



# T O G **P** R A T / 22



Wednesday 15 June 2022, Lodalen,  
Oslo

## Maintenance driven bogie and running gear innovation

*A. Bracciali*

Note: references are to papers freely downloadable from [www.andreabracciali.it](http://www.andreabracciali.it)

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# Is it just a problem of *how* we maintain trains?

- Modern maintenance may benefit by a large number of tools previously unavailable, mainly derived from IT (cloud, artificial intelligence, big data, internet of things, etc.)
- Despite this, maintenance of structural components (running gear, bogie frames, etc.) is still «a hard job»
- Maintenance optimization of large fleets in wide territories is by far one of the most complex task in operations engineering & research
- This meeting shows that the topic is crucial for sustainability of modern railways
- *...but... after all...*
- «We have to look after our kids»
- **Is there anything we can do to design *better trains* that require *less and easier maintenance*?**

## Case study A (1)

### A wheelset that revolutionizes maintenance saving itself and the track at the same time

- Independently Rotating Wheels (IRW) mounted on inboard bearings bogies can be easily replaced
- The combination of inboard bearings bogies and IRW (i.e. wheels on individual bearings) is a dream for whoever deals with trains maintenance
- AXLES DISAPPEAR!!!!



## Case study A (2)

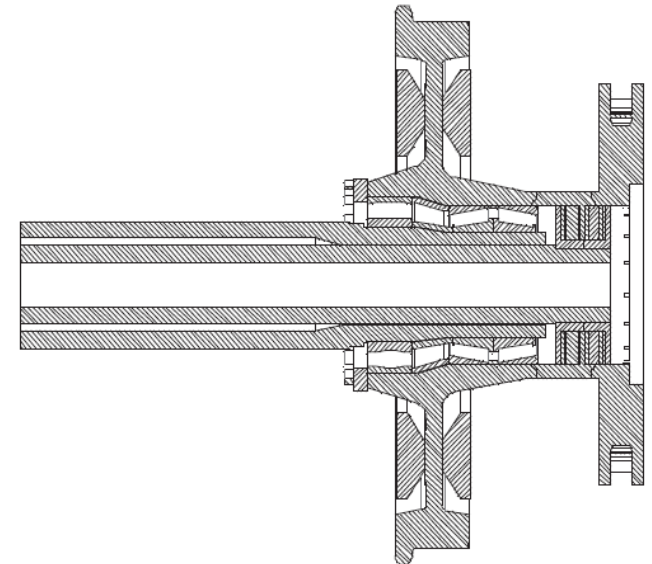
- The problem is that IRWs DO NOT work (steering is totally missing) – used in low floor trams with many headaches
- Running dynamics tell us that *longitudinal forces* are needed for steering but at the same time they are responsible for wheel and rail damage
- Having spent years trying to combat (without success) rail corrugation [71] and groundborne noise and vibrations [73], around ten years ago a thorough study was started on a new wheelset
- The idea was also to preserve track from damage (winding routes, metros with sharp curves) requiring no rail grinding and/or rail replacement

## Case study A (3)

- The idea was to get a «torsionally controlled» wheelset that behaves as a «conventional» wheelset in straight track (guidance is fundamental...) and as a «controlled torque» wheelset in tight curve to ensure steering while avoiding rail corrugation and wheel polygonization [104]
- Studies on torque limiter [108] and specific bearings arrangement [110] were published

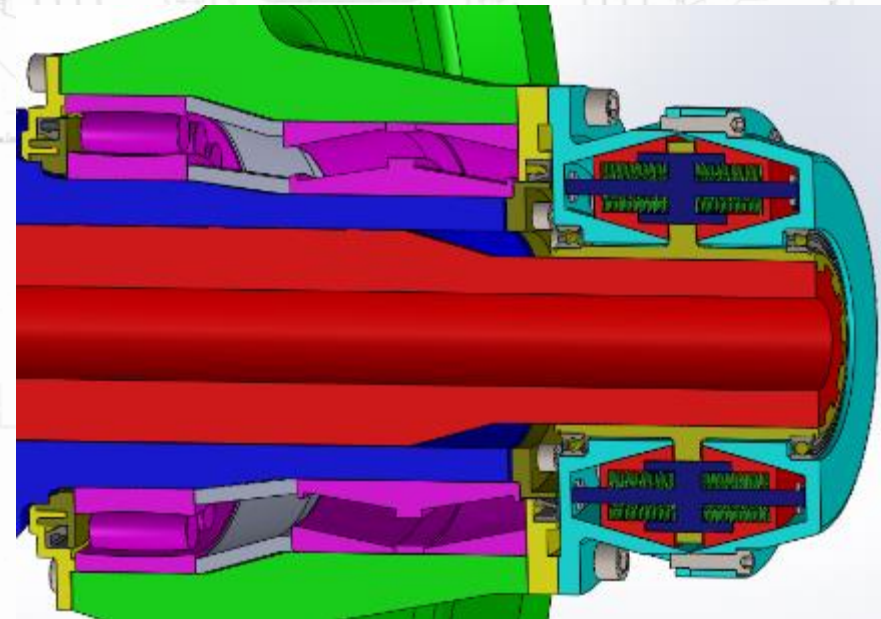
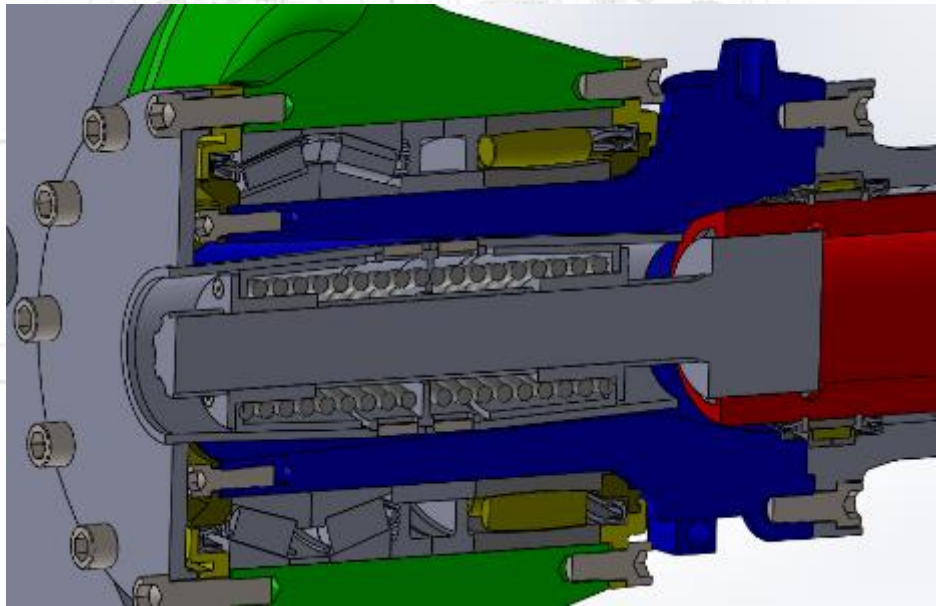
**Apparently independently rotating wheelset – a possible solution for all needs?**

**A Bracciali**  
University of Florence, Italy  
AB Consulting sas, Italy



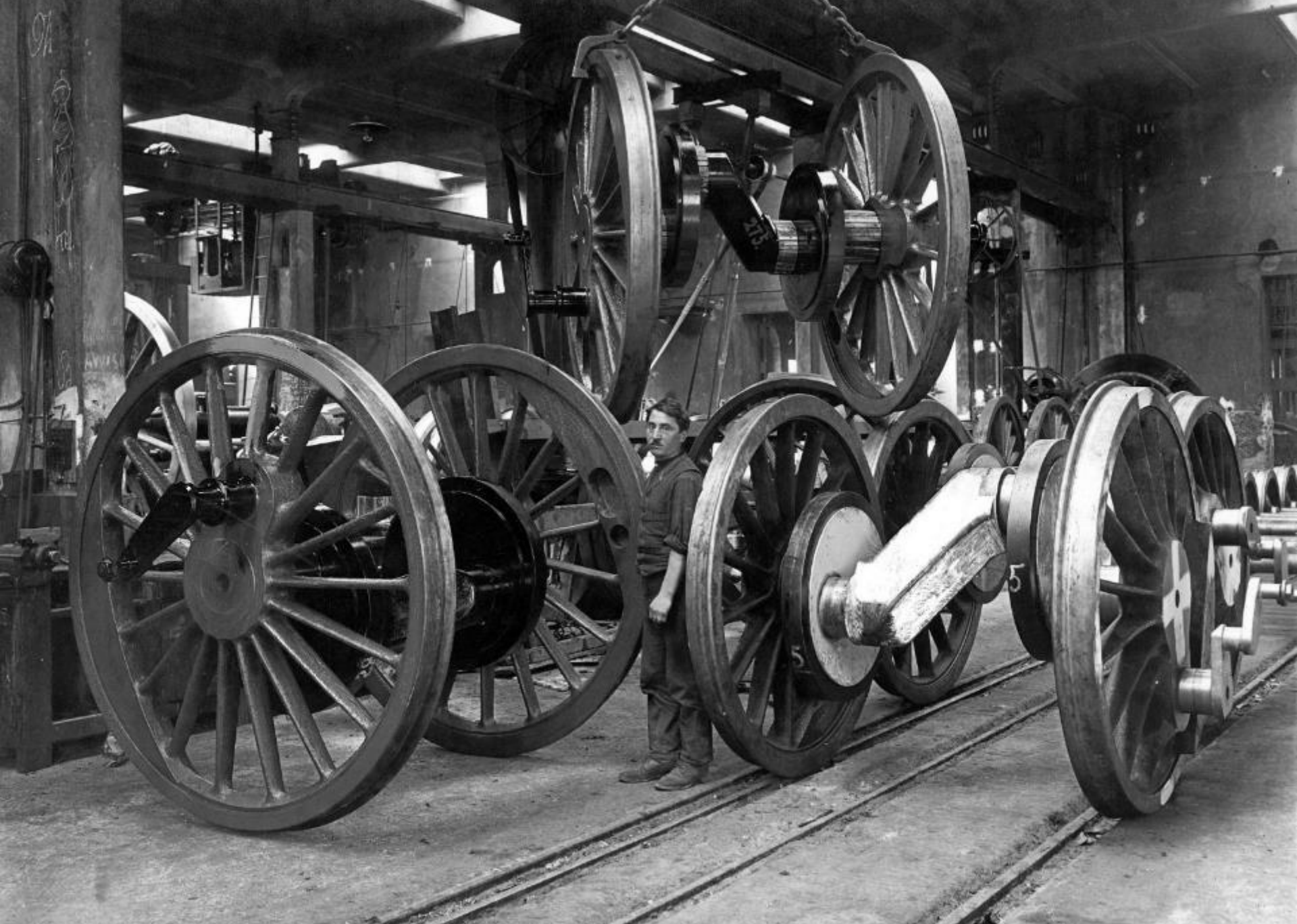
## Case study A (4)

- A study was presented at WCRR 2016 with some colleagues from Trenitalia [111] showing maintenance cost reduction close to 25% (largely underestimated, in my opinion)
- Detailed drawings, FEM and running dynamics calculations were all very promising
- Common Safety Methods analysis made by an independent assessor said the wheel is safe [128]



## Case study A (5)

- Wheelset industry had no interest in developing something that reduces the market
- Bearings manufacturers refused to use bearings different from TAROL/TBU saying that CARB was developed for other sectors
- Just one ridiculous offer was received for the patent
- Burocrats said that the wheelset doesn't fit the current European standardization frame (are you surprised???)
- Only people from the service department of a couple of «global train suppliers» were enthusiastic, but designers and commercial guys decided to bury the idea
- So, a revolution in wheelset maintenance was lost
- **END OF THE GAME**



**TOGPRAT 22 – A. Bracciali - Maintenance driven bogie and running gear innovation**

# Case study B (1)

## A wheel that kills maintenance and logistics costs

- European standards only consider monobloc wheels --- did you ever ask yourself why???
- We travelled for decades with tired wheels and the human kind did not extinct

*The Queen of German locomotives... DB E 03 (103)*

*Co'-Co' wheel arrangement*

*Max speed 200 km/h (280 km/h during tests)*

*Short-term maximum power output 10.400 kW (1733 kW/axle)*

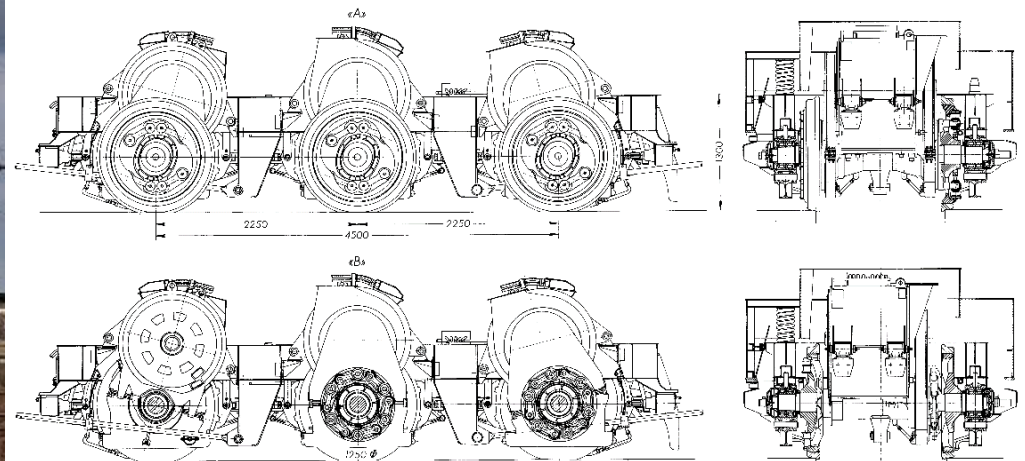


Abb. 3.485 b. Dreiaxliges Drehgestell der C<sub>0</sub>C<sub>0</sub>'-Lokomotiven Serie 103 der DB mit Gestellmotoren und Henschel-Verzweigerantrieb gemäß Abb. 3.324 oder Gummigelenk-Kardantrieb gemäß Abb. 3.324  
(Hilfsstahl) Henschel AG, Kassel  
A Längsschnitt für Henschel-Verzweigerantrieb  
B Längsschnitt für Gummigelenk-Kardantrieb

## Case study B (2)

- Speeds in excess of 300 km/h were safely reached!

Giugno 1994

INGEGNERIA FERROVIARIA

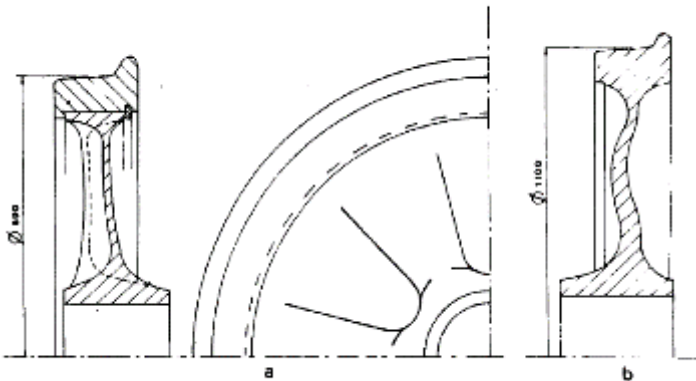


Fig. 3.6 - Vista e sezione della ruota della vettura (a) e sezione della ruota della motrice dell'ETR500 (b).

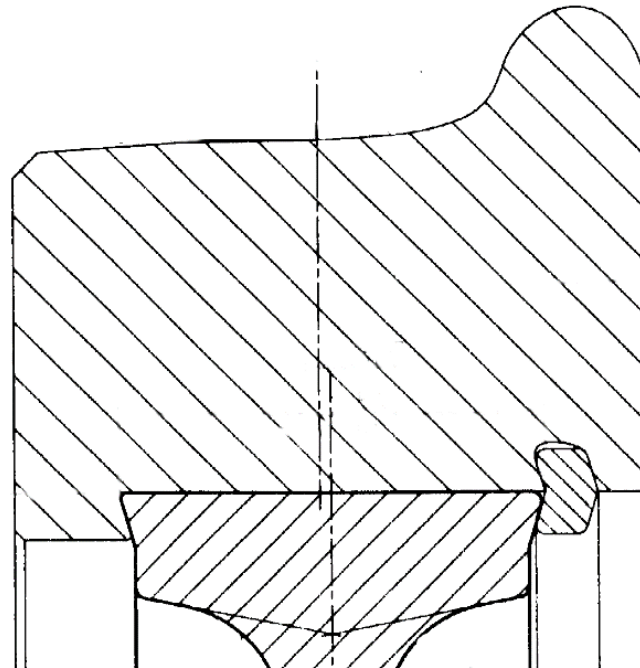


*Two trainsets, called ETR Y 500, were put in service in 1990 for the football world championship*

*One of them reached 321 km/h in 1991, that represented the speed record in Italy until 3.2.2009 (362 km/h)*

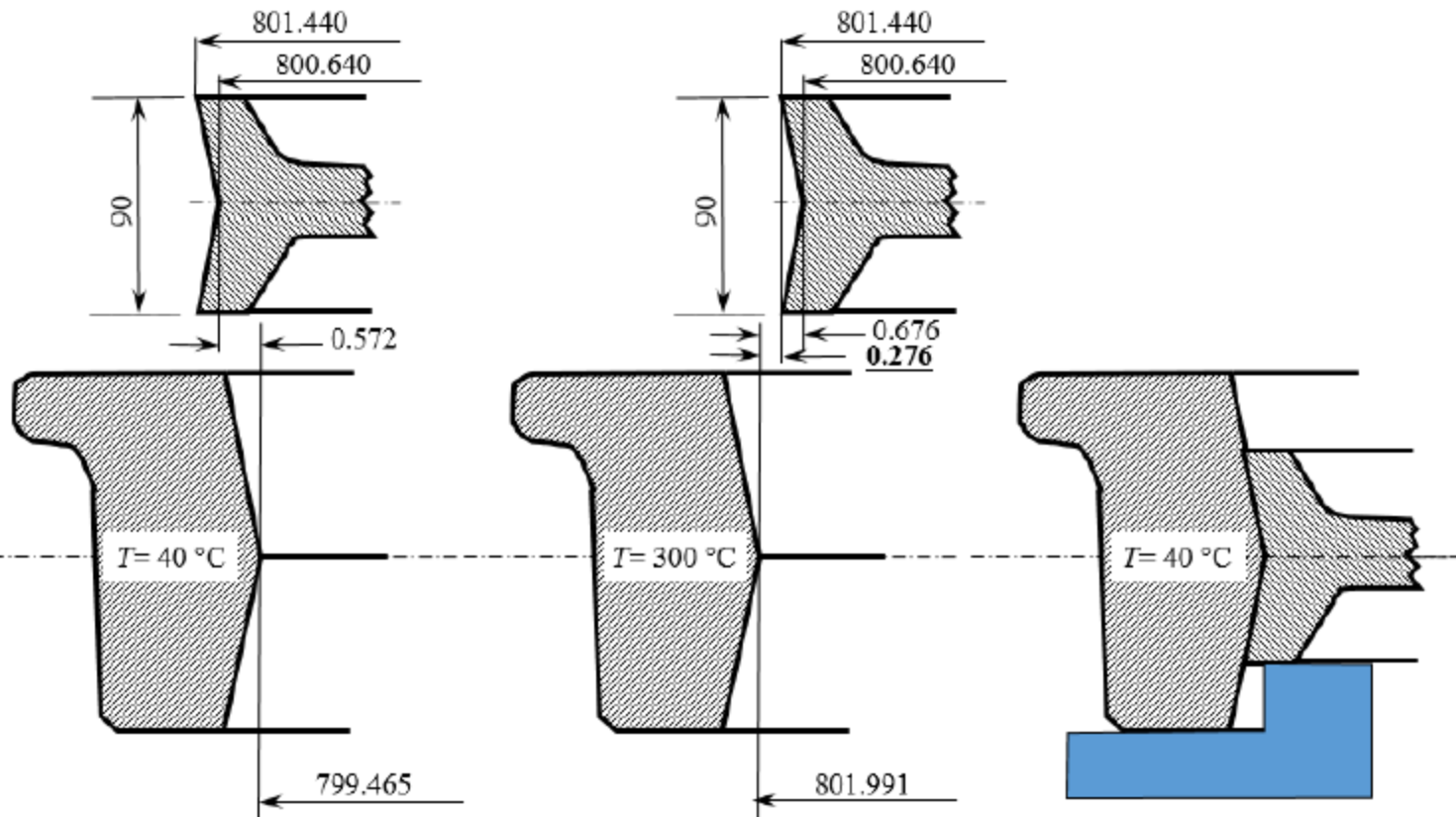
## Case study B (3)

- The end of tired wheels was due to the crazy maintenance cycle
- Before trying to change something, we carefully analyzed stresses and strains by detailed non-linear FE analyses [118]
- As modern passenger trains are disc braked, we discussed tolerances and fitting interference that are really needed to ensure that the tyre does not rotate w.r.t. the wheel centre [119]



## Case study B (4)

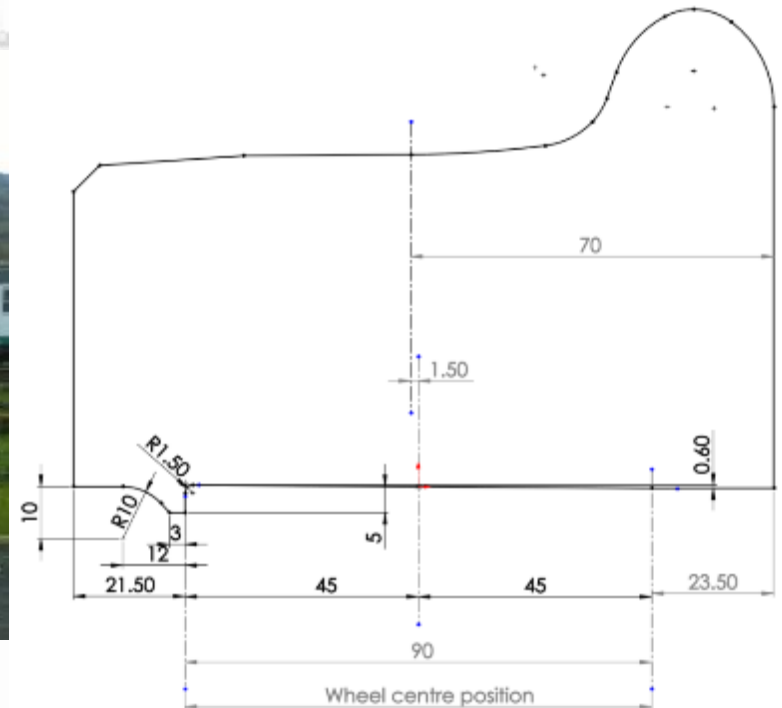
- We therefore introduced the concept of «dovetail coupling» that doesn't require the retaining ring offering the same safety, making all machining and thermal calculations to ensure applicability to real cases





## Case study B (6)

- This is the first train in the history of railways that ran with tyres without any abutment and/or retaining ring (21.11.2018) [127]
- For ease of machining, the workshop requested to change the drawing of the tyre that became simply tapered with a small abutment (but still without retaining ring)



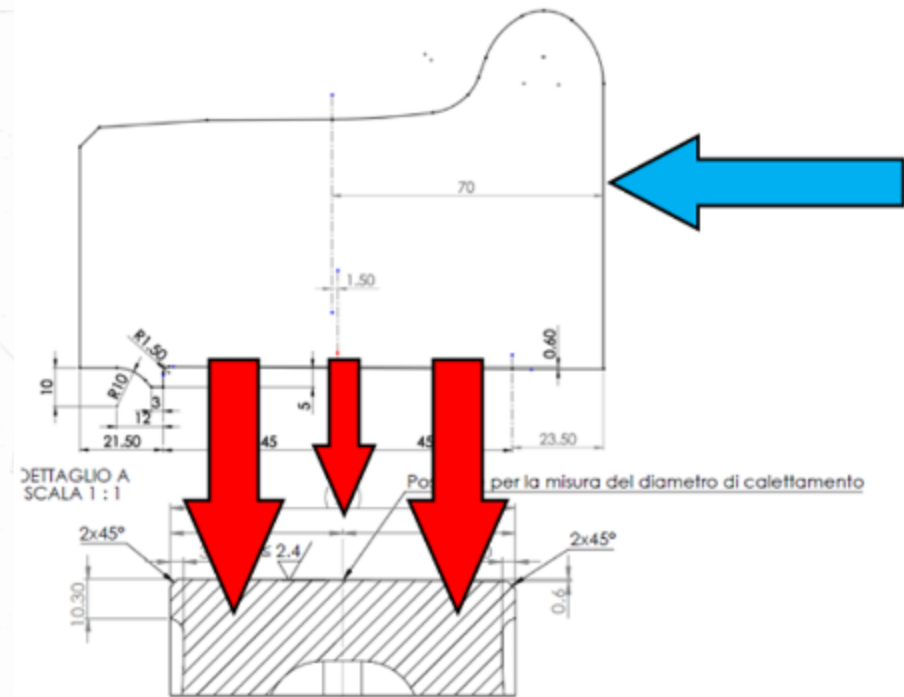
## Case study B (7)

- All tests were totally positive, no problems at all
- Many companies (especially small railways, for which wheel change represent a significant expenditure) were enthusiastic about the possibility of changing tyres even in remote shops with relatively inexpensive equipment
- But wheelset manufacturers were not interested in reintroducing tyred wheels
- People dealing with safety **HAVE NO IDEA** of how a wheel work and which is the role of the retaining ring and refused to consider this opportunity
- **END OF THE GAME**

# Case study C (1)

## A wheel centre that breaks the supply chain reducing noise

- During the development of the new tyred wheel, we realized that a unique, central wheel web was not the best solution
- A wheel with two webs would have been certainly much better
- But... how could we do it???
- It was impossible by forging and rolling...



## Case study C (2)

- We looked for a casted solution, but steel casting is complex and expensive
- We then moved to cast iron... but conventional spheroidal graphite (SGI) cast iron properties are insufficient...
- The solution was found by using Austempered Ductile Iron (ADI) that has a fantastic castability and properties similar to an alloyed steel after heat treatment

180 kg



130 kg

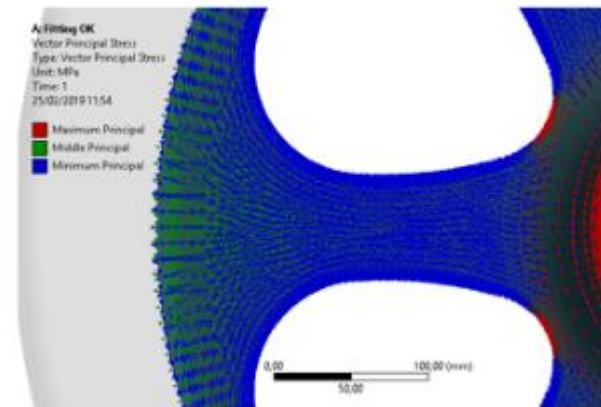
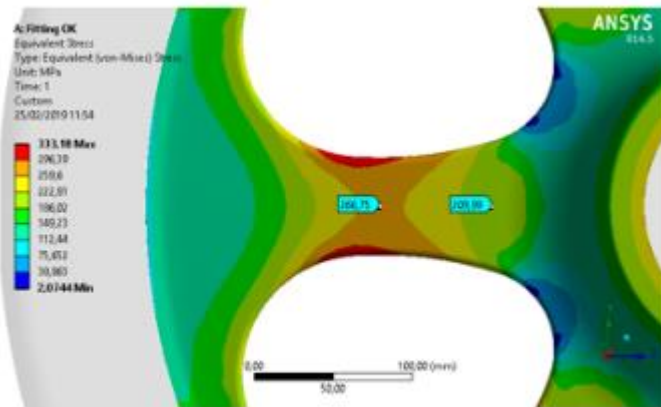


-30% of unsprung mass

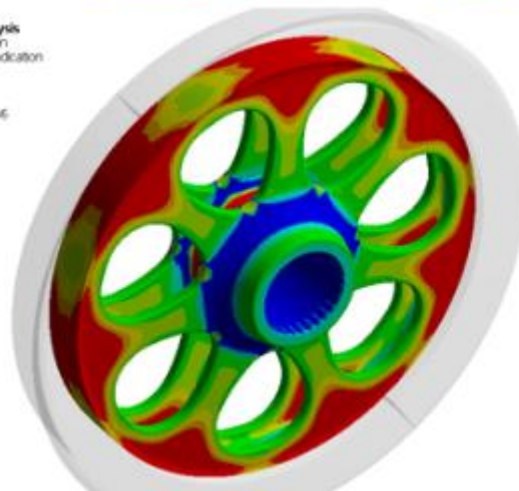
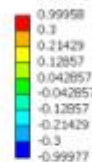
-50 % of lateral emitting surface

## Case study C (3)

- Extensive casting and structural FEA were performed, reaching very interesting properties of the new design [126]



H: Fatigue analysis  
Biaxial Indication  
Type: Biaxial Indication  
Time: 0  
Max: 0.99958  
Min: -0.99977  
05/02/2019 16:46



## Case study C (4)

- All manufacturing issues of casted wheels were faced and all tests were successfully passed [125], including full scale fatigue tests
- Our solution keeps steel tyres interfacing with rails to ensure compatibility with the infrastructure

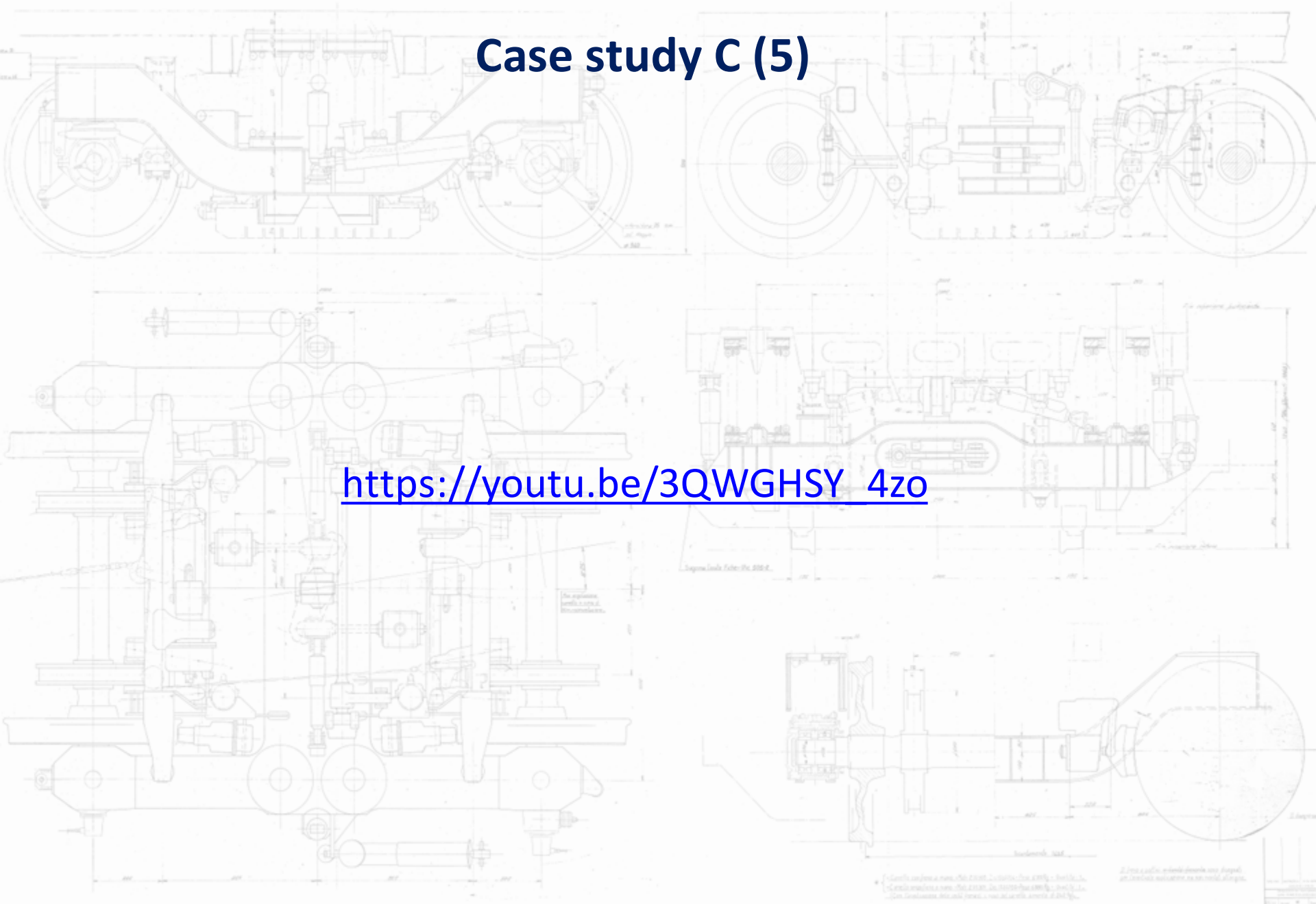


## Case study C (4)

- Another DMU was equipped with the casted wheels without any problem
- Tests made on 14-16.5.2019 revealed that the solution is feasible and keeps the promises it made
- A short video just to rest my voice?



# Case study C (5)



[https://youtu.be/3QWGHSY\\_4zo](https://youtu.be/3QWGHSY_4zo)

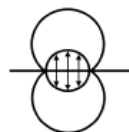
## Case study C (6)

- Austempered Ductile Iron offers very interesting casting, strength and wear, but nobody knows it (Kevlar and carbon fibers are much more trendy, I know...)
- The solution breaks the supply chains, as we have maybe 4 or 5 wheelset manufacturers in Europe but possibly more than one hundred cast iron foundries
- Maintainability is therefore increased because of very reduced lead times and a wider market, reducing costs
- Once again the regulatory frame is against the solution, and the presentation at IWC 2019 was a complete fiasco
- **END OF THE GAME**

# Case study D (1)

## «A track friendly metro», or how to eliminate noise, vibration and rail grinding

- Bogies are made to run straight ( $R > 500\text{m}$ ) and fast ( $> 160\text{ km/h}$ )
- But metros operate in completely different environments
- As a result, rail corrugation affects metro everywhere in the world
- Modern motors and power electronics development allow the use of previously unavailable solutions
- The paper [122] discusses how to reduce wear and in fact it was not accepted for publication in *Wear*

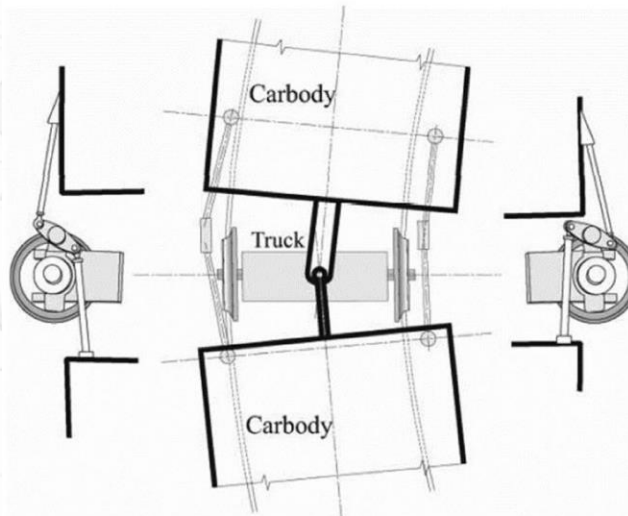
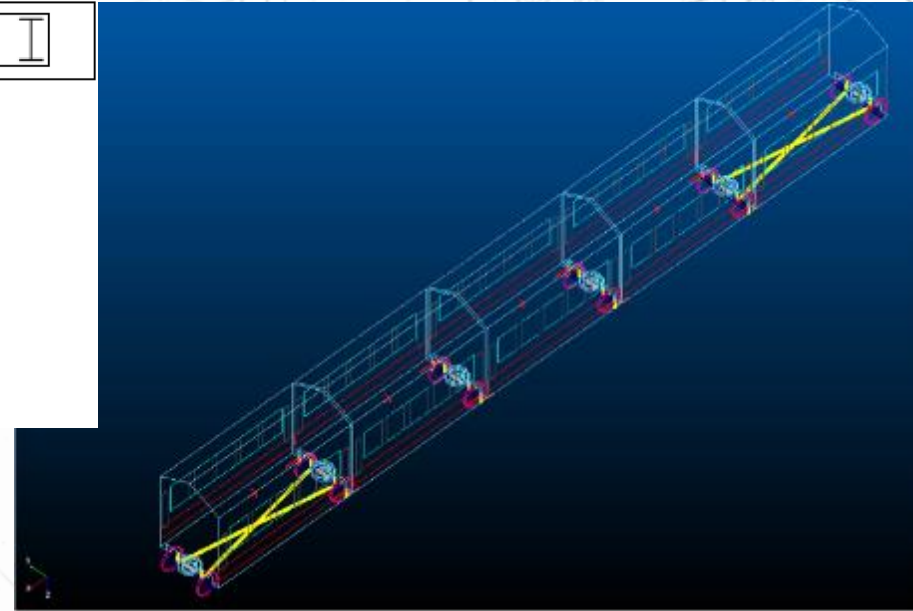
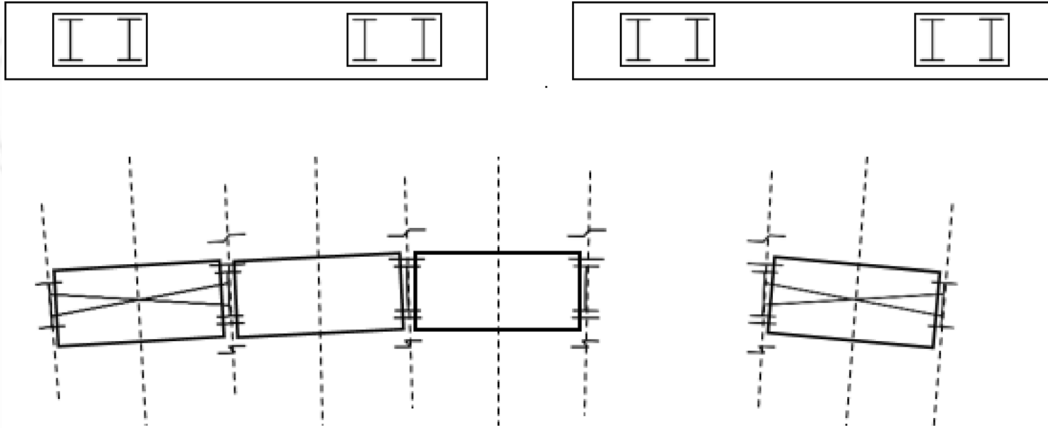


11th INTERNATIONAL CONFERENCE ON CONTACT MECHANICS AND WEAR  
OF RAIL/WHEEL SYSTEMS (CM2018)  
DELFT, THE NETHERLANDS, SEPTEMBER 24-27, 2018

**TRACTION AND CURVING OF VEHICLES EQUIPPED WITH GUIDED  
INDEPENDENTLY ROTATING WHEELS**

Andrea Bracciali, Gianluca Megna\*

# Case study D (2)



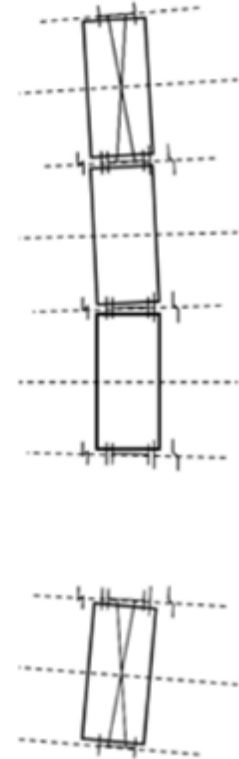
## Case study D (3)

- But after all the idea was simple: direct drive, no gearboxes, mechanically steered axles, simple driving strategies
- A dream for maintenance!



A	Vehicle name	B
Conventional (bogies)	Architecture	GDGRW (rodals)
6	Number of cars	19
18 m	Car length	5.65 m
12	Number of bogies	N/A
24	Number of axles	20
108 m	Overall length	108 m
1208	Total # of passengers	1143
12 t / 6 t	Axleload / wheel load	12 t / 6 t
24	Number of driven axles	20
288 t	Fully loaded mass	240 t

- End axles of vehicle B are connected with classical cross-bracing links
- Torque applied for each axle for vehicle A
- Torque applied for each wheel for vehicle B
- Wear numbers for each wheel and for full trainset are evaluated



## Case study D (4)

- Wear numbers nearly disappear in all conditions: no wear, no surface damage, zero angle of attack [137]
- *«The superiority of TFM vehicle over CONV vehicle in terms of rail damage is overwhelming, with a reduction of wear numbers in the order of 1/4 in the worst case to 1/400 in the best case... (for TFM) there is possibly neither wear on the high rail nor corrugation on the low rail. In the same cases, vehicle CONV exhibits high wear numbers that explain the extensive damages observed even if the vehicle runs in apparently favourable kinematic conditions»*

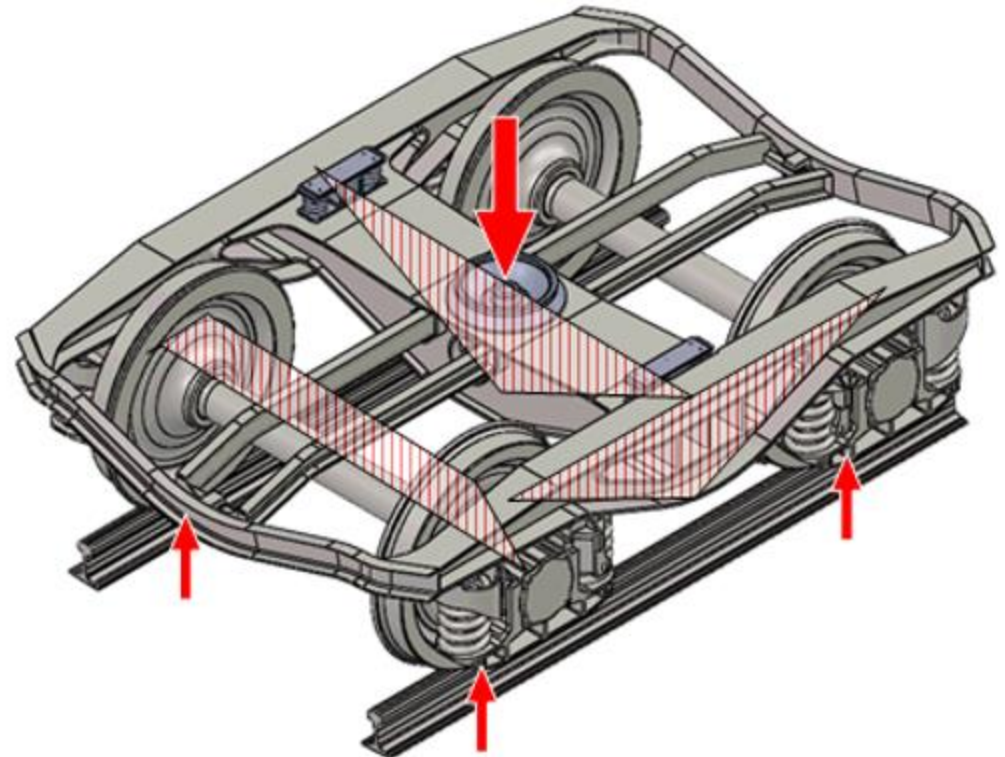
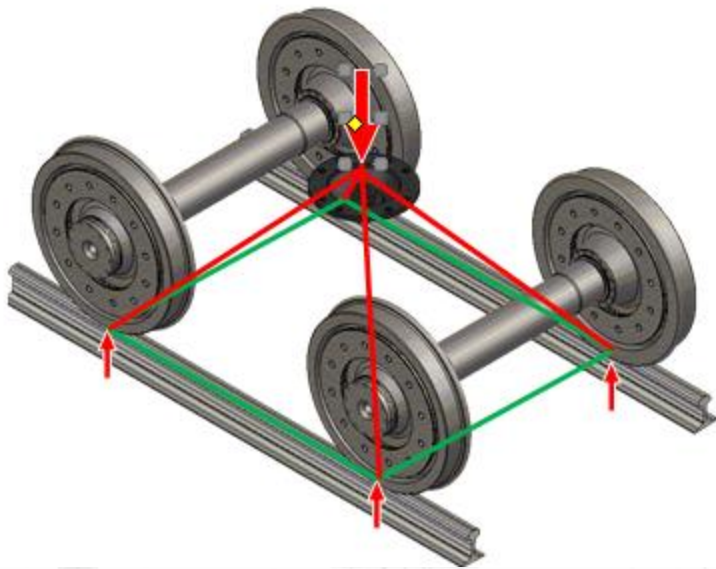
## Case study D (5)

- «We sell trains, we don't care about tracks»
- «We prefer investing in noise insulation materials than designing solutions that are not under our control»
- «Short cars are expensive»
- «Previous experiences were ill-fated»
- **END OF THE GAME**

## Case study E (1)

# A lighter and more track friendly freight bogie born to replace Y25

- Y25 is nearly as old as me (time to be scrapped?)
- Load is transferred to wheel/rail contact points via bending of frame and wheelsets



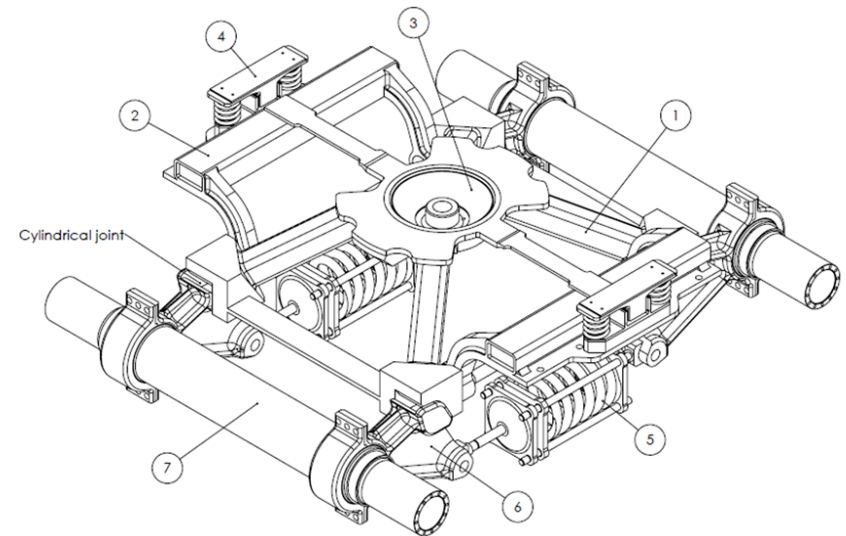
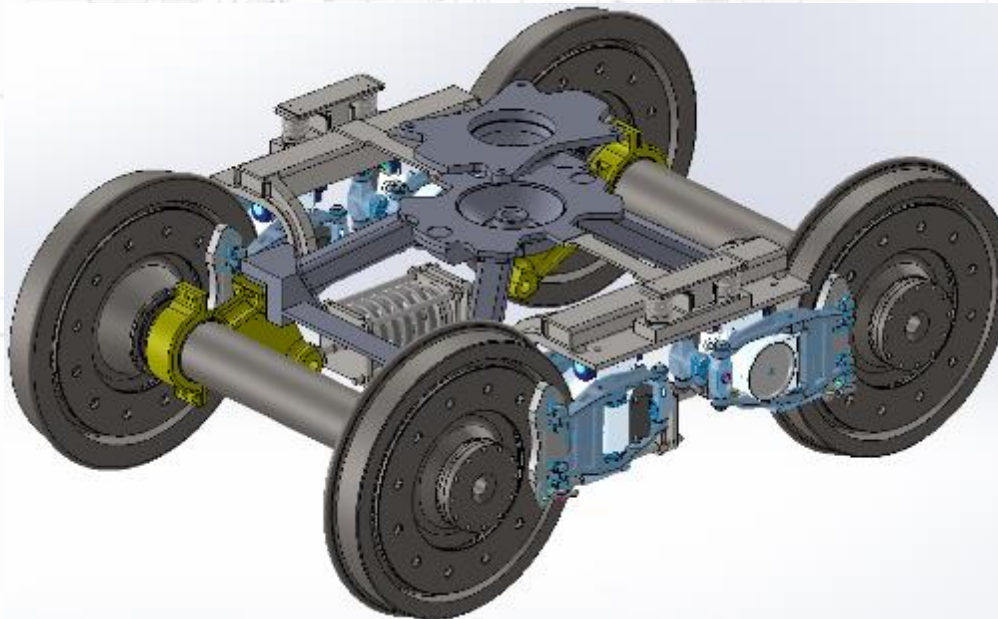
## Case study E (2)

- A completely different concept was developed taking inspiration from cranes



## Case study E (3)

- Wegmann-Kassel bogie inspired suspension
- Wheelsets are «short-circuited» by the suspension
- The bogie results lighter, track friendly, inexpensive (an independent study estimated 25-30% lower production costs)
- Full virtual homologation was performed about structural strength and running dynamics [130]
- Many solutions were drafted (wheelsets, braking, etc.)



## Case study E (4)

- The two major freight bogie manufacturers were contacted, dozen of meetings remote and in person were made but...
- «We make business with Y25, our customers buy what we sell them. They have no idea of what they are buying»
- «Manufacturing cost is not so important»
- «We don't care about maintenance of wagons we sell»
- «Homologation costs are around 400.000 Euros, we can't afford it»
- «We are owned by a finance company, there is no warranty of return from the investment»
- **END OF THE GAME**

# Case study F, or «A picture is worth a thousand words»

<https://youtu.be/w8VQywVjV8E>

## Some (bitter) conclusions

- Maybe I'm wrong, but I hope not to be *always* wrong
- «You may say I'm a dreamer, but am I the only one?»
- It's much easier destroying something than creating it
- Our world is full of people with masters in business administration that make miracles with Excel sheets
- The company you work for wants you to do on your last working day exactly what you did on your first working day
- Burocrats never sleep
- EN standards, TSI and money will prevent any development in the railways till the end of the world (but it won't take that long)
- «We don't need no innovation»
- WE ARE ALL GUILTY IF THINGS NEVER CHANGE.