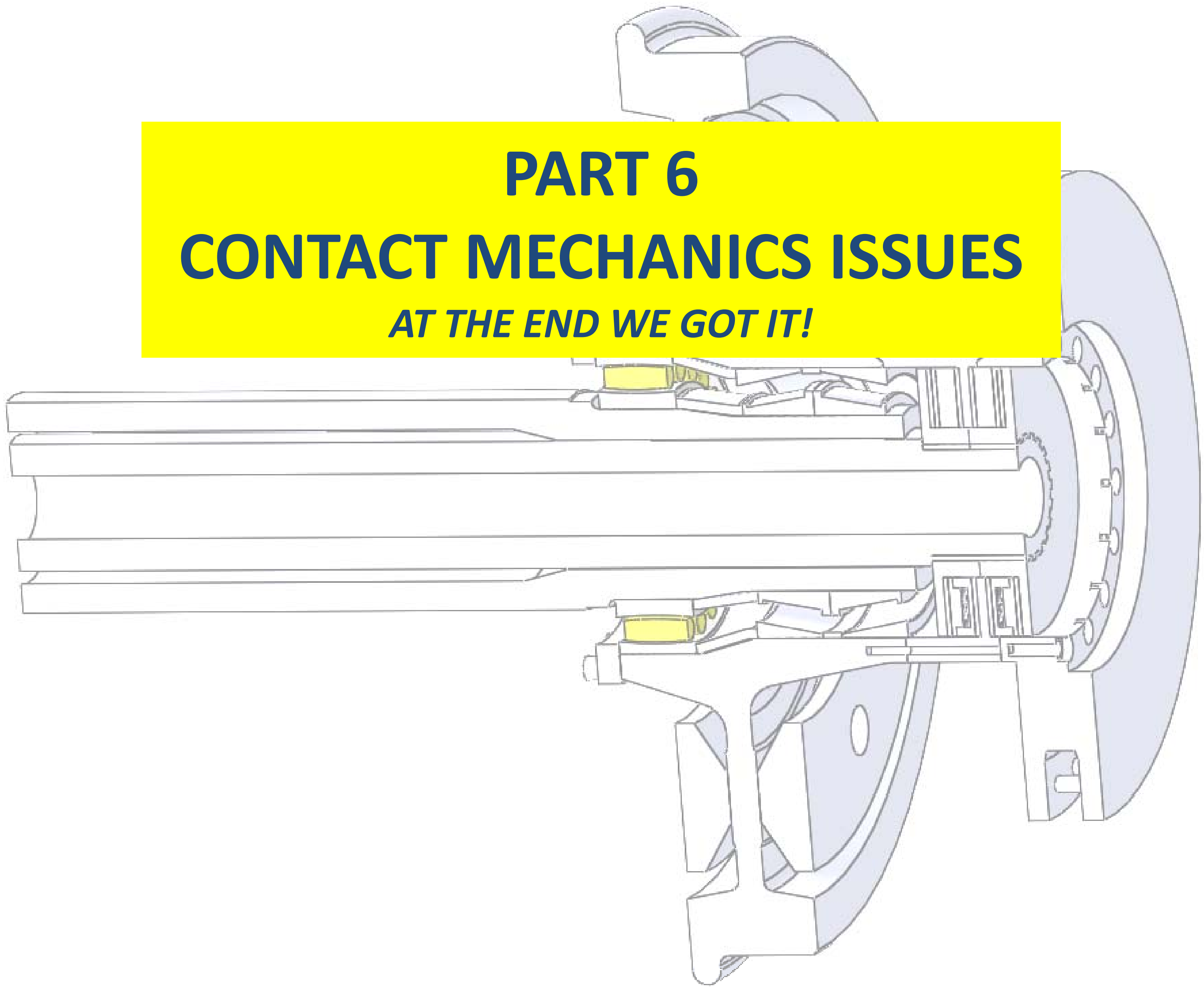
1. One locating (axially fixed) and one non-locating (axially floating) supports are generally needed
2. “New combination” of face-to-face TBU + CARB/TORB
3. Same C/P for both bearings (complex subject)



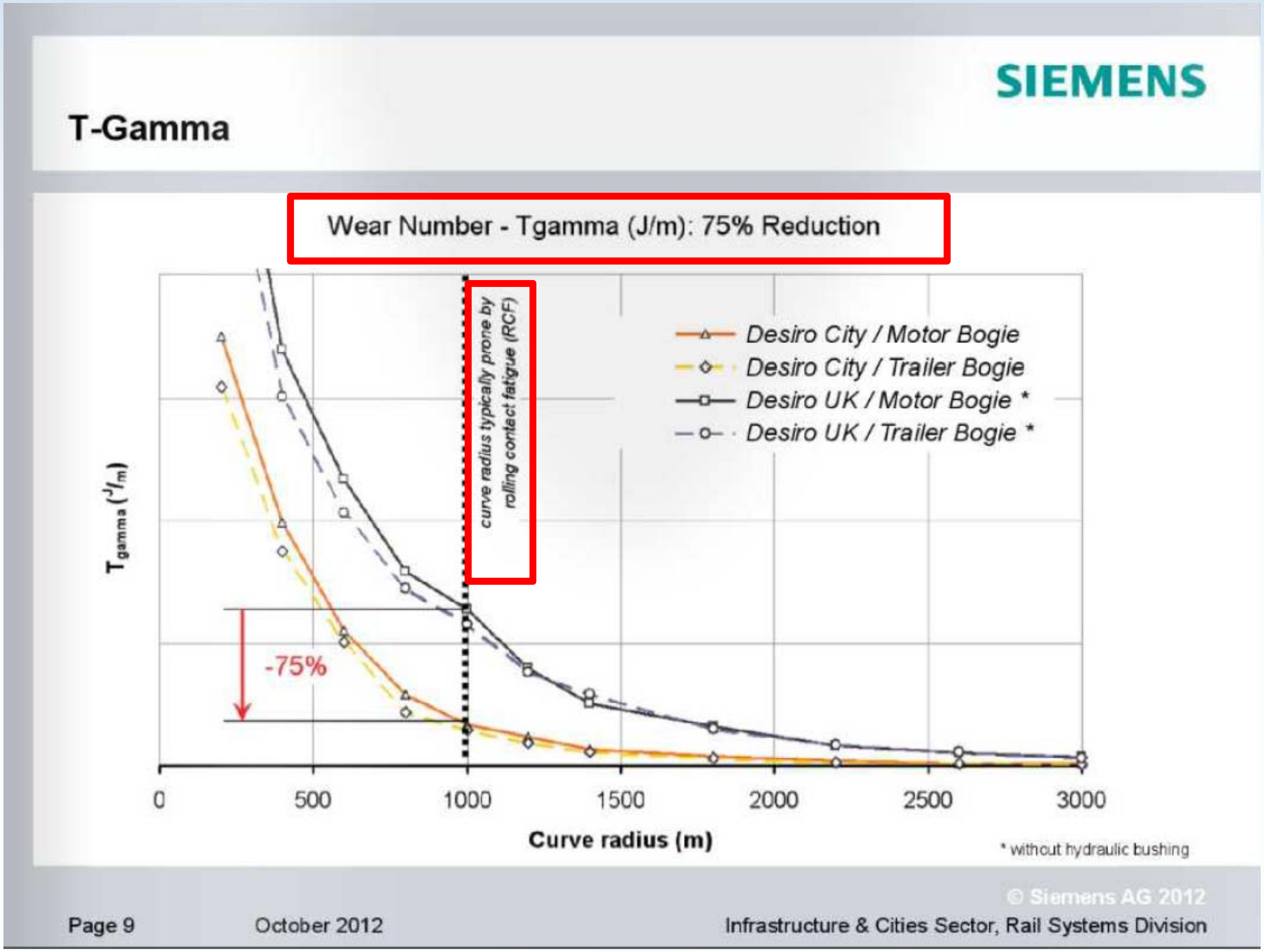
Schaeffler is presenting a new bearing type at the 2015 Hannover Messe with its FAG TORB toroidal roller bearing in X-life quality.

PART 6
CONTACT MECHANICS ISSUES

AT THE END WE GOT IT!



Modern vehicles steer better ☺



V300Zefiro during homologation tests

Y&Q forces measurement (EN14363)

WHAT ABOUT STEERING IN A FLAT 150 m RADIUS CURVE?

ISN'T THIS CORRUGATION?

Something we can’t do without (1)

A Model to Predict and Understand Rolling Contact Fatigue in Wheels and Rails

M. C. Burstow

AEA Technology Rail, Jubilee House, 4 St. Christopher’s Way, Pride Park, Derby, DE24 8LY, UK

Recent findings in the understanding of vehicle/track interaction on track damage and rolling contact fatigue (RCF)

[1]M. C. Burstow, [1]M. A. Dembosky, [2]S. Gurule and [2]C. Urban
Network Rail, 40 Melton Street, London, UK[1]; TTCI UK Limited, 13 Fitzroy Street, London, UK[2]

Vehicle/track interaction and rolling contact fatigue in rails in the UK

J. R. EVANS* and M. C. BURSTOW

AEA Technology Rail, Derby, UK

Something we can't do without (2)

Rail Safety & Standards Board

Research Programme

Engineering

Whole Life Rail Model application and development:
Dynamic modelling of rolling contact fatigue (Evans report)

Rail Safety & Standards Board

Research Programme

Engineering

Whole Life Rail Model application and development:
Development of a rolling contact fatigue damage parameter
(Burstow report)

Something we can't do without (3)

U.S. Department of Transportation
Federal Railroad Administration

Rolling Contact Fatigue: A Comprehensive Review

Office of Railroad
Policy and Development
Washington, DC 20590

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 2011	Technical Report

4. TITLE AND SUBTITLE Rolling Contact Fatigue: A Comprehensive Review	5. FUNDING NUMBERS DTFR53-05-H-00203
6. AUTHOR(S) Eric E. Magel	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Centre for Surface Technology 2320 Lester Road, Ottawa, Ontario K1V 1S2, Canada	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Railroad Administration Office of Railroad Policy and Development Washington, DC 20590	10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT/FRA/ORD-11/24
11. SUPPLEMENTARY NOTES Program Manager: Ali Tajaddini	
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the FRA Web site at http://www.fra.dot.gov.	12b. DISTRIBUTION CODE

AIR Wheelset – Contact Mechanics

Effects of torque limiter on *W*: → $W = T\gamma = T_x\gamma_x + T_y\gamma_y$

Wear Number

Limitation of longitudinal forces: ↓ $T_x\gamma_x$ 👍

Increase of lateral forces: ↑ $T_y\gamma_y$ 👎

Large modifications of overall value of *W* were not expected

Can the limitation of longitudinal forces lead to noticeable improvements in terms of wear and RCF? Does the damage mechanism remain the same?

The reference case

- STATIONARY curving behaviour of the ERRI wagon for different values of *R* e a_{nc}

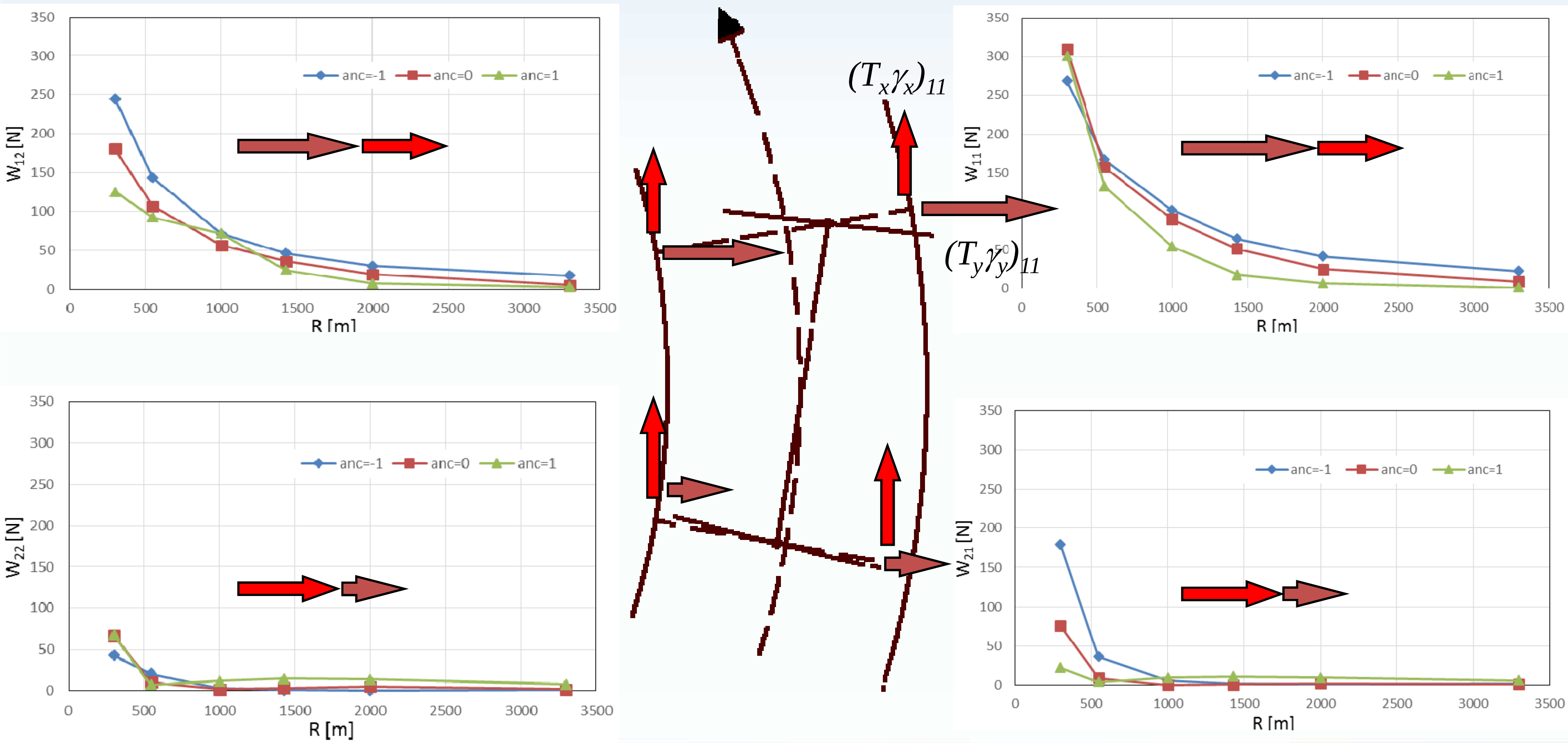
Curve radius [m]	a_{nc}= -1 m/s^2	a_{nc}= 0 m/s^2	a_{nc}= 1 m/s^2
300	13	64	89
548	18	86	121
1000	25	116	163
1430	29	139	195
2000	35	165	230
3300	45	212	296

v [km/h] for *h=160* mm
full speed range covered

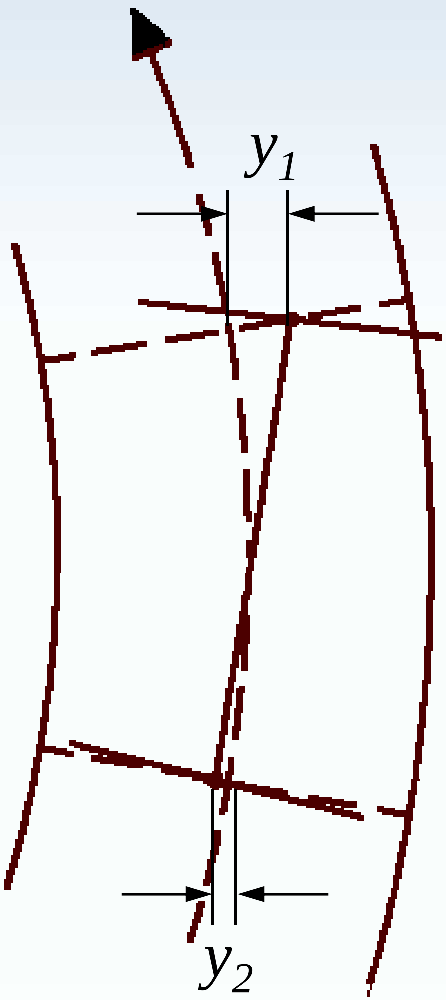
- Different adhesion conditions → *f = 0.1, 0.22, 0.33,* ***0.4****, 0.5, 0.6*
- The results are vehicle dependent
- Calculation of reference ***W*** to be compared with the torque limited case
- Focus on **longitudinal forces** $\boldsymbol{T_x}$ and **torque acting on the axle** $\boldsymbol{M_y}$ of the *i*-th wheelset → $M_{yi} = \Delta T_{xi}\, r$

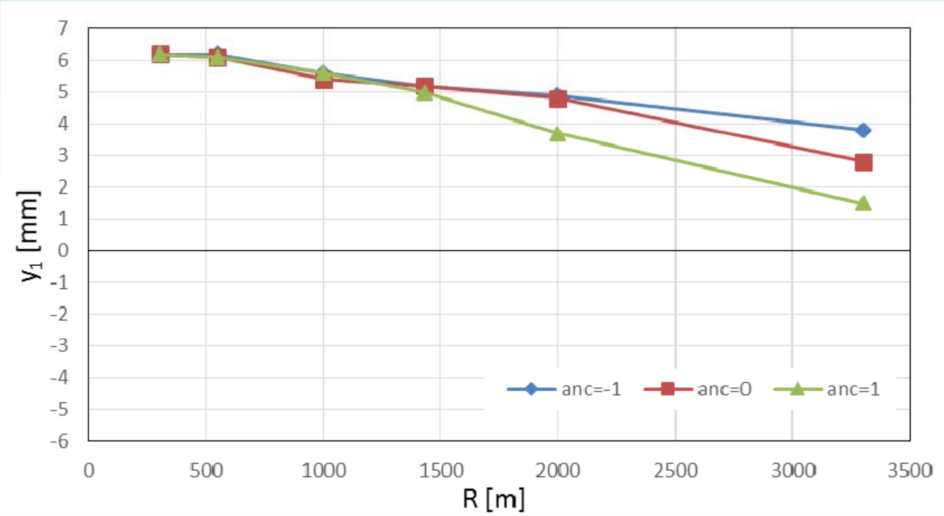
The reference case – Wear Number

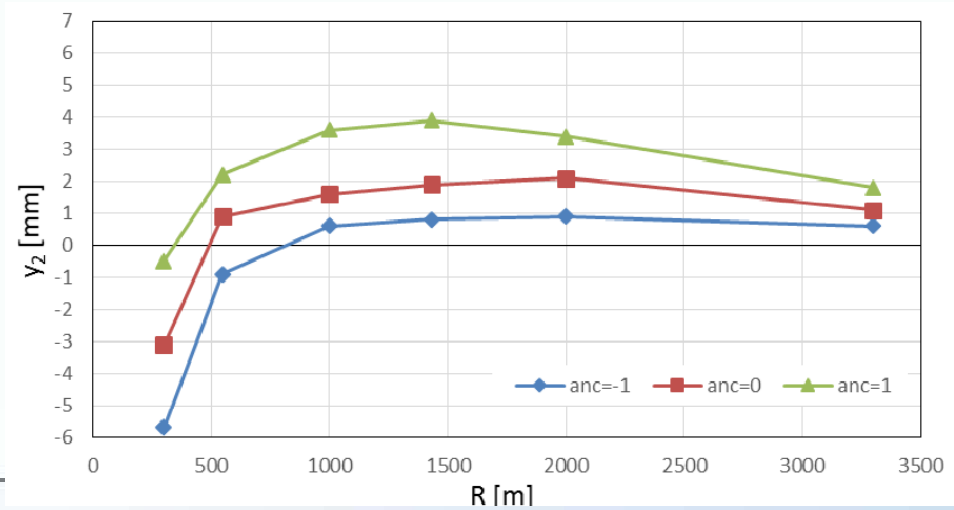
$$W = T\gamma = T_x\gamma_x + T_y\gamma_y$$



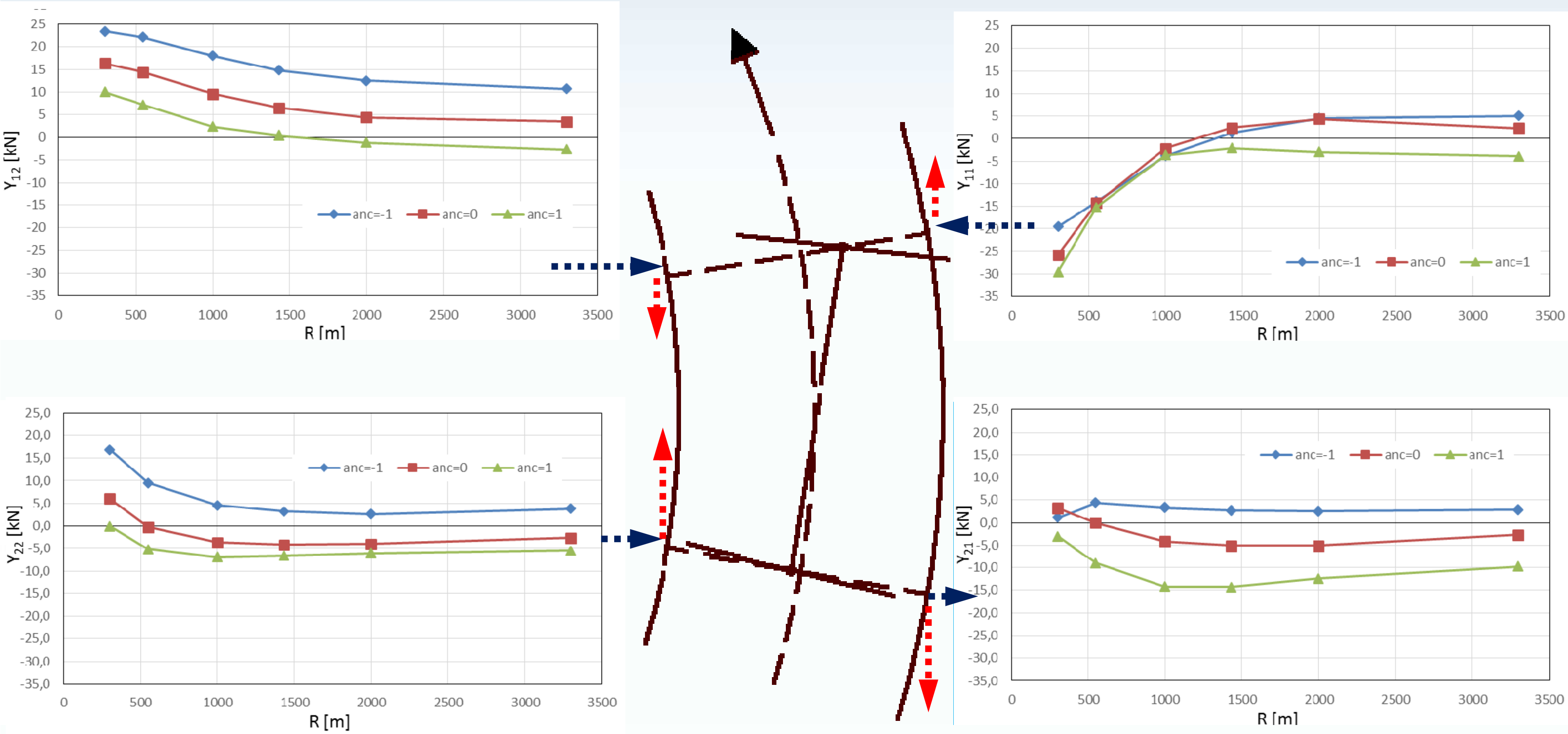
The reference case - Displacement







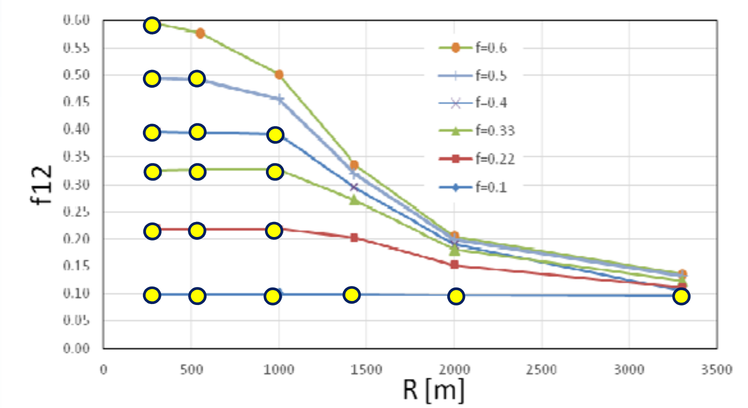
The reference case - Forces

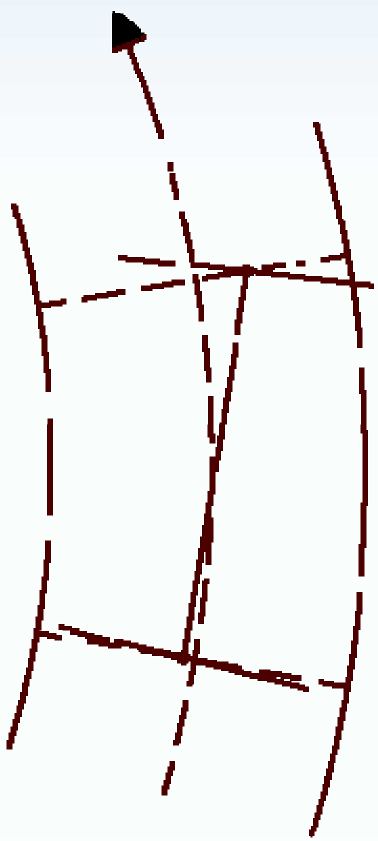


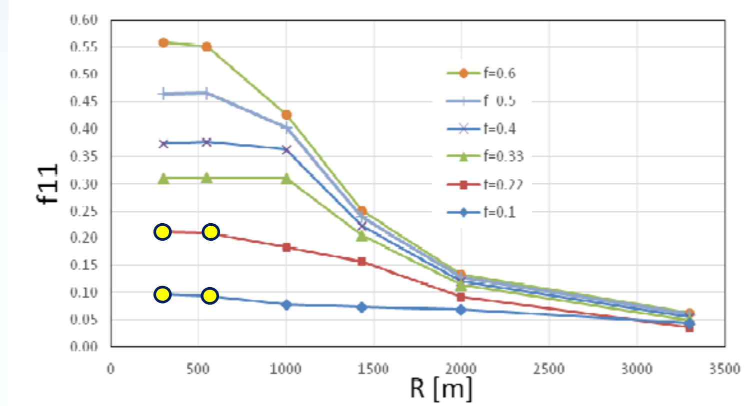
The reference case – Adhesion

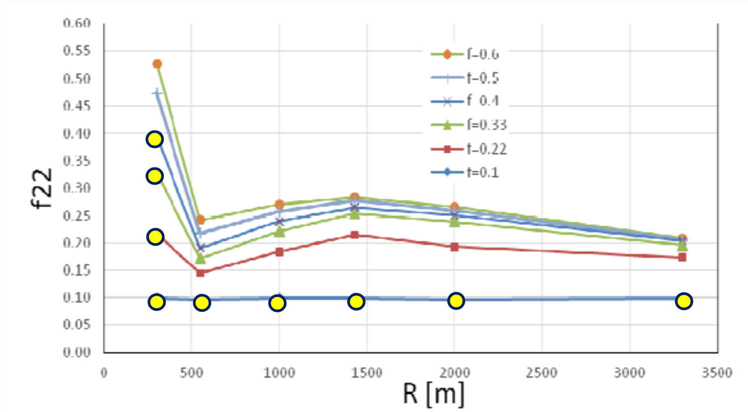
$$f' = \frac{T}{Q} = \frac{\sqrt{T_x^{\,2}+T_y^{\,2}}}{Q} \leq f$$

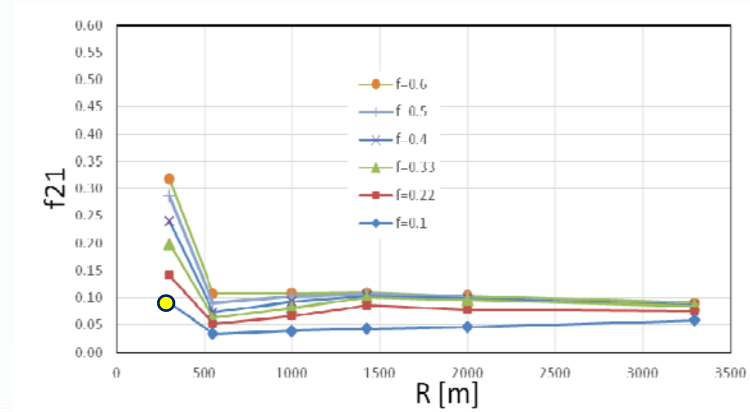
= adhesion limit reached



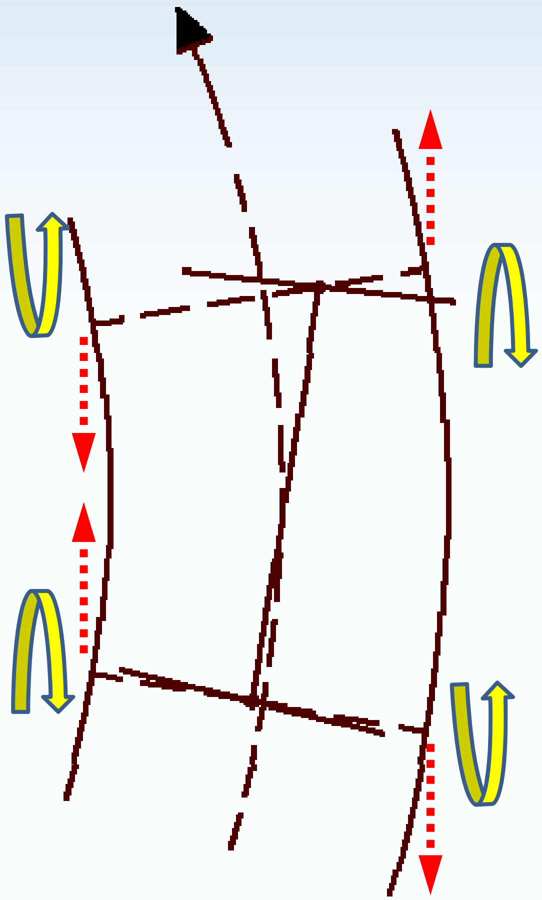


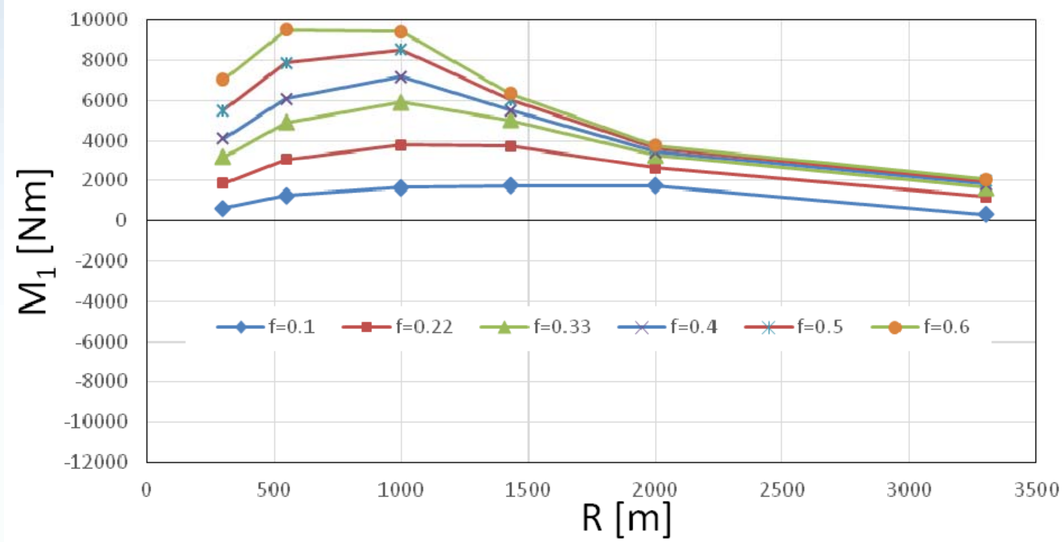


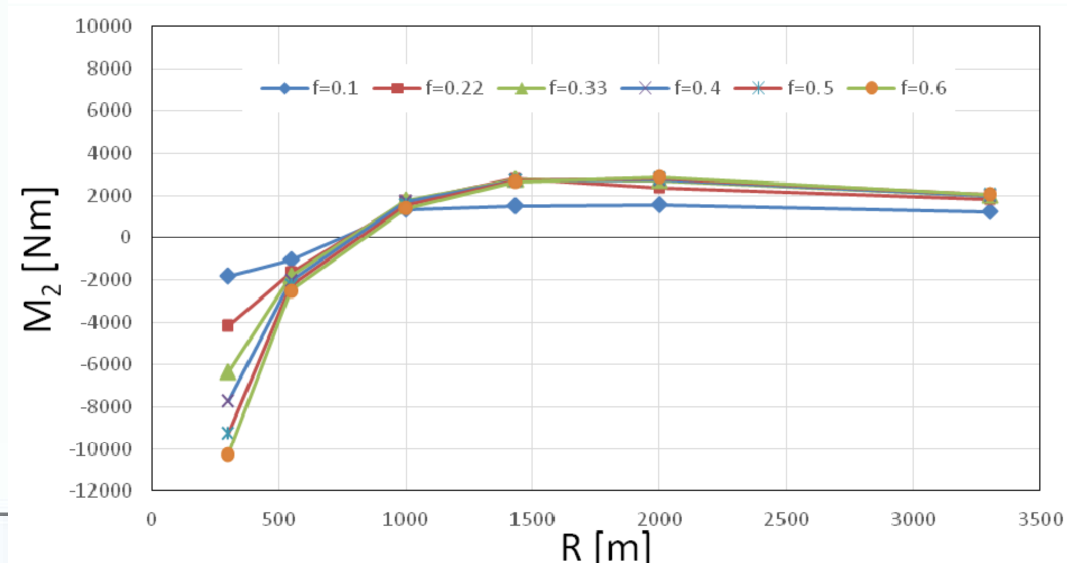




The reference case – Torque

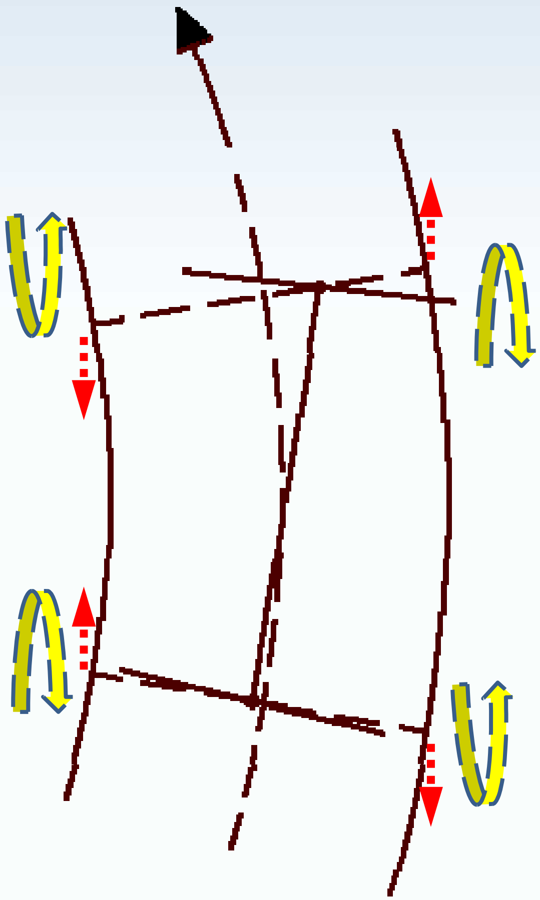


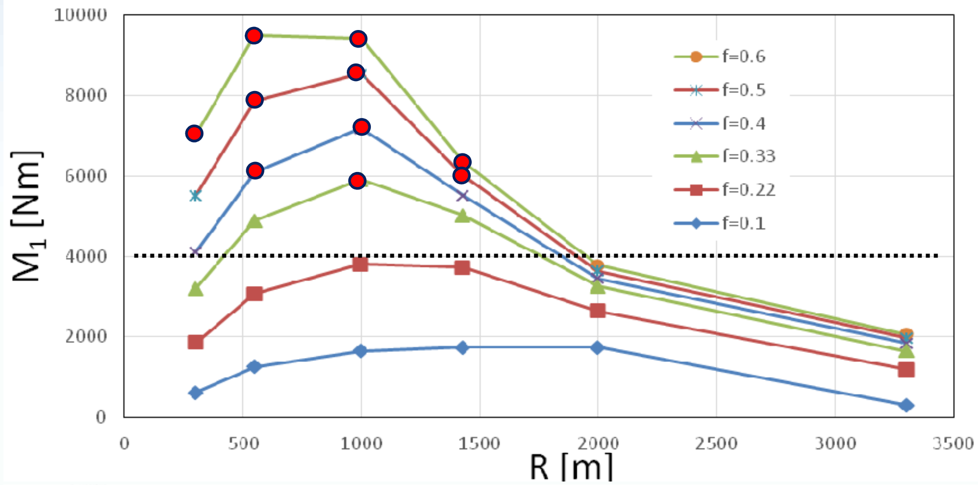


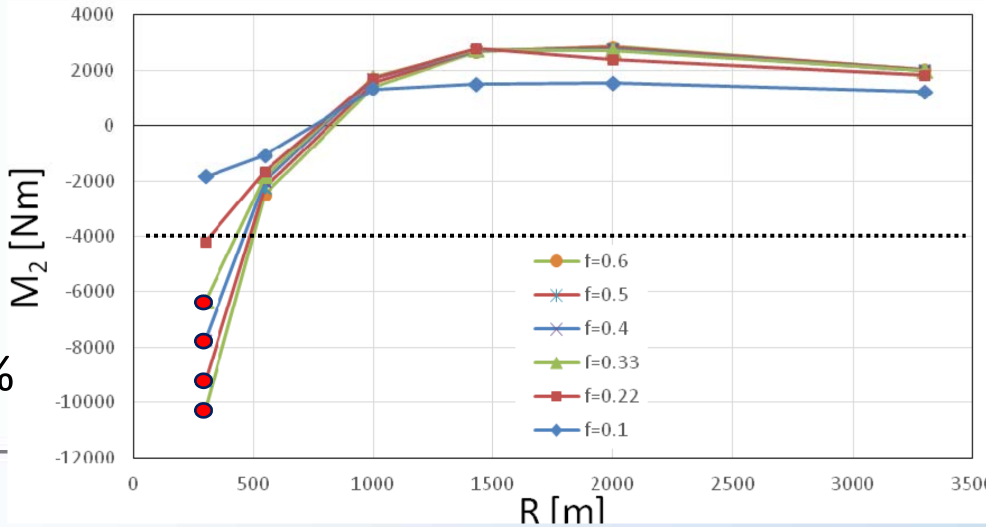


The torque limited case

M_{lim}= 4000 Nm ⟹ T_{max}≅ 8700 N

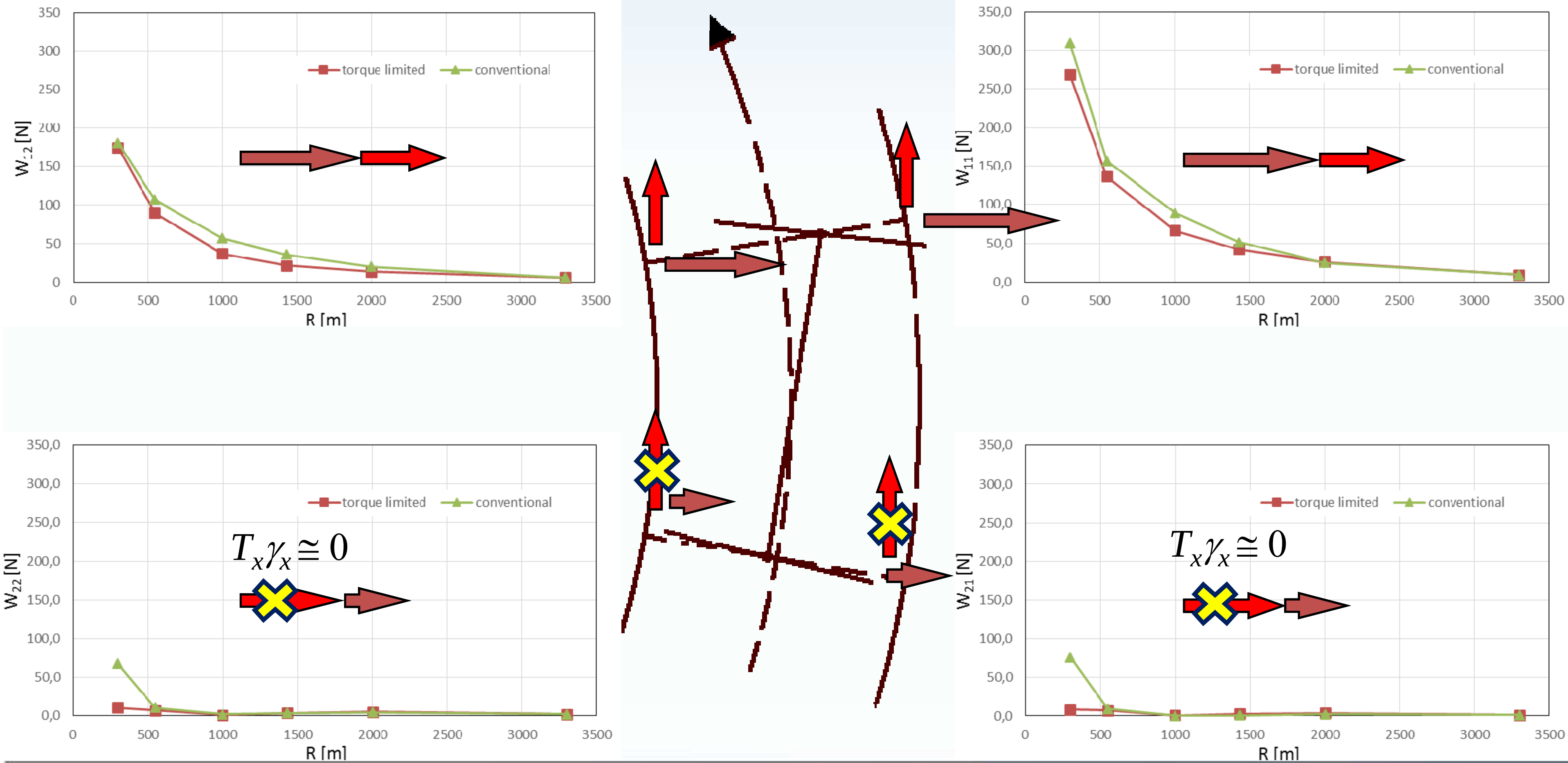




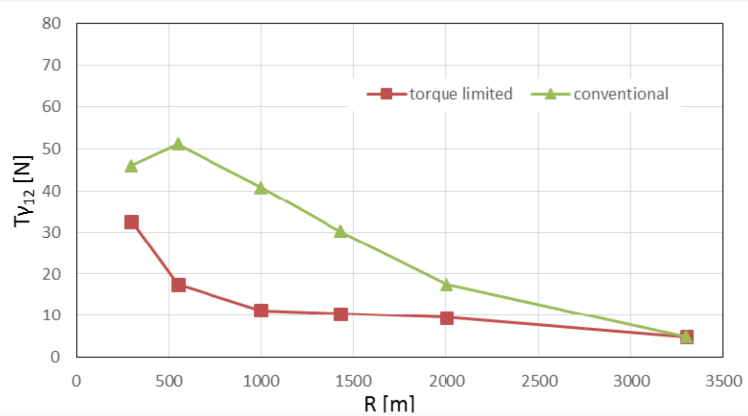


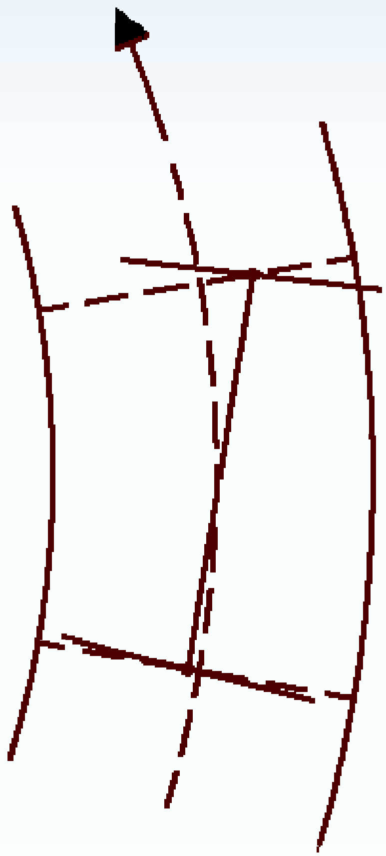
● = torque reduction > 33%

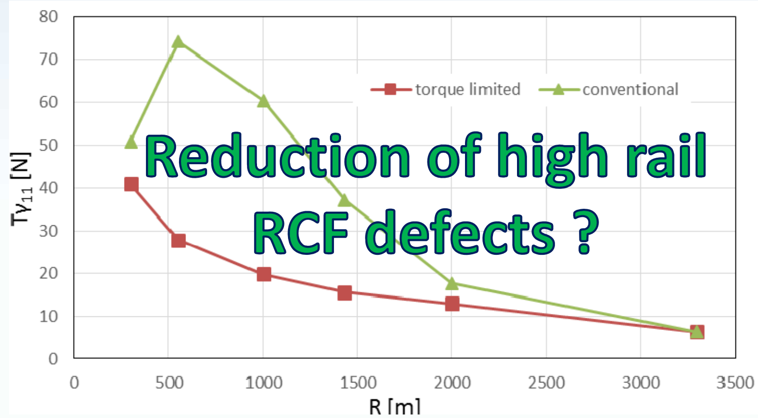
The torque limited case – Wear number

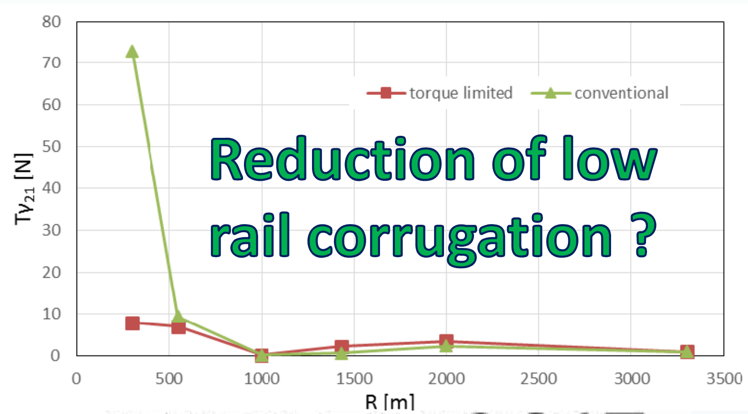


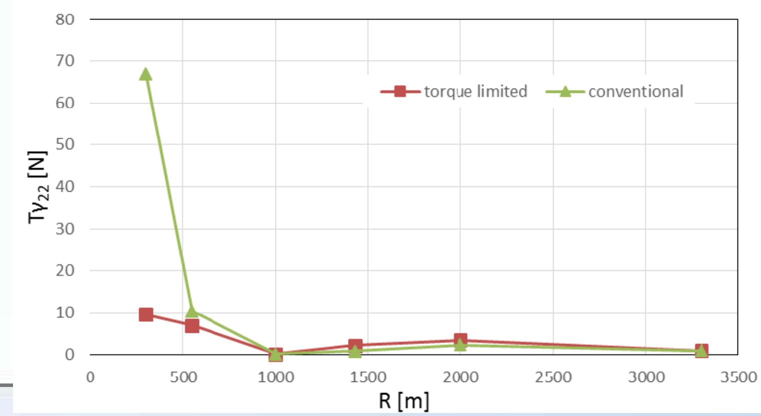
The torque limited case – $T_x\gamma_x$





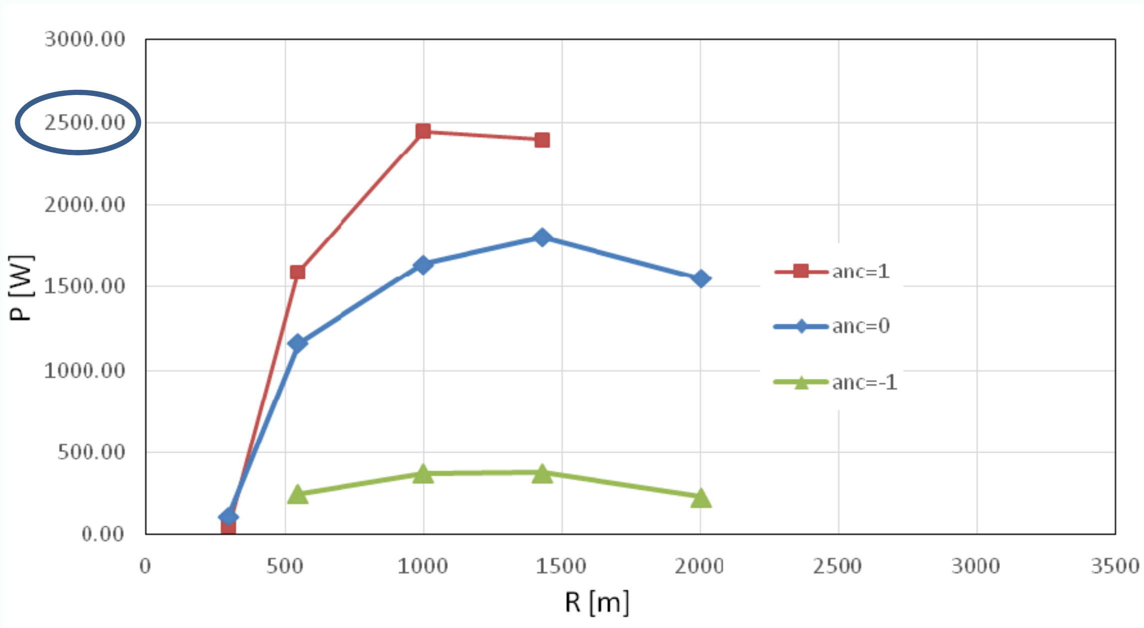






Power dissipated in the torque limiter

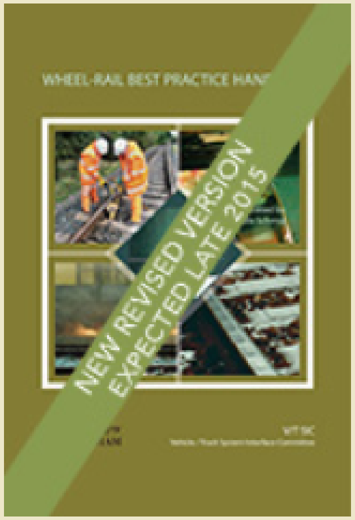
- The dissipated power is always lower than 2.5 kW
- No problems for cooling
- It represents a fraction of the energy that would be dissipated by longitudinal creeping
- Design critical (frequent interventions under high torque and very low angular speed)



A quite interesting book to read!!!!

Wheel-Rail Best Practice Handbook

(ed) F Schmid, Hardback, 500 pages, £50.00+p&p
ISBN13 978-0-952-9997-3-7 (9780952999737)



A handbook on Best Practice in the Management of the Wheel-Rail Interface on Mixed Traffic Railways. Britain's Vehicle/Track Systems Interface Committee commissioned the best practice hand-book as a means of disseminating understanding, knowledge and know-how on good practice in managing the wheel-rail interface. This interface is critical in the safe and efficient operation of railways of all types since it experiences high loads in demanding environmental conditions.

The information to be presented has been accumulated by practitioners and academics through theoretical and applied studies, in railway research centres, university laboratories and at the trackside.

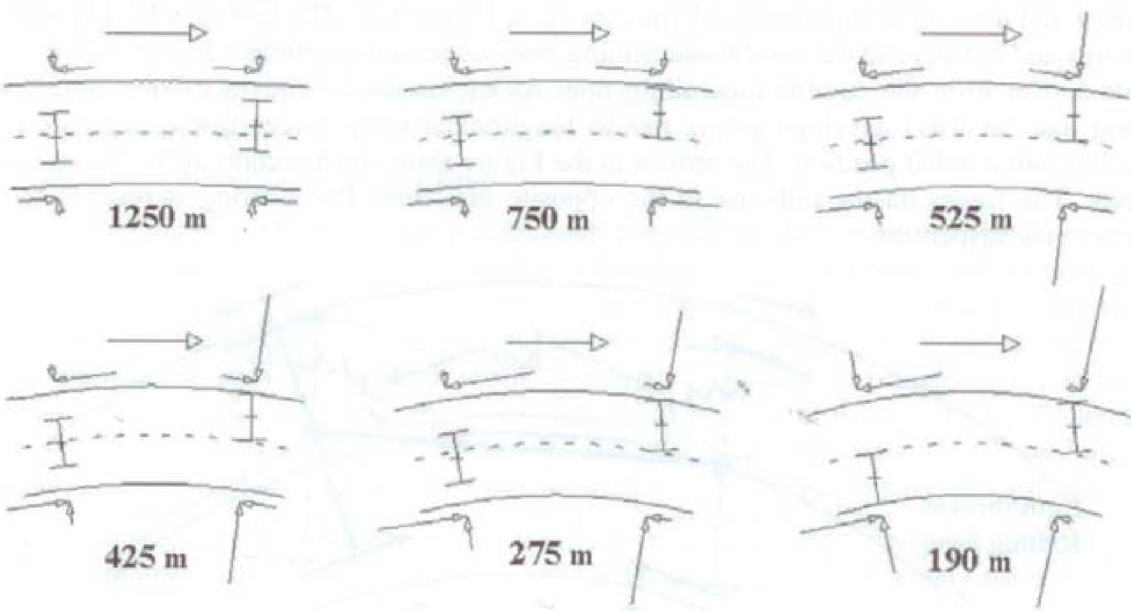
In particular, the book will contain the results of the research undertaken between 2000 and 2009, as a result of the realisation that the last years of the 20th century saw great changes in terms of both the technology used by the railways and the management of operations. The handbook will support the development of cost-effective methods for managing the lifecycle of both the wheel and the rail and for minimising the risk of future failures. The editorial team is being supported in its efforts by Network Rail and its partners in Britain's railway industry.

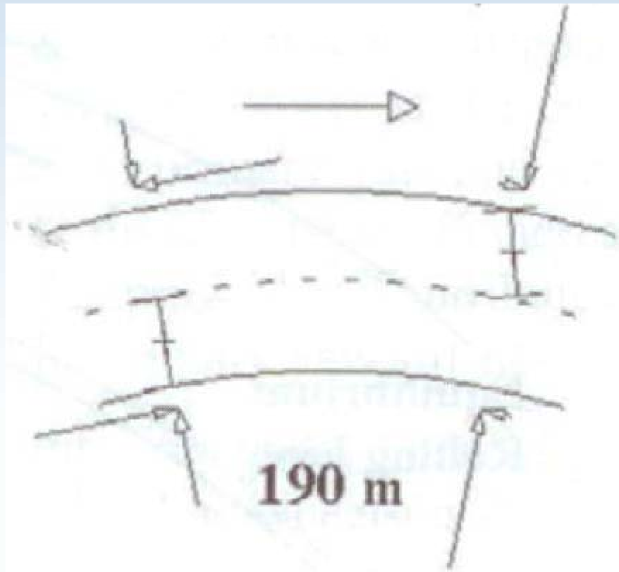
How much time do I have?

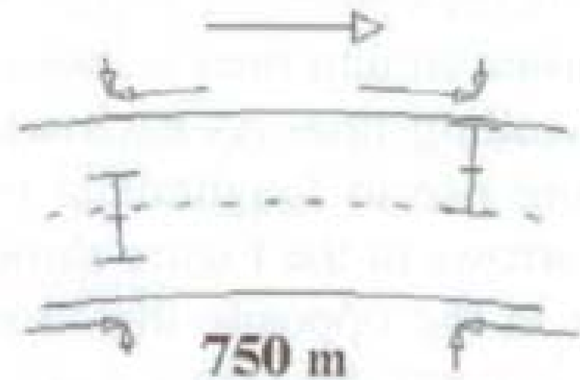
3.2.5 Examples of Curving Behaviour

The behaviour of vehicles in curves can be shown by a number of examples as shown in Figure 3-7. For each case, the behaviour is indicated by a curving diagram that shows the lateral and yaw positions of the wheelsets relative to the flangeway clearance in the track. The arrows indicate the size and direction of the longitudinal and lateral creep forces on the wheels.

The first example is a 6 m wheelbase two axle wagon running at balancing speed, that is, the speed at which the track cant exactly balances the lateral acceleration in the curve. This has been modelled for curves of varying radius using the VAMPIRE™ dynamic analysis software, with the results shown in Figure 3-7, which is reproduced here by kind permission from the copyright owner, DeltaRail. Despite a soft primary yaw suspension, the long wheelbase means that the curving behaviour is quite poor.







Radial steering index

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

FINAL DRAFT
FprEN 14363

June 2015

ICS 45.060.01

Will supersede EN 14363:2005, EN 15686:2010, EN 15687:2010

English Version

Railway applications - Testing and Simulation for the acceptance of running characteristics of railway vehicles - Running Behaviour and stationary tests

Annex Q
(informative)

Radial steering index

$$R_E = r_0 \frac{2b_A}{\Delta r_E}$$

Where R_E is the smallest curve radius where radial steering is possible with given Δr_E. The radial steering index is defined as:

$$q_E = \frac{R_E}{R}$$

so that:

— when $q_E \le 1$ radial steering is possible;

— when $q_E > 1$ radial steering is not possible but flange contact will occur before a rolling radius difference, Δr, big enough for the curve in question is achieved.

Rail surface damage quantity

Annex K
(informative)

Evaluation and background of the rail surface damage quantity T_{qst}

The mostly used and accepted parameter to indicate RSD is $T\gamma$ (or sometimes called the wear number) which is the product of tangential creep forces and creepages in the wheel/rail contact. $T\gamma$ is the essential input to prevailing wear modelling and is a measure of the friction energy dissipation in the wheel/rail contact. $T\gamma$ is often expressed in units of energy per unit of sliding distance (Nm/m) and can only be determined by vehicle dynamics simulation since it depends on the tangential creepages which are not measured today.

In order to overcome this problem during vehicle tests a new simplified approximation of $T\gamma$ is introduced. This quantity is called the rail surface damage quantity, denoted T_{qst}. It is a quantity combined from the lateral, longitudinal and vertical wheel forces. Thus the evaluation of this quantity can only be carried out in case the steering force in the longitudinal direction, $T_{x,qst}$ is measured.

$$T_{qst} = \frac{Q_{qst}}{10\,000}\left(330 \cdot f^2 - 62 \cdot f + 4\right)$$

where

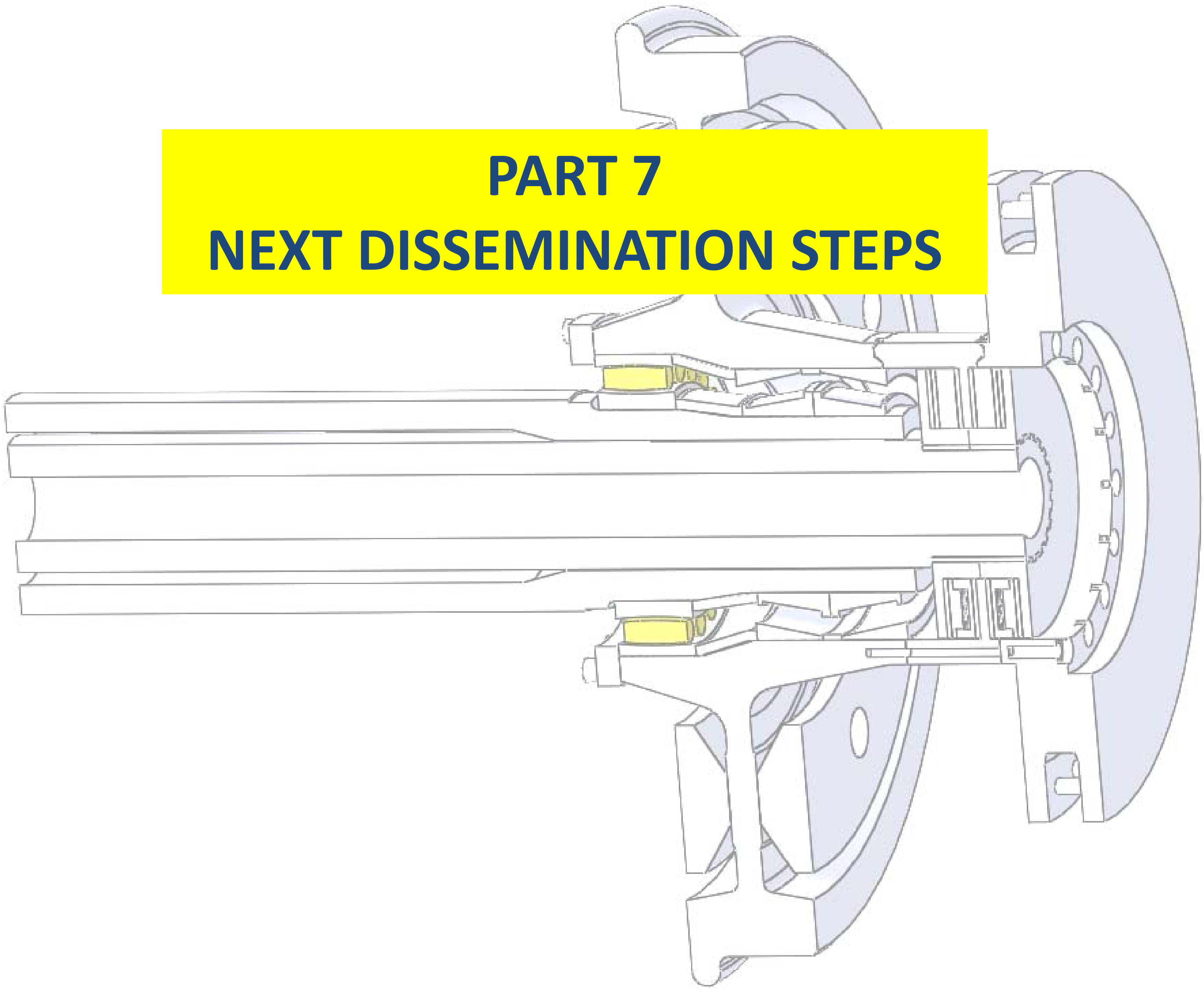
$$f = \frac{Y_{qst}}{Q_{qst}} + 0{,}62 \cdot \frac{|T_{x,qst}|}{Q_{qst}}$$

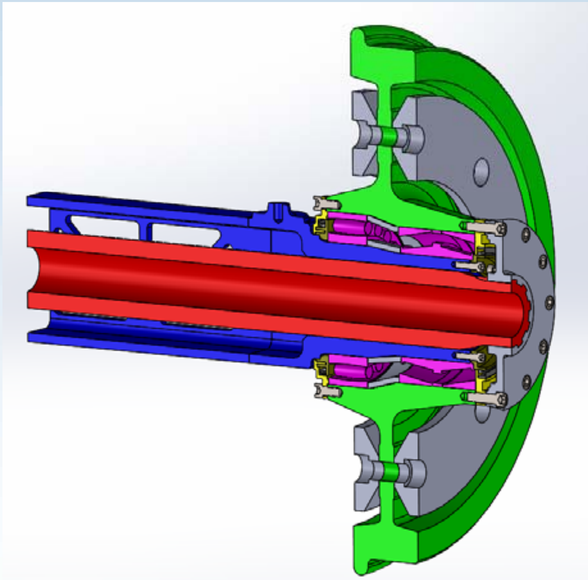
For further reference on technical background refer to [19].

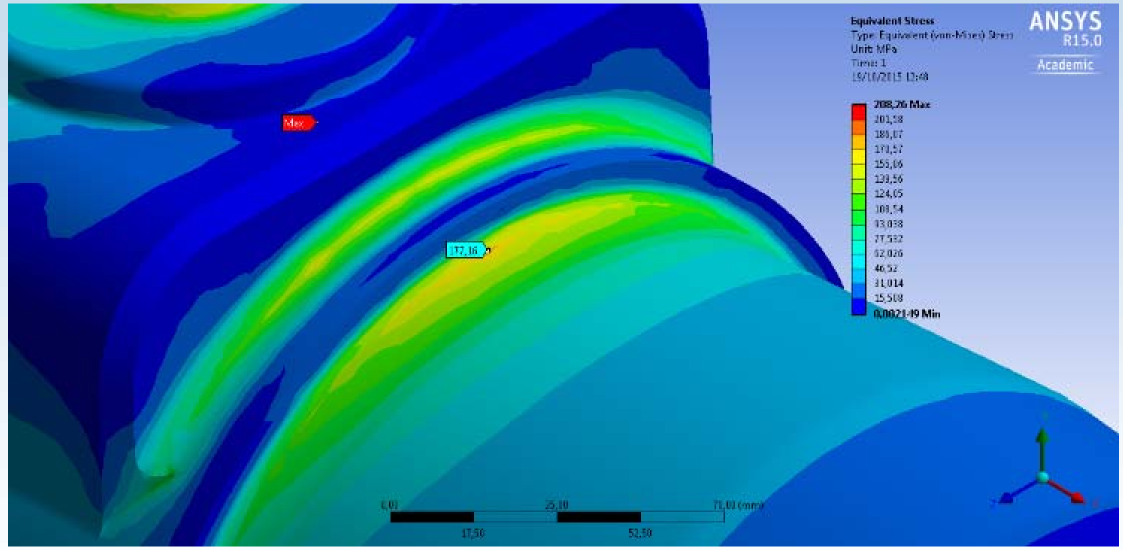
[19] *Assessing Rail Vehicle Curving Performance And Wear Of Rails By Relations Between Vehicle, Track And Operational Parameters – A Parametric Simulation Study*, Öberg, J. Proceedings from IAVSD 2009. Make reference to book if available

Johan Öberg, M.Sc. Vehicle/Track Engineering.
Department of Track and Civil Engineering, Banverket (Swedish Railway Adm).
Landsvägen 50A
SE-172 22 Sundbyberg, Sweden
johan.oberg@banverket.se

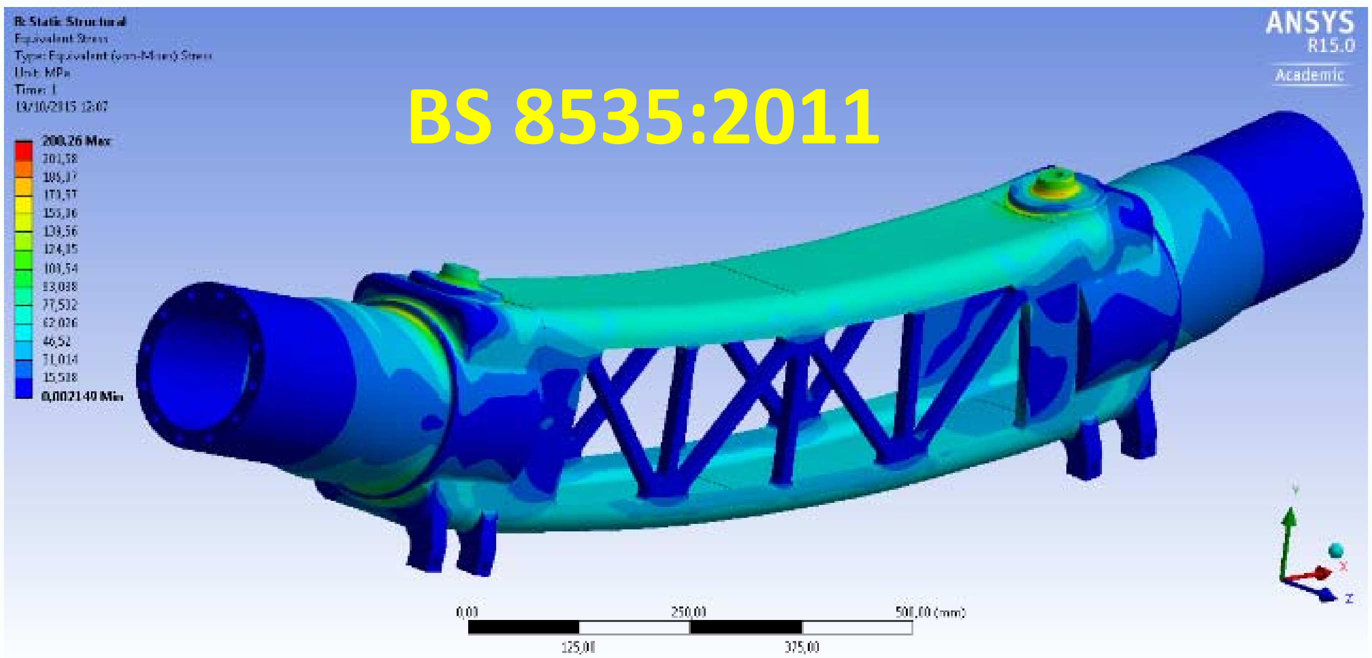
PART 7
NEXT DISSEMINATION STEPS







BS 8535:2011



WRI EU 2015

Dissemination plan

- VI-Rail User's Conference, Trieste, 15 April 2015 **OK**
- Stephenson Conference, London 22 April 2015 **OK**
- IAVSD, Graz, 17 August 2015 **OK + VSD**
- CM2015, Colorado Springs, 30 August 2015 **OK + Wear**
- WRI EU, Derby (UK), 23 October 2015 **OK**
- Railway Engineering (3), Cagliari, 5 April 2016 **OK**
- WCRR, Milan, 29 May 2016 **abstract accepted**
- IWRN, Terrigal, 12 September 2016
- Innotrans, Berlin, 20 September 2016
- IWC, Chengdu, 7 November 2016


The Third International Conference on
Railway Technology:
Research, Development and Maintenance
5-8 April 2016 - Cagliari, Sardinia, Italy
Railway wheelsets: history, research and developments
A. Bracciali
Dipartimento di Ingegneria Industriale, Università di Firenze, Florence, Italy
Validation of the design of the torque limiter of the AIR Wheelset on the Sardinian backbone network
A. Bracciali, G. Megna
Dipartimento di Ingegneria Industriale, University of Florence, Italy
Civil-Comp

WCRR 2016 – Milan 29.5.2016

Document ID: 46186

Authors:

Bracciali Andrea, Dipartimento di Ingegneria Industriale, Università di Firenze, Firenze, Italy

Cavicchi Paolo, Direzione Tecnica, Ingegneria Rotabili e Tecnologie di Base, Materiale Trainato, Trenitalia S.p.A., Firenze, Italy

Corbizi Fattori Alessandro, Direzione Tecnica, Ingegneria Rotabili e Tecnologie di Base, Tecnologie Meccaniche, Trenitalia S.p.A., Firenze, Italy

Session : Vision&Future

Themes : A) Rolling stock

Abstract Title : MAINTAINABILITY OF WHEELSETS: A NOVEL SOLUTION TO SAVE TIME AND MONEY

Conclusions

- A new wheel arrangement (named *AIR Wheelset*) has been introduced
- The main advantage (reason for design) is MAINTENANCE
- Design targets were particularly severe, leading to a potentially «universal» solution
- Several studies were conducted to verify the applicability of the *AIR Wheelset*
- Vehicle dynamics is in practice unaffected by *AIR Wheelset*
- Contact mechanics simulations look promising
- Two wheelset manufacturers and a system integrator have confirmed their interest in this new design

Thank you very much for your attention!