"Railway Wagon Model with Anti-slip Braking System"

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Introduction

Aim of this work is to realise an MBS model (Multi-Body-System) of the railway wagon "*Bagagliaio Z1*" in order to perform braking tests simulations and to compare these to the results of experimental tests.

"Bagagliaio Z1" is a luggage van currently in use on the Italian Railway that has been converted in experimental rail car to perform several tests; among these tests particular interest is stirred up by the braking manoeuvre tests.

Modern braking systems are equipped with active devices as WSPD (Wheel Slide Protection Device); our work is focalised on the study of the dynamic interaction of these devices with the track-vehicle system.

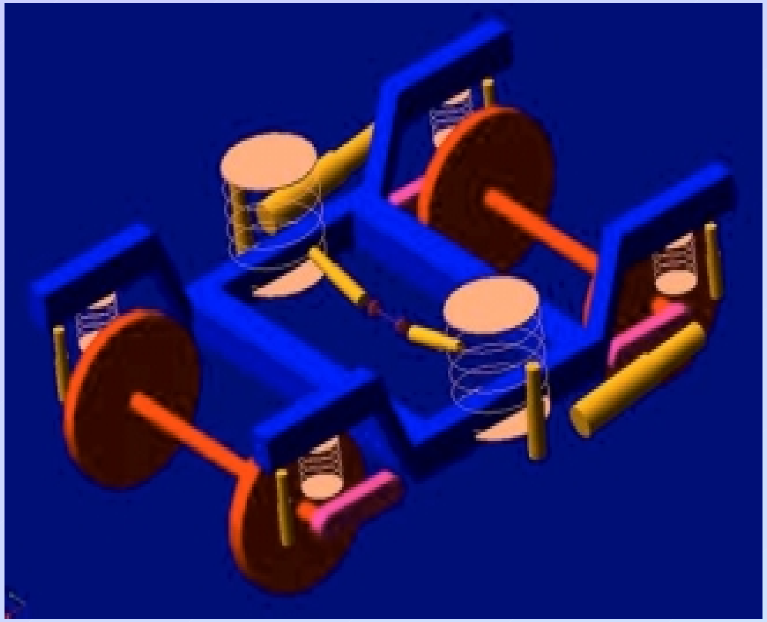
Summary

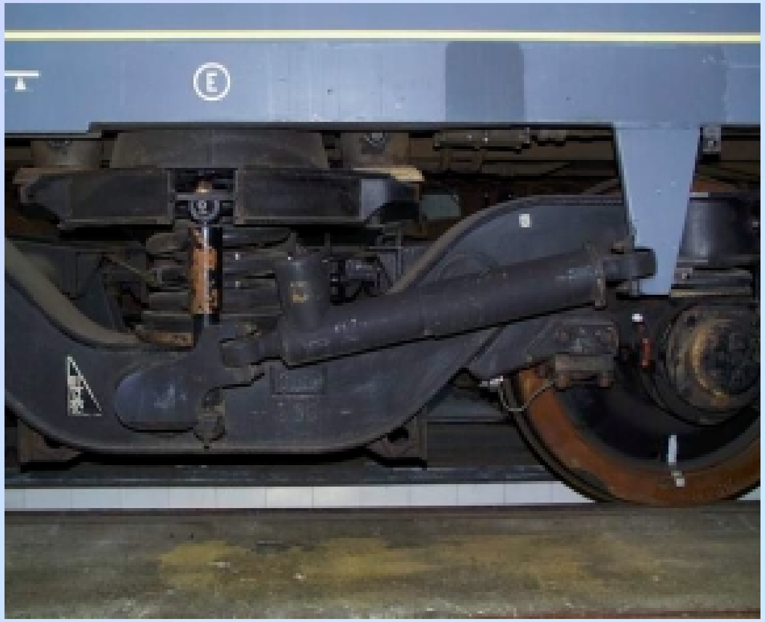
- Description of the mechanical model;
- Construction of the contact model (Matlab pre-processor);
- Construction of the Anti-slip Device model (Simulink);
- Simulations (A/rail-A/Controls-Simulink co-simulations);
- Comparison with experimental data;
- Conclusions.

Description of the mechanical model

The standard A/Rail Erri bogie is modelled to reproduce a classic FIAT bogie so our work has been simplified significantly. We only had to modify the position of the main markers and to insert the characteristic data of our bogie.

The only real modification acted on the standard A/Rail Erri bogie, in order to model in the best way the FIAT 85A bogie, was the creation of the traction system.

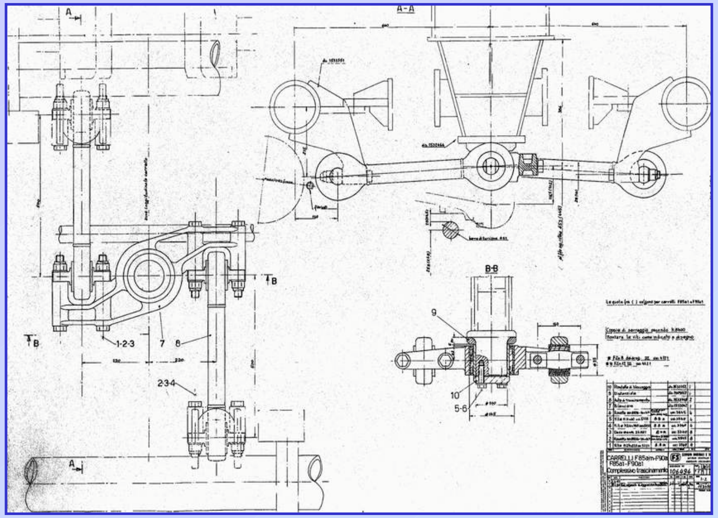


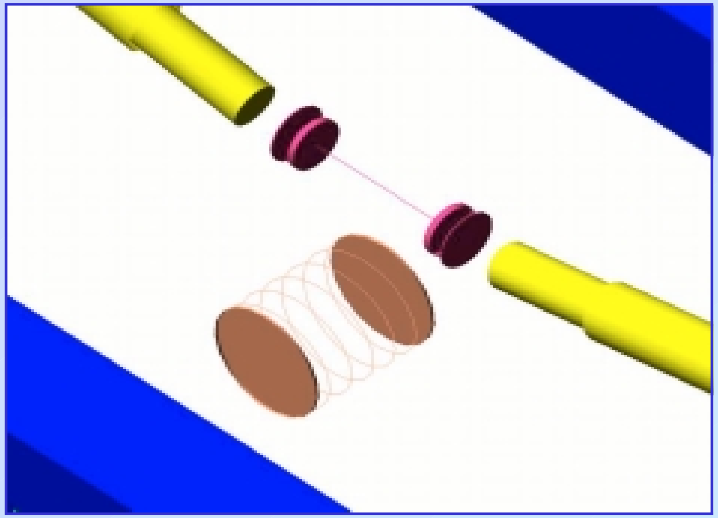


Mechanical model: traction system

This element is necessary to limit the pitching moment in the braking manoeuvre.

In the FIAT 85A bogie this system is obtained with a rocking arm articulated on a vertical joint pin rigidly connected to the car body so the only relative degree of freedom removed between bogie and car body is the longitudinal translation.





We considered useless an accurate modelling of the traction system. This element, in fact, gives a force that acts only in the longitudinal direction so it has been decided to model it inserting a spring whose axis is parallel to the X axis (the rail axis) with a very high axial stiffness and an insignificant transversal stiffness.

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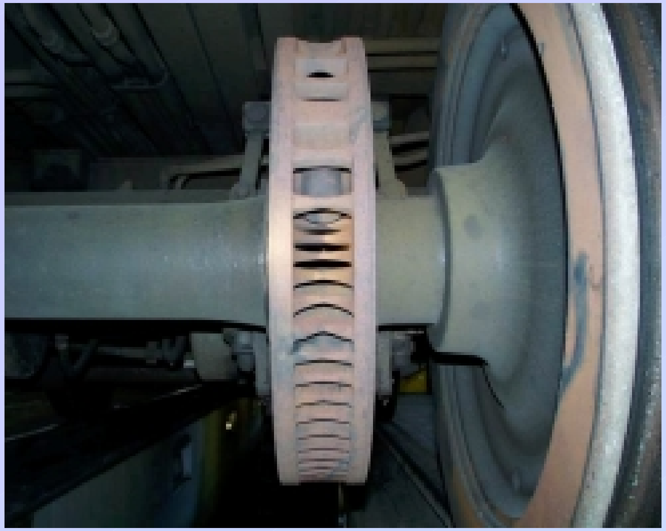
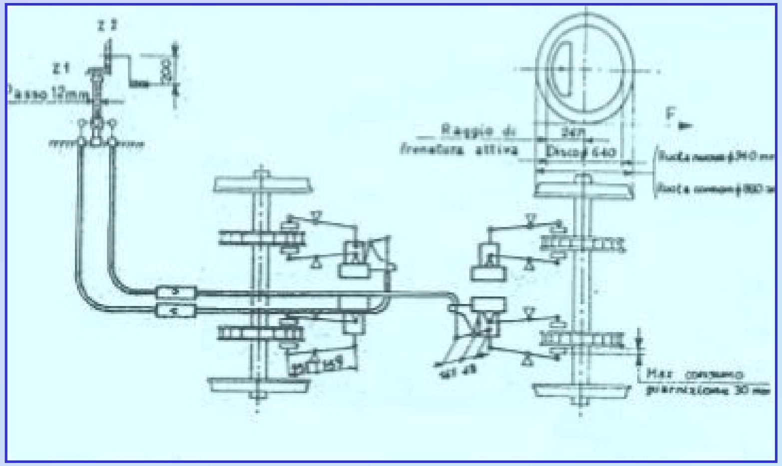
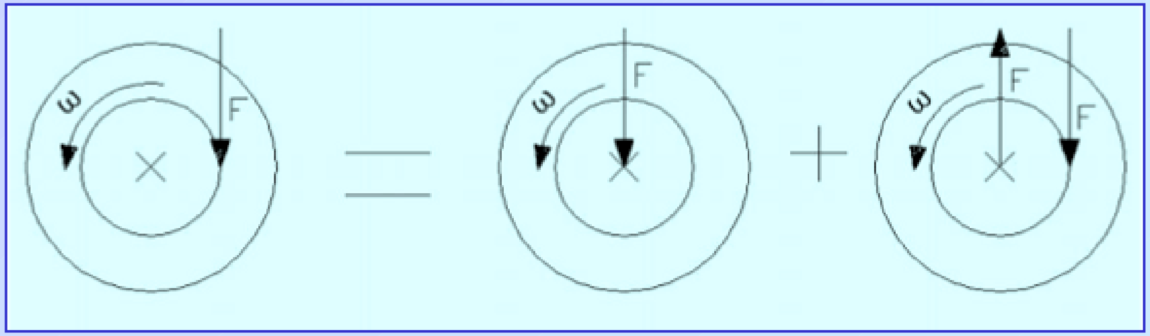
Mechanical model: braking system





F = M/r

r = braking radius



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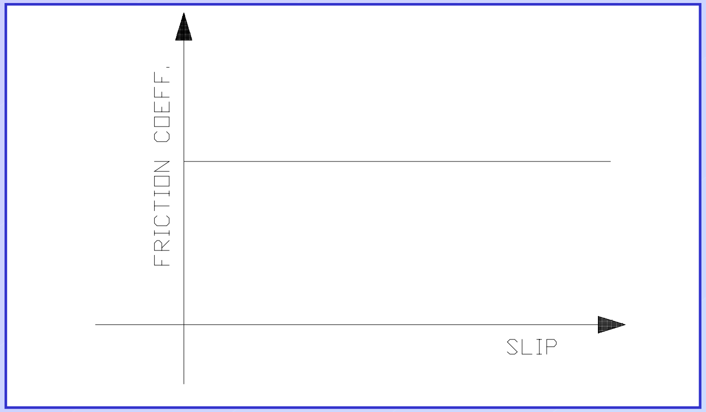
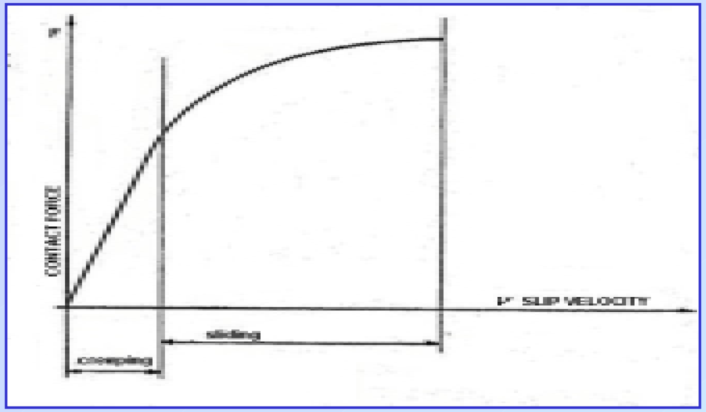
Contact model

The four property contact files that rule the wheel rail contact in ADAMS use a Coulomb adhesion law that does not make difference between static, or adhesion coefficient, and dynamic friction coefficient.





With such a contact model, there is a shorter braking distance in case of wheels blocked and complete sliding rather than in a case in which we avoid this situation using a wheel slide protection device.

The modern contact models take into account that the passage from <u>complete adhesion</u> to sliding conditions is not discontinuous and sudden, but is preceded by an intermediate situation called "creeping", during which wheels peripheral speed is slightly different from the linear advancing speed, and the greater is the horizontal force transmitted the bigger is this difference

Contact model

Parameters affecting the Adhesion coefficient:

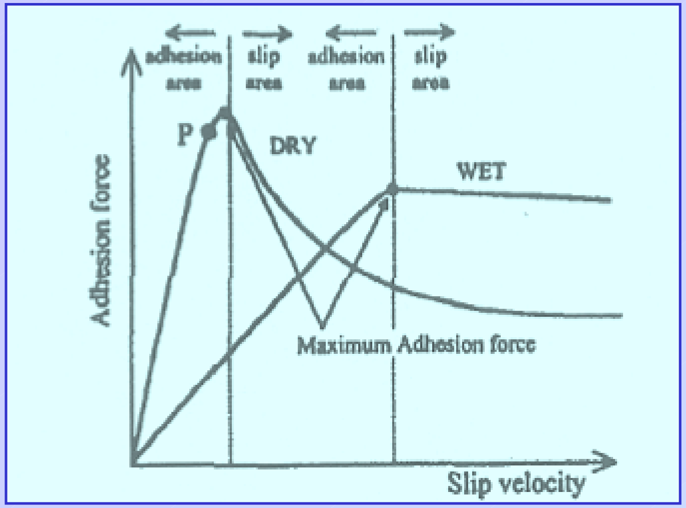
- contact area between wheel and rail
- pitch angle of the case and the boogie
- electrical current
- rail condition
- atmospherical condition (rain, ice, dead leaves...)
- vehicle speed

In presence of rail and environmental constant condition the adhesion coefficient depends on slip:

$$\nu = (\pi nD - L) / \pi nD \quad \text{relative slip}$$

$$?_{\nu} = (\pi nD - L) \quad \text{absolute slip}$$

Available contact models

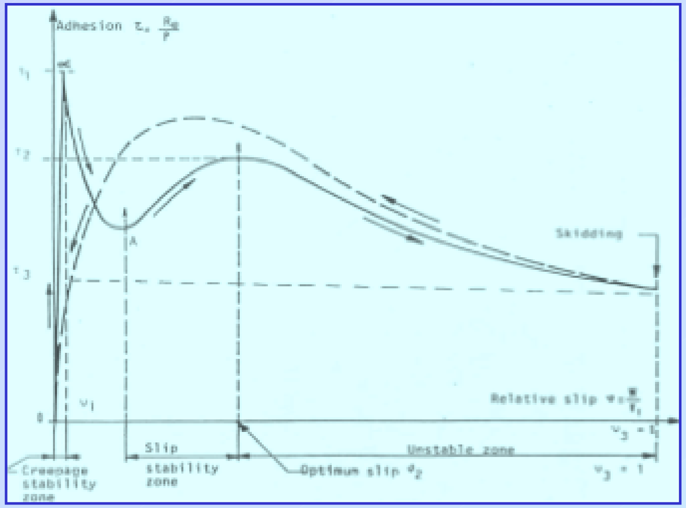


adhesion coefficient/relative slip curve

K. Ohishi, Y. Ogawa, I. Miyashita, S. Yasukawa

Anti Slip Re-adhesion Control for Electric Motor Coach Based on Force Control using Disturbance Observer

Document tecnique DT257, Office de Recheres st d'Essay De L'Union internationale de Chemins de fer, July 1992



adhesion coefficient/relative slip curve

M.Boiteux, M.Cadier, J. Kling, W. Kunnes

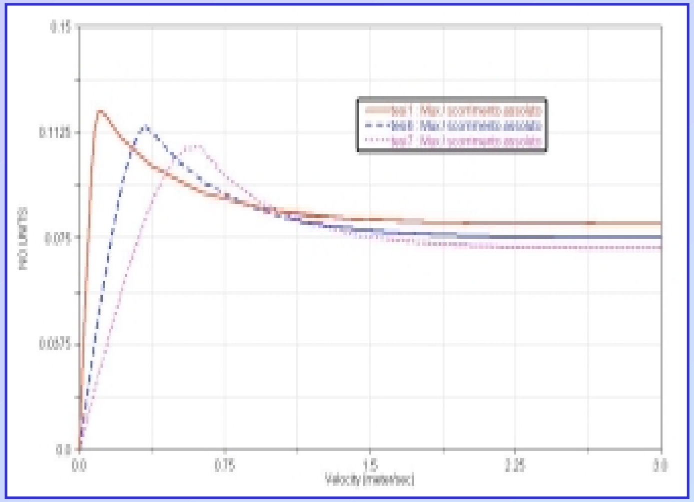
Adhérence en freinage et anti-enrayeurs

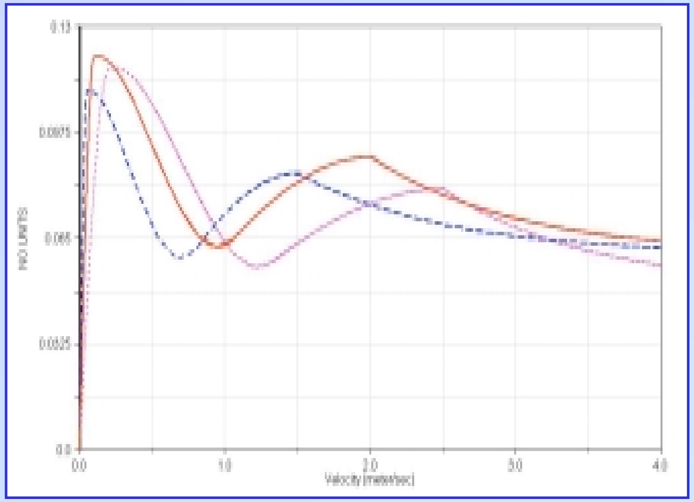
Document tecnique DT257, Office de Recheres st d'Essay De L'Union internationale de Chemins de fer, July 1992

Contact model: Matlab Pre-Processor

To introduce these contact models it was necessary to create a pre processor who facilitated the modifying operation on the system characteristic files and offered the opportunity to modify the contact curves according to necessity.

- Possibility of varying the adhesion curve modifying the peak and regime values.
- Possibility of choosing the kind of adhesion curve.

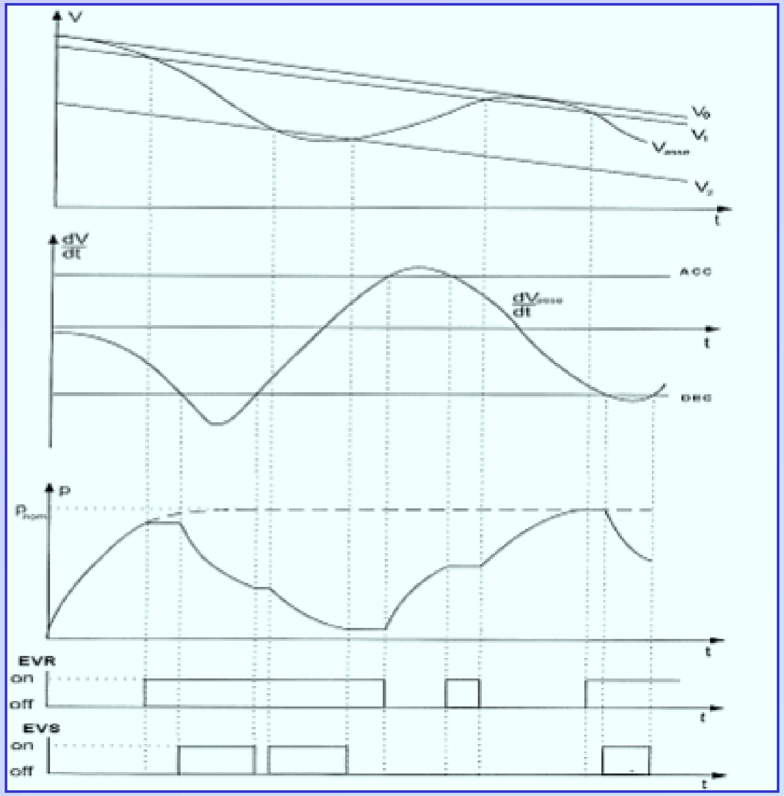




The Pre-Processor directly acts on adm, .acf, .nam files, who characterise the dynamic analysis, inserting the contact forces according to the chosen law.

Anti-slip Device

The wagon “Bagagliaio Z1” is equipped with a “Parizzi-Wupar 83” WSPD (Weel Slide Protection Device)

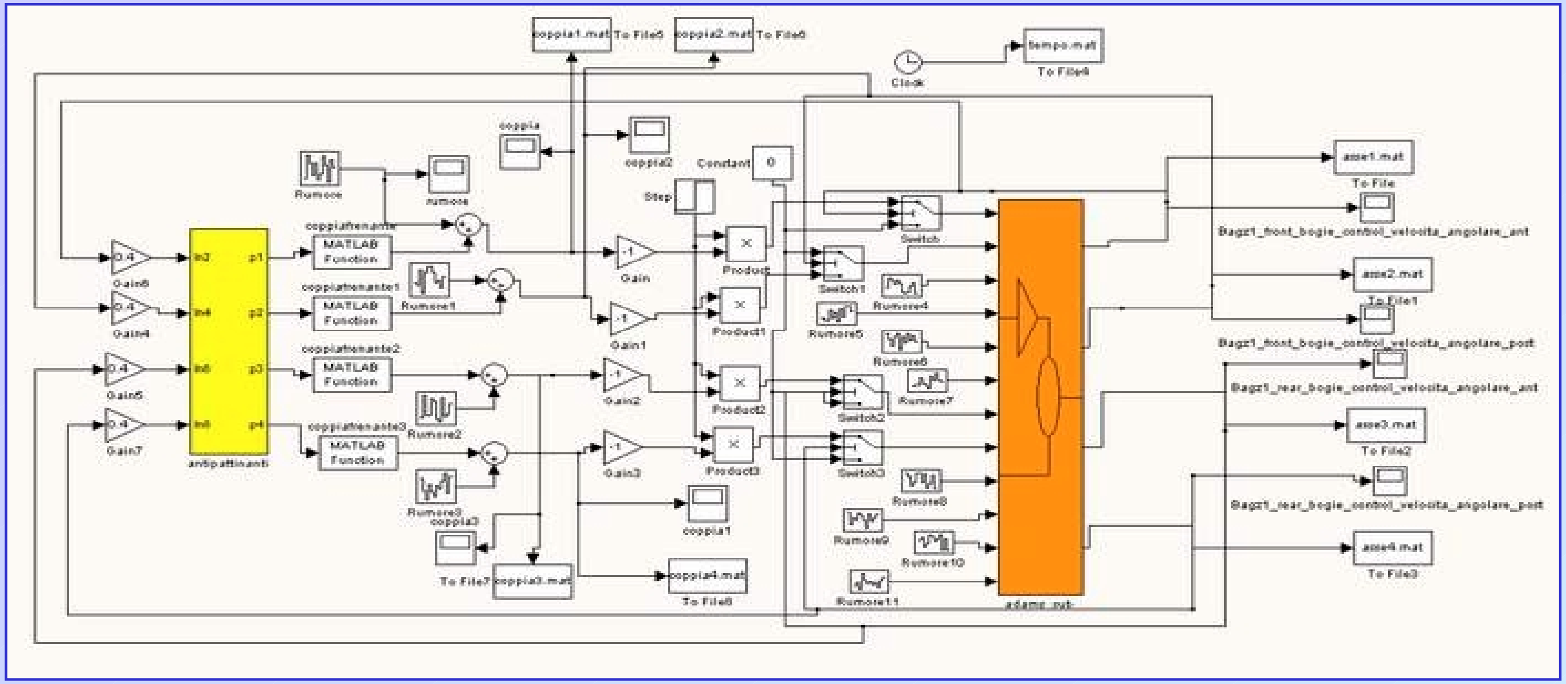


Intervention thresholds: V1, V2, ACC, DEC

Intervention logic:

v > V1	p increases	
v < V2	p decreases	
V2 < v < V1		
	dv/dt > ACC	p increases
	dv/dt < DEC	p decreases

Anti-slip Device Model: A\Controls-Simulink

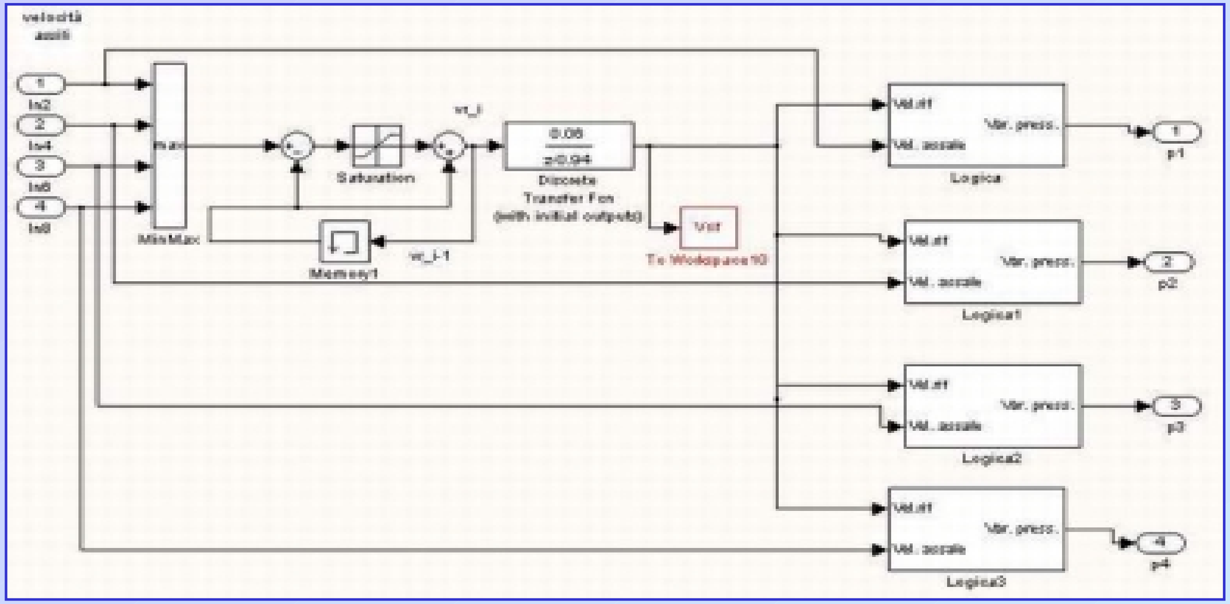


Adams/Controls Simulink block reproduces wagon mechanical behaviour, whose inputs are the braking couples and whose outputs are the angular velocities of the four wheel-sets

The WSPD Simulink modulus is composed of a common part whose inputs are the angular velocities of the four wheel-sets, necessary to define and individuate a reference speed on whom defining the intervention thresholds, and of the four blocks that reproduce the intervention logic on which the WSPD are based.

Anti-slip Device Model: WSPD block

Reference speed evaluation



We consider as reference speed the greatest among the four axles velocities unless the deceleration overpasses a certain threshold; in this case we reconstruct the reference velocity integrating the threshold value.

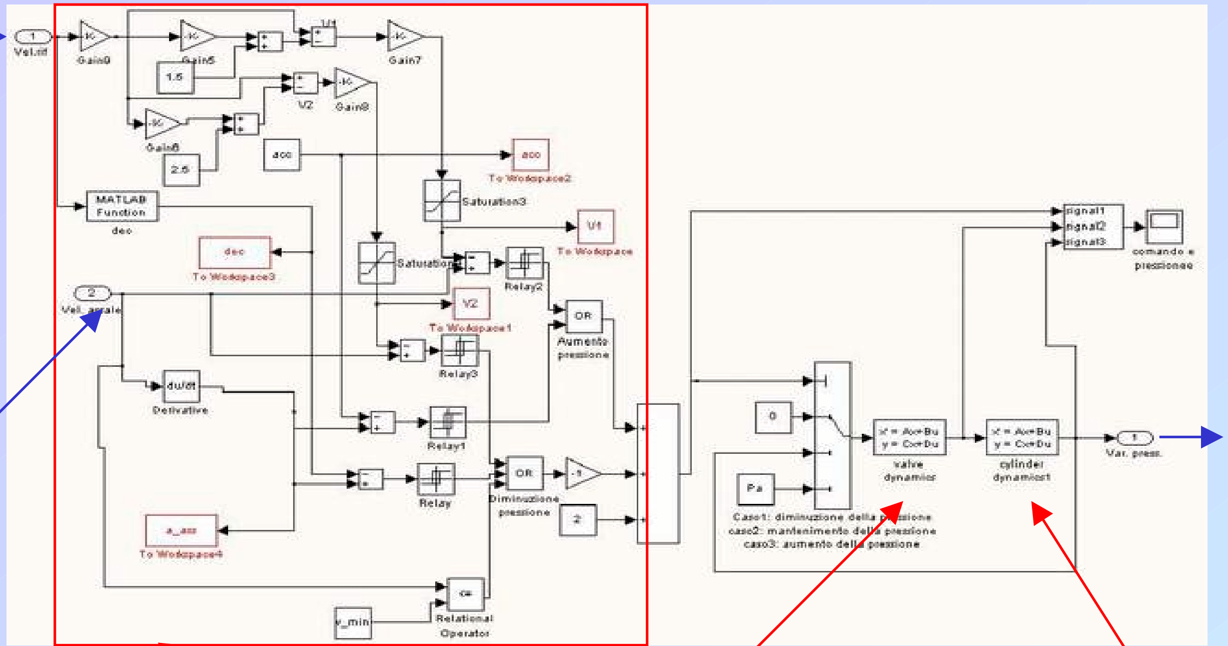
Anti-slip Device Model: WSPD block

Reference speed

Evaluated by Simulink

Axle speed

Evaluated by A\rail



Pressure value

To A\rail

Intervention logic

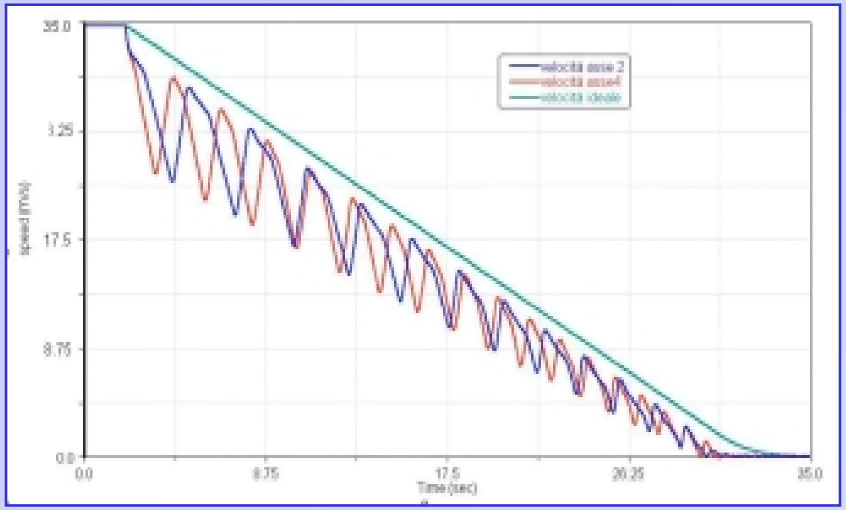
Valve dynamic

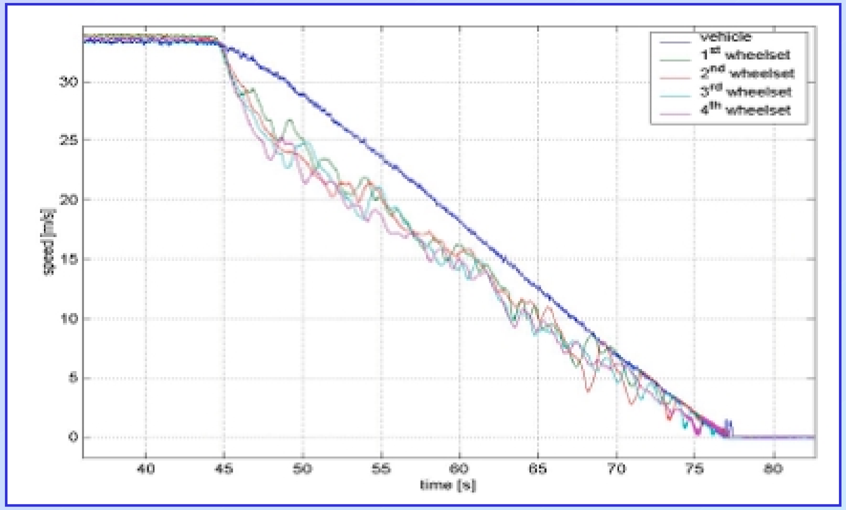
Cylinder dynamic

We took in account the air brake dynamics i.e. the pressure delay in reaching the sought value. Knowing the pressure values in the brake cylinders a function calculates automatically the correspondent value of braking couples that is applied to the wheelsets and these values are the input data for the Adams/Rail block.

Comparison with experimental data

Reference and peripheral velocities



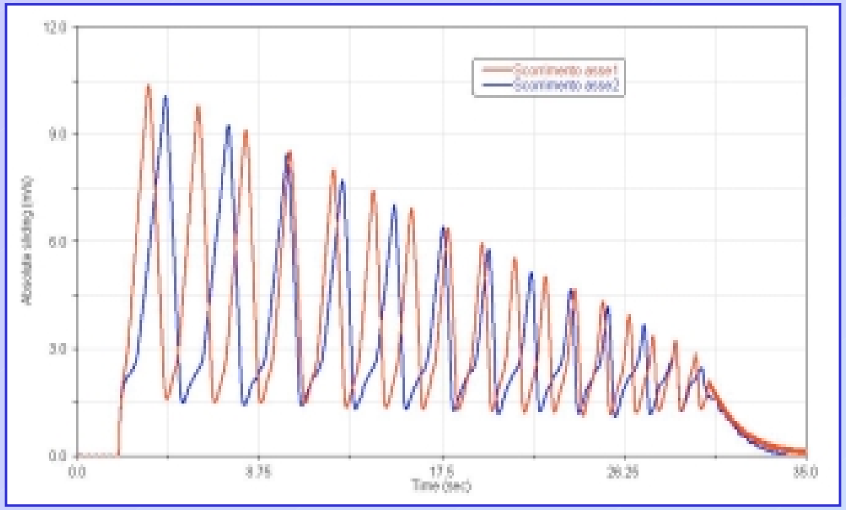


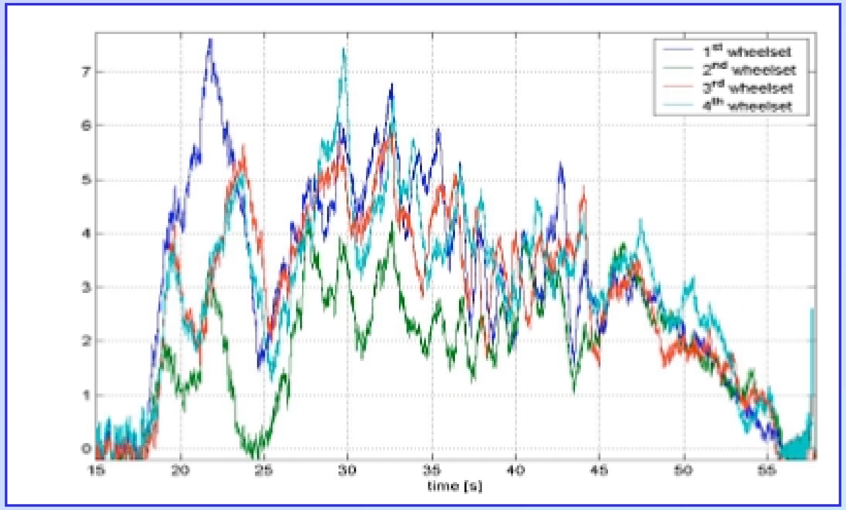
We must observe that experimental tests are carried-out in condition of artificially degraded adhesion and that no information is available on the real adhesion condition of the test.

As visible from the figures, the angular speed decreases very quickly because of the low wheel-rail friction coefficient that makes the wheels begin to slide and when this phenomenon reaches a certain threshold the WSPD acts modulating the pressure and making the wheels recover the adhesion.

Comparison with experimental data

Absolute sliding





The noise present in the experimental graphics is mostly due to the high sampling frequency of the measuring instruments, while the longer time step characteristic of the Adams simulation acts like a low-pass filter and smoothes discontinuities.

The difference between experimental and simulated absolute sliding is probably also due to the variation of the adhesion coefficient along the path in the experimental test, coefficient that is instead assumed as a constant during the simulation.

Conclusion

- A 3D MBS model of a railway wagon has been created with the purpose to reproduce all the characteristic motions that happen in braking manoeuvre.
- Great attention has been put on the characterisation of the wheel rail contact law.
- Also very important is the development of the control model with Simulink and its interfacing with the Adams model.
- The numerous simulations performed show that the proposed model has a behaviour qualitatively and quantitatively analogous to the on line tests.
- A further develop of this model could be finalized to perform tests and successive modifications on the WSPD or on the parameters of the railway wagon characteristic elements reducing the number of tests to be performed on line.
- Further develops are also necessary for the modelling of the wheel rail adhesion phenomenon: in our opinion, it is superficial to consider the adhesion coefficient function only of the sliding as is usually done.
- We are now extending this approach to the motor vehicles and therefore contemplating the traction problems having already filled the gap that ADAMS/Rail showed on the contact model.

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