The Rolling Gear of Independent Guided Wheels: Opportunities to Optimise Wheel-Rail Contact

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Non-conventional technologies of Talgo trains
A historical review

The articulated train: the “triangular guidance“

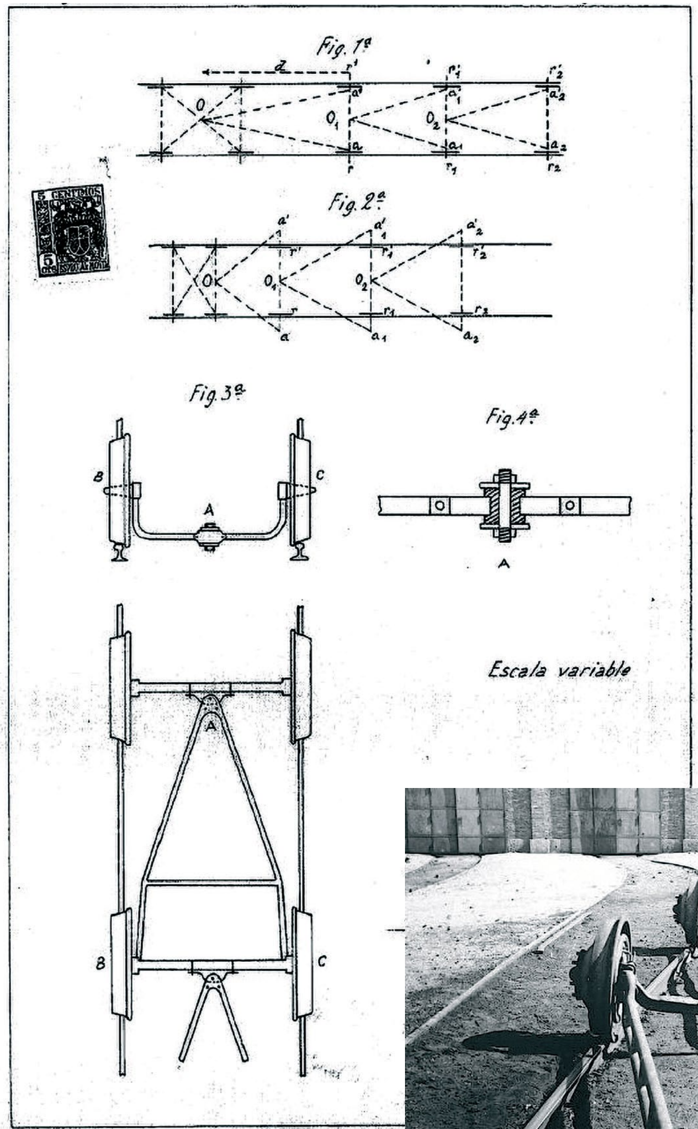
Continuous articulated coachset

Elimination of bogies

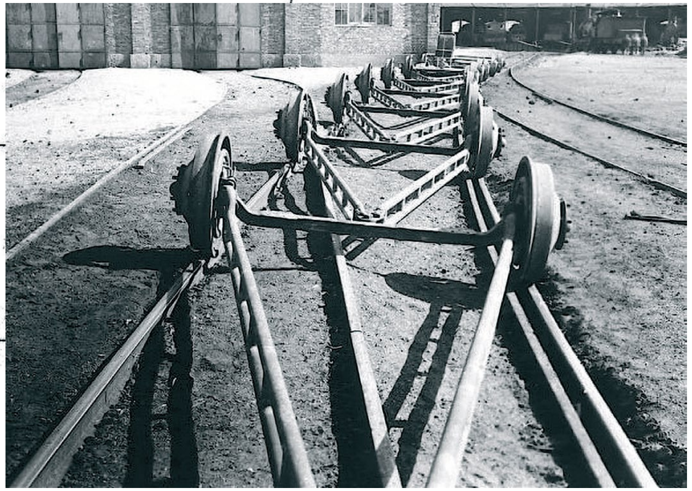
Light and simple triangular structures, with a single axle at the rear

Front vertex articulated on the centre of the axis of the immediately preceding triangle

The direction set by the first triangle (or the cabcar) is followed by the others. No need for additional guidance



First patent filed in 1941



First prototipe of triangular guidance

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The independently rotating wheel

Inner and outer wheels have to turn at different speeds when curving

Free and independent rolling of each wheel.

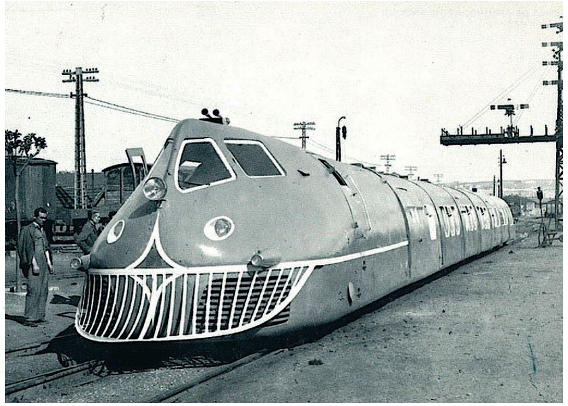
The physical axle can be eliminated.

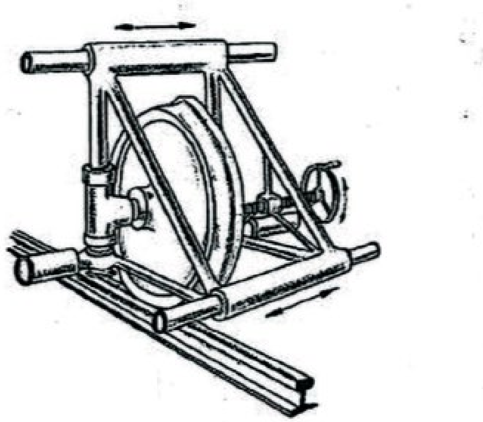
Significant lowering of the centre of gravity, increasing stability and curving speed

Possibility of continuous low floor

Easy possibility of transversal displacement of the wheels, to adapt to different track gauges

Rolling gear with independent free wheels in the Talgo I prototipe





Movable wheel in the patent filed in 1942

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The reversible guidance system

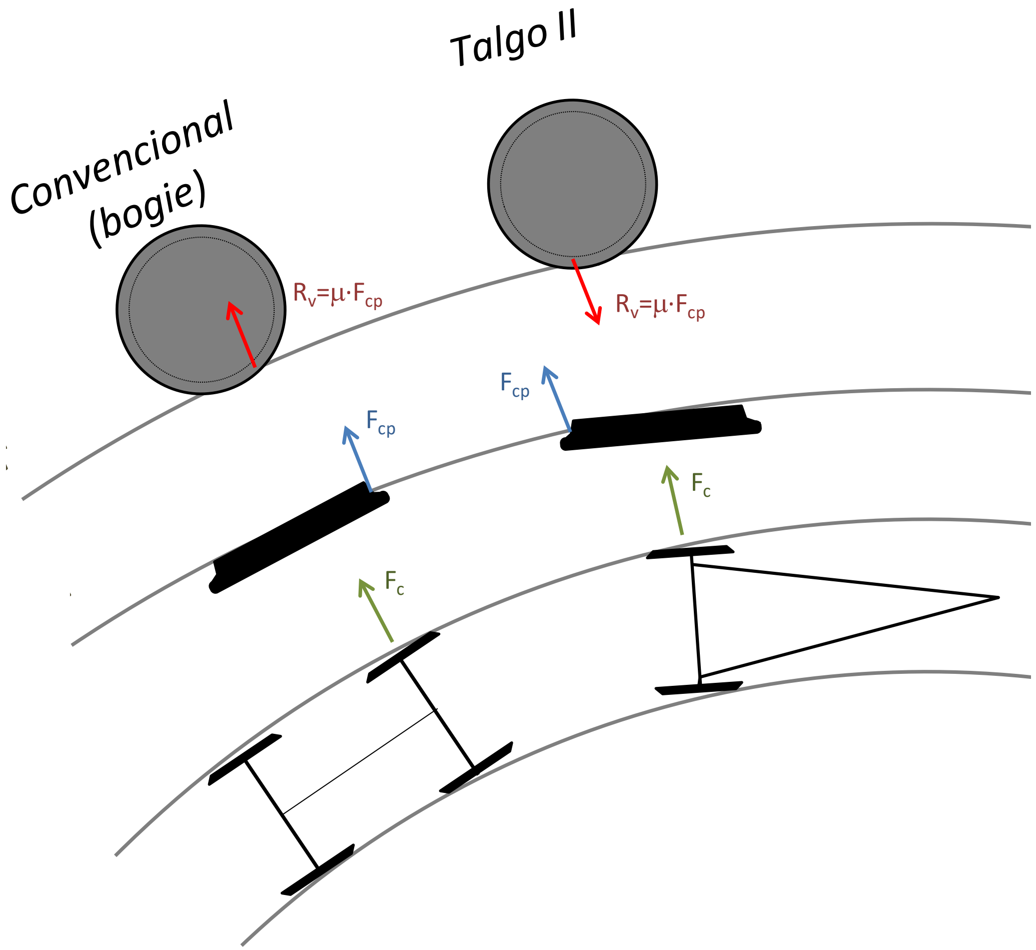
Main problems of the simple triangular guidance system:

- Negative angle of attack towards the inside of the curve

- Limited length of the triangular elements and the coaches

- Vertical frictional effort (outer rail to flange)
  avoids derailment forward
  but promotes it in reverse direction

→ **Irreversibility**



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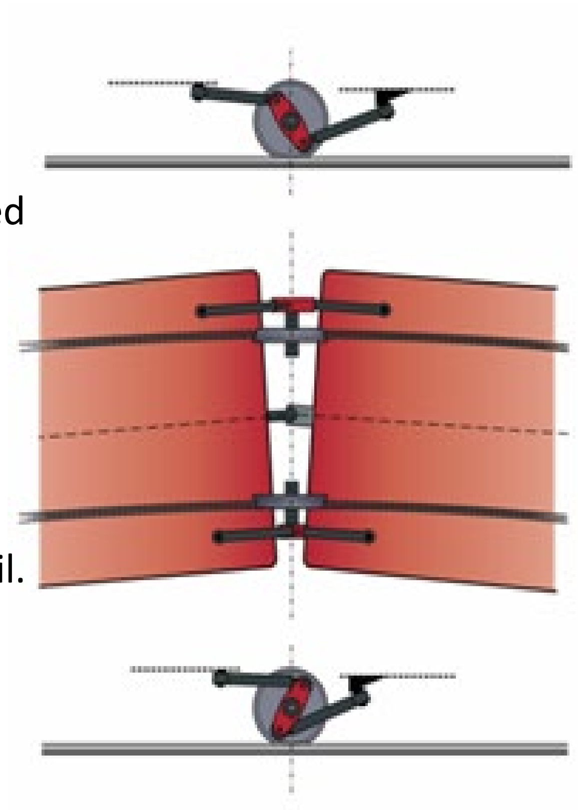
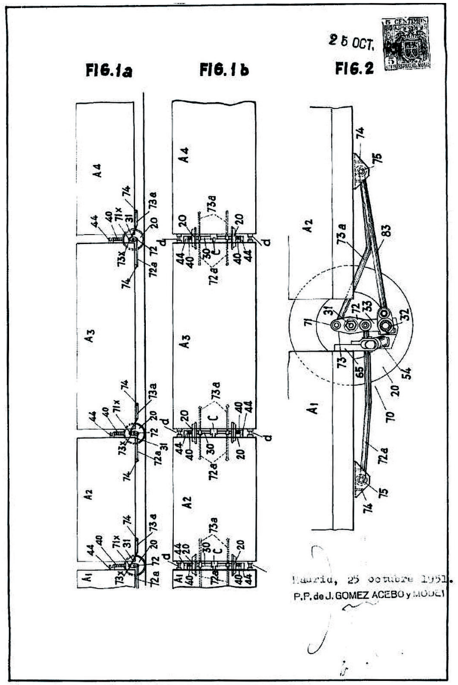
The reversible guidance system

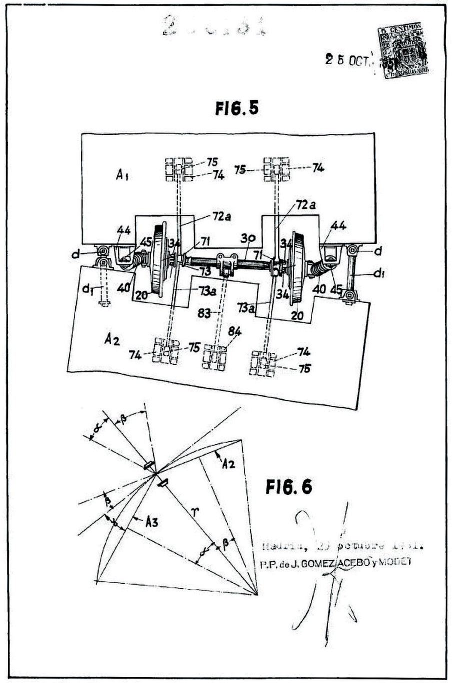
Every pair of independent wheels is located on a structure called “rodal”

The rodal is oriented normal to the rails by two mechanism, inspired in the Watt mechanism, on both sides

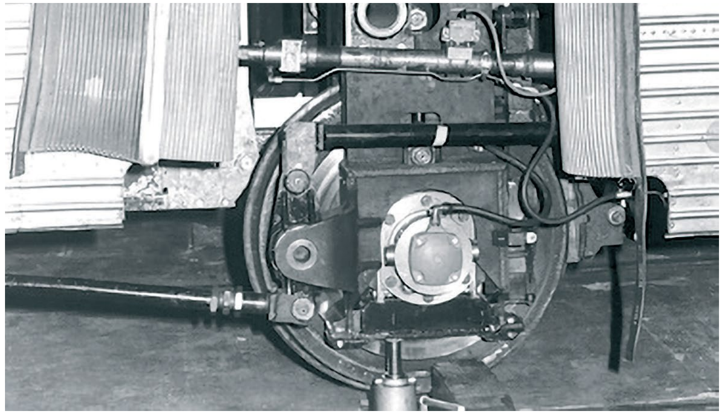
This way, wheels are tangentially to the rail. Near-zero angle of attack.







First patent of reversible guidance mechanism filed in 1950



First application of the reversible guidance in the Talgo III (1964)

Non-conventional technologies of Talgo trains
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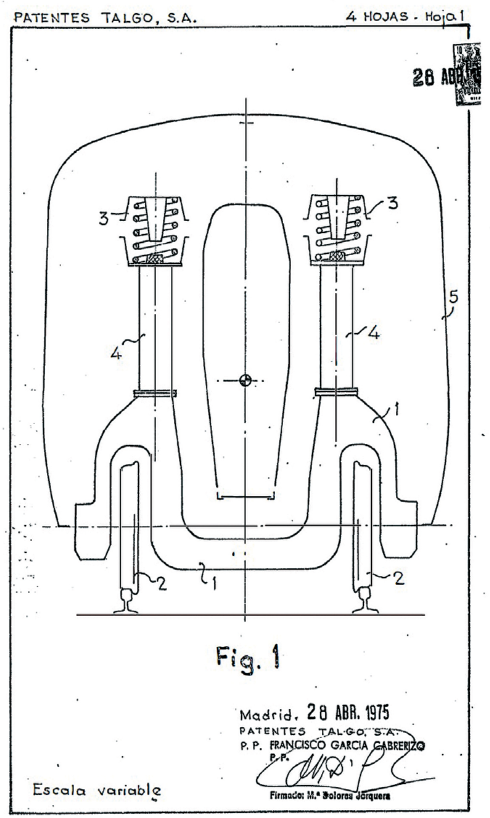
The natural tilting

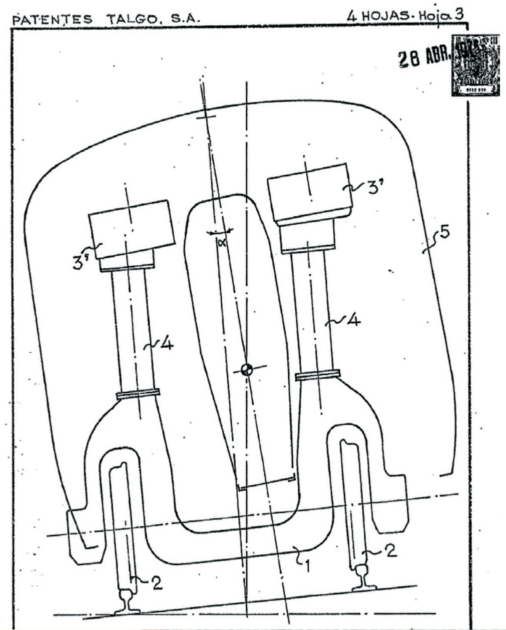
While forced tilting systems were in development since 1950’s, Talgo proposed a passive tilting system.

Raising of the plane of the suspension (and therefore its roll centre) above the centre of gravity

Air springs are allocated on the top of two columns placed in the rodal, being compatible with the reversible guidance mechanism

Redesign of the articulation between cars, to allow them to be tilted successively as they enter the curve





First patent of natural tilting filed in 1975

First comercial implementation of natural tilting, Talgo pendular (1980)

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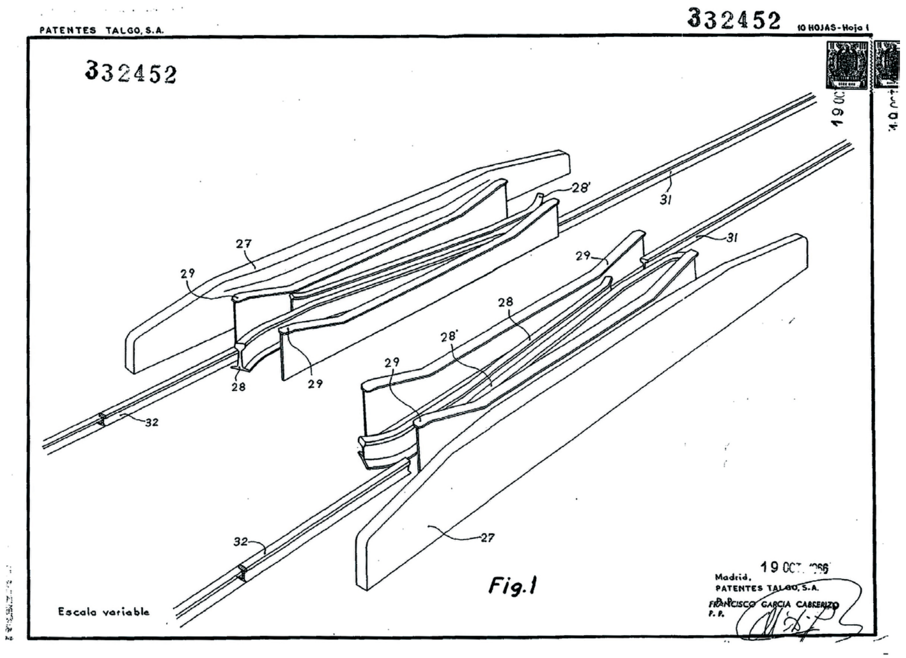
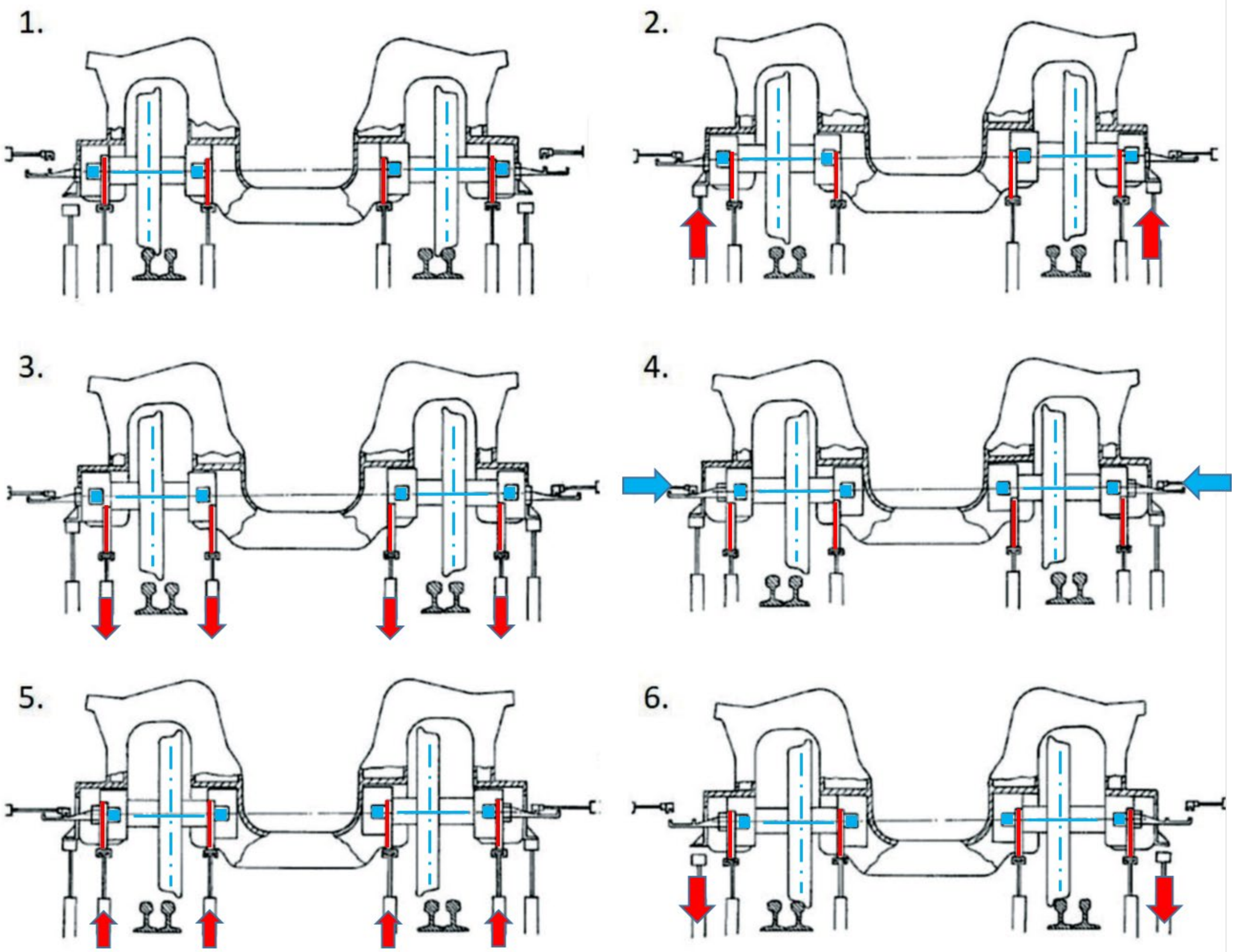
The track gauge variation



Patent for track gauge variation while running (1966)



The rolling gear of today‘s Talgo trains

Main disruptive technologies of Talgo are successfully combined today in its high-speed trains.

- Independently rotating wheels
- Low continuous floor, without axels nor bogies
- Reversible guidance system
- Natural tilting suspension
- Track gauge variation on running

Rolling gear of the new Talgo AVRIL

The rolling gear of today‘s Talgo trains

Fine tuning and active control of the guidance mechanism

To ensure the zero angle of attack of the wheels, minimising losses, friction and vibrations.

Active control system, based on the comparison of rotational speeds of each wheel

Small deviations in trajectory are detected

Correction in real time by acting on the length of certain bars of the mechanism.

The rolling gear of today‘s Talgo trains

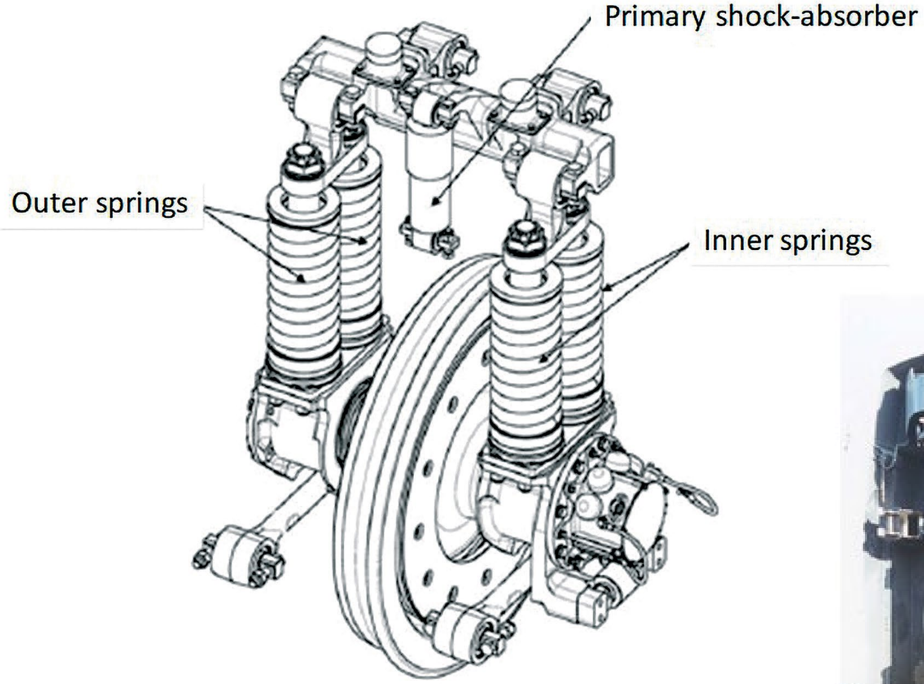
Suspension improvements

The natural tilting mechanism is maintained, but the air springs are at a lower level

A primary suspension is introduced in each wheel

Improved confort and dynamics

Additional possibilities for finetuning the wheel position



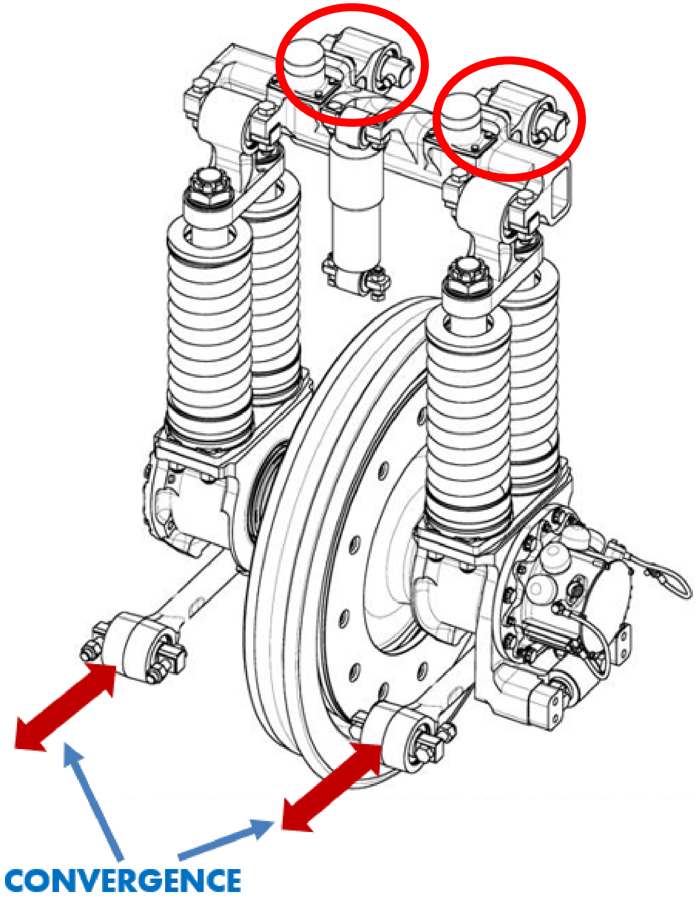
Parameters that can be varied in the independent wheels to optimize wheel-rail contact

Angle of attack (convergence)

Small changes in the angle of attack can be achieved by varying the length and/or stiffness of several longitudinal bars and supports.

We can think in fix, optimun angle values

But also in active or passive systems for real-time optimization



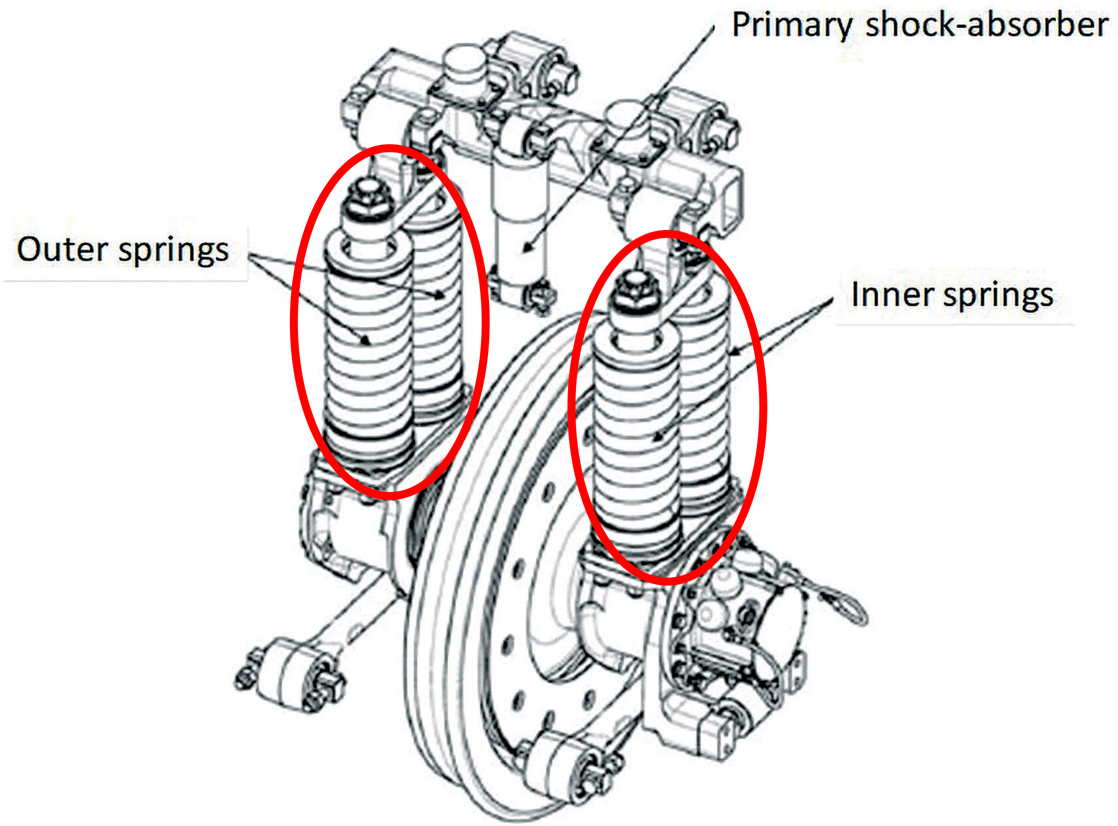
Talgo MH

Parameters that can be varied in the independent wheels to optimize wheel-rail contact

Camber angle

small changes in the camber angle of attack by varying the length and/or stiffness of springs and/or their supports

Active or passive systems for real-time variation could be also considered



Optimization of wheel-rail contact aimed at reducing wear

(a PhD research Project)

Objectives

To analyse the sensitivity of efforts, stresses and slippage of the IRW contact, to small variations of different parameters: attack angle, camber angle, etc.

To apply wear models to estimate the wear to be expected for each case studied.

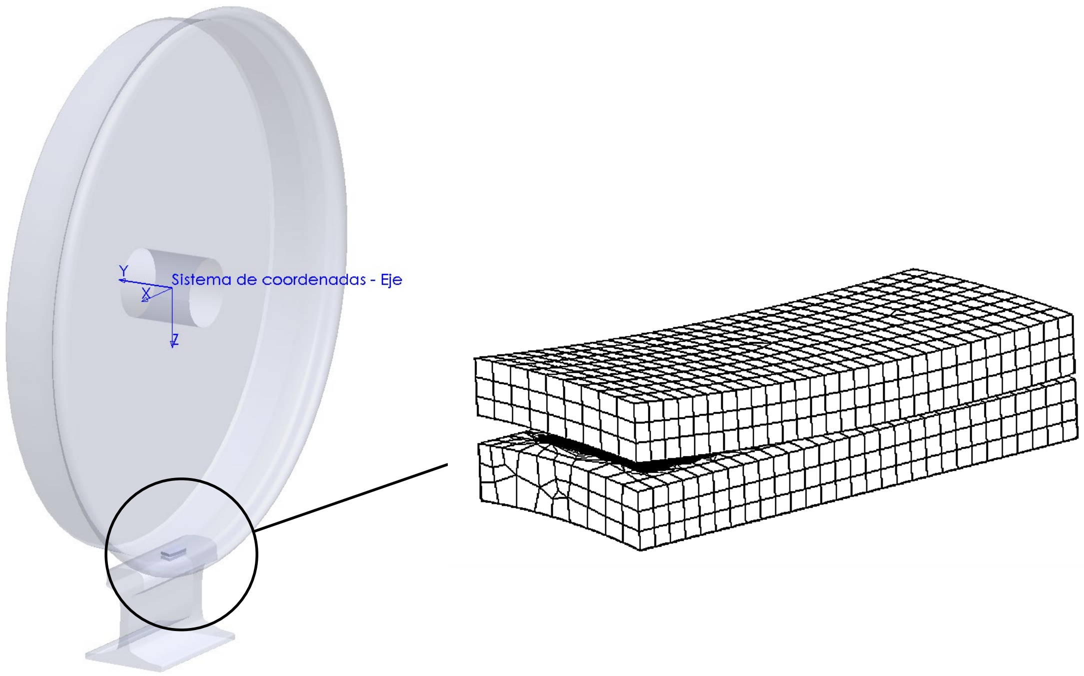
Discussion and comparison of the results obtained for different wheel and rail profiles, different degrees of wear, and different work conditions.

Proposal of the optimum combinations of parameters leading to a better wear results in each condition.

To explore design possibilities for practical implementation

Optimization of wheel-rail contact to reduce wear

FEM modelling



Simplified modelling of the whole Wheel and rail, and detailed meshing of the contact area

Free variation of 3D geometries, position and boundary conditions

Includes stiffness and damping of materials and supports

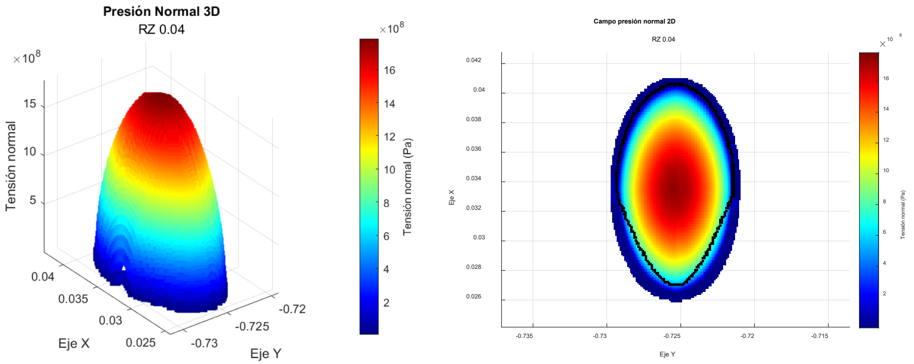
Non-linear model, explicit integration.
Cuasi-static and dynamic transient calculations.

validation

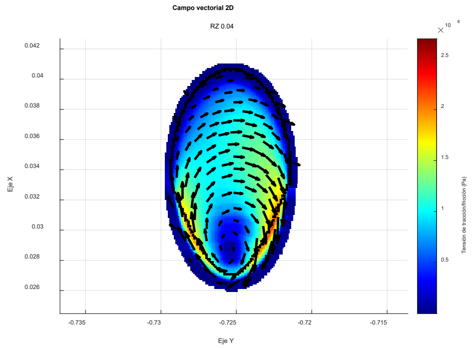
Comparison against Kalker theories (using CONTACT software) in a number of standard cases.

Optimization of wheel-rail contact to reduce wear

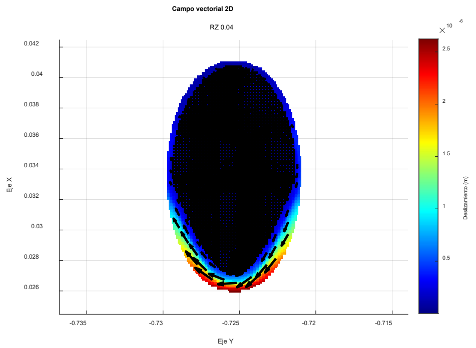
Primary results to be obtained



Normal pressures (pz)



Tangential stresses (px, py)

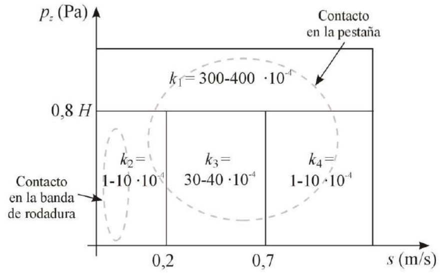


Slippages (sx, sy)

Implementation of wear theories and laws (from literature)

$$V_{wear} = \int_A k \frac{p_z\, s}{H}\, dA$$

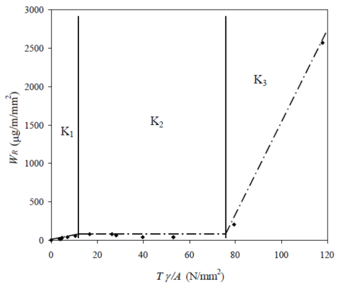
$$s = \sqrt{s_x^2 + s_y^2}$$



source: Royal Institute of Technology-Stockholm (KTH)

$$V_{wear} = \int_A W_R\ dA$$

$$\frac{T_\gamma}{A} = |p_x \boldsymbol{s}_x + p_y \boldsymbol{s}_y|$$



source: University of Sheffield (USFD)

Others

. . . .

Optimization of wheel-rail contact to reduce wear

First examples of application: sensitivity to convergence angle

<u>Modelling conditions:</u>

Rail profile: 60E2

Wheel profile and track: standard Talgo

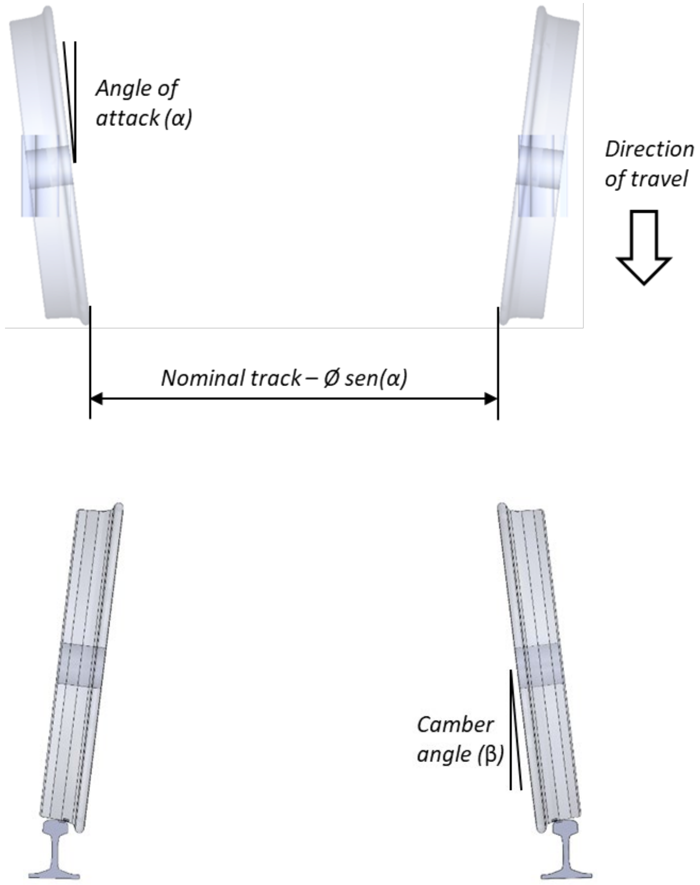
Load per Wheel: 100 kN

Lineal velocity: 28 m/s (100,8 km/h)

Curve radius: 0 (straight run)

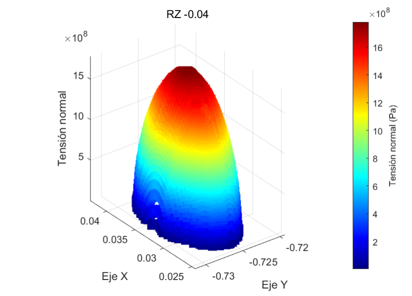
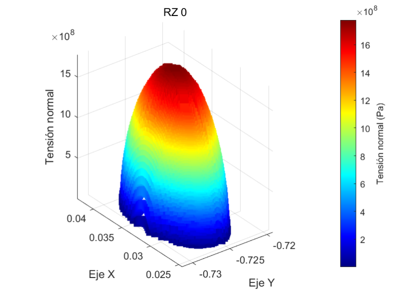
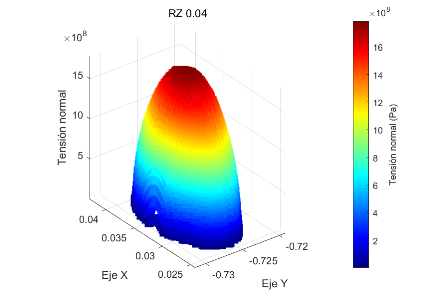
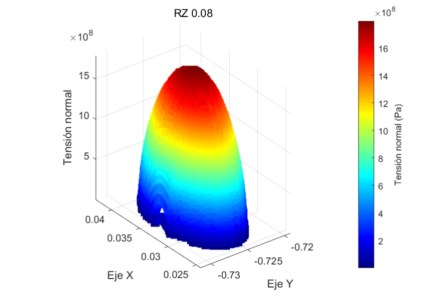
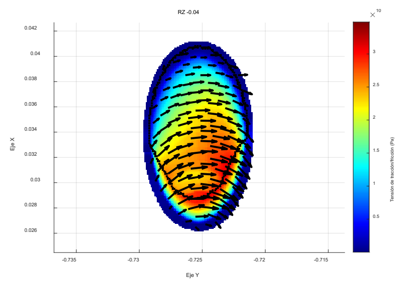
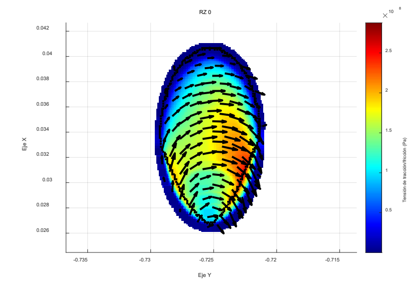
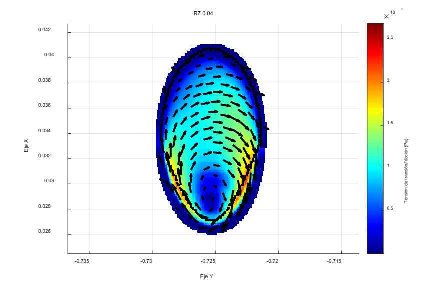
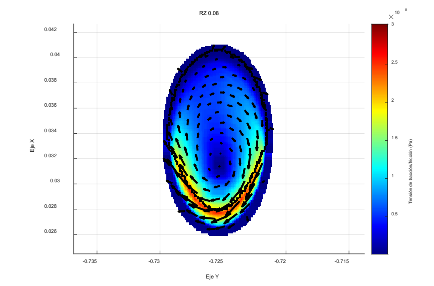
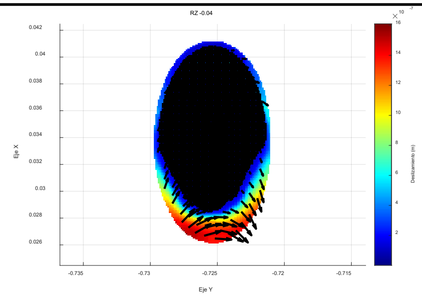
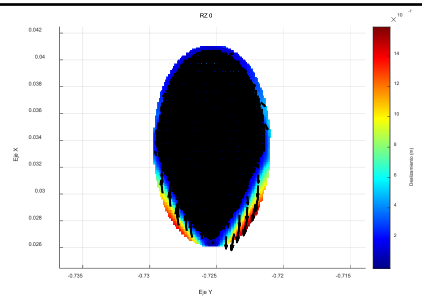
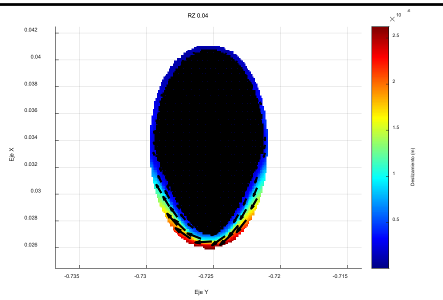
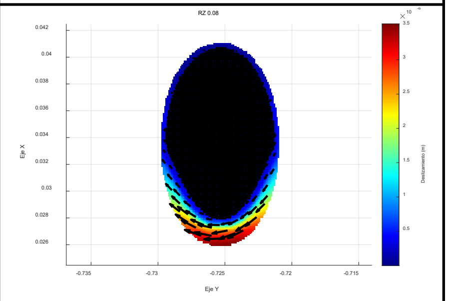
Camber angle: 0º

Attack angle variation: -0,1º ÷ +0,1º (-1,7 ÷ +1,7 mm)



Optimization of wheel-rail contact to reduce wear

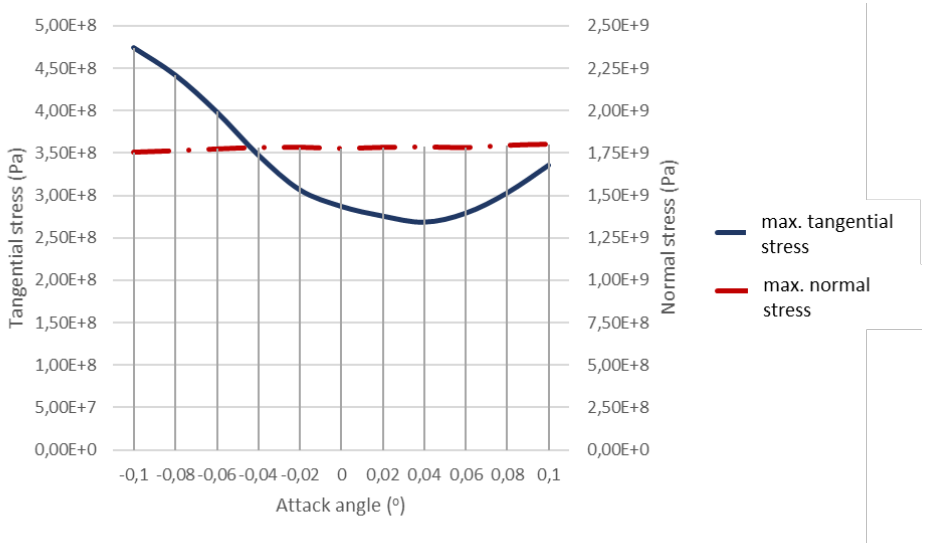
First examples of application: sensitivity to convergence angle

Attack angle / Camber	α = - 0,04º β = 0º	α = 0º β = 0º	α = + 0,04º β = 0º	α = + 0,08º β = 0º
Normal pressures				
tangential stress				
total slip				

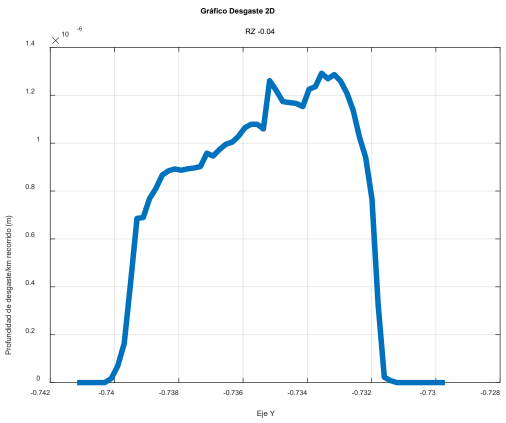
Optimization of wheel-rail contact to reduce wear

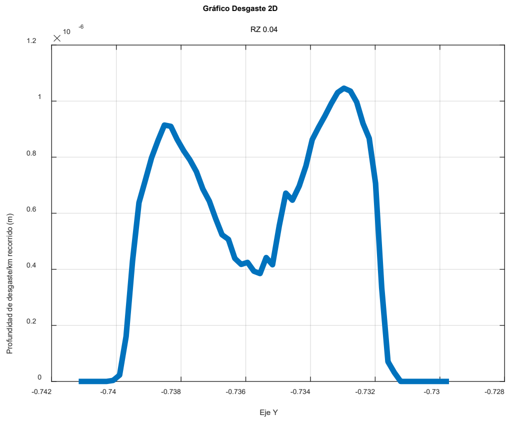
First examples of application: sensitivity to convergence angle

Example analysis: Comparison of peak values of normal and tangential efforts



Example analysis: Comparison of wear depths for two different angles of attack





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Conclusion and next steps

The independently rotating guided wheels offer possibilities to optimise wheel-rail contact, by varying different parameters, which are unthinkable in conventional rolling gears

A research project is underway with the collaboration of Talgo and UMH, to analyse the influence of different parameters on wear, and to advance in its optimisation.

A model has been developed that allows this analysis to be carried out in a flexible way, including multiple possibilities and configurations.

Results are expected to be published in the coming months.

At a later stage, the same approach can be applied to the analysis and optimization of rolling noise, taking advantage of the same chances of parameter variation.

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Contact

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