MULTIBODY SYSTEM APLICATION – RAILWAY COUPLING BEHAVIOR STUDY

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Abstract. *This paper will show a study on railway coupling and shock device while two vehicles were braking. The purpose was to simulate the brake of two railway vehicles and study the coupling behavior observing the shock device influence. The vehicles, rail, shock device and coupling were modeled and mounted at Solidworks and the simulation was done at Cosmosmotion. The boundaries were set up according to the dissertation of Barbosa (1993). The results show more oscillations in the guide vehicle speed in the coupling strength and the spring strenght shock device when it started braking. It is possible to see the influence of the shock device stiffness in the strength amplitude and frequency in time response. The use of software makes the study easier thus allowing for more reliable results. These instruments will offer great functionality and importance in future studies for the railway sector.*

Keywords*: Railway, Multibody Systems, Simulation*

1. INTRODUCTION

The Brazilian railway transportation has recently been faced with a big request caused by economic growth. The load sector has the mining sector as a strong allied. The growth of large cities creates the need for more public transportation means such as the metro and others.

As the railway transportation grows, so do investments to increase its mesh, which have become necessary according to the heated economy before the 2008 crisis. However, the current economy situation has not stopped the investments on the railway system. Railway tends to be a better cost-benefit than the roadway transportation. To better exemplify the railway transport benefit we may say that there is no traffic jam on railways, delivery is made on time, transported load and the load capacity are higher than by road.

The need to understand the railway vehicle dynamic behavior and its components are of great important for load increase transported for each train and also the need for increasing the number of vehicles.

2. BIBLIOGRAPHIC REVIEW

Barbosa (1993) approached the longitudinal effects on train. The vertical and lateral effects are evaluated trough a complete vehicle model where the coupling efforts produced by longitudinal dynamic of the train are combined with the results which were obtained by complete dynamic of the vehicle studies.

In 1984 in Brazil a complete longitudinal dynamic of trains study was carried out by Felicio (1984). The breaking system and shock-absorbing device were modeled and a numeric integration program has been written .

The model investigated by Hoever (1969) was a homogeneous rigid bar carried, longitudinally, by breaking strength and it allowed obtaining a magnitude order along the bar. However Hoever observed that the coupling elasticity had a fundamental function on system behavior.

2.1. Coupling

The coupling and shock-absorbing device set is responsible for physic interconnection between vehicles. The coupling does the union between two consecutive vehicles and the shock-absorbing device stays between the coupling and the vehicle structure.

The complete system assembly is shown in “Figure 1” displaying each component.

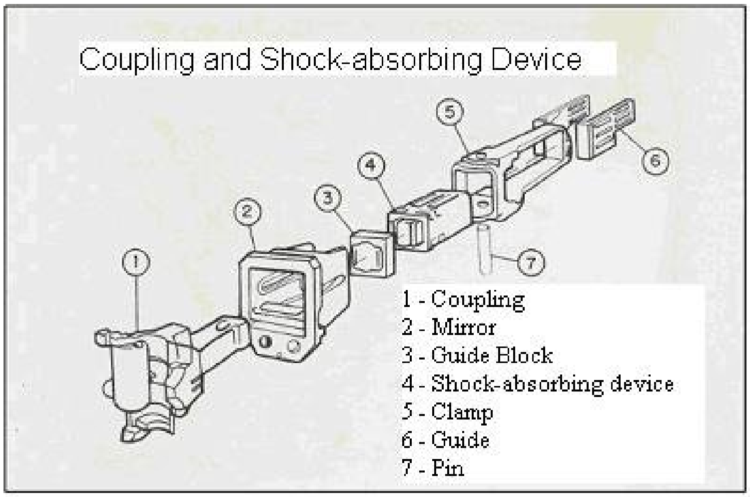

Figure 1. Detailed view – Coupling and Shock-absorbing device.

The shock-absorbing device has the basic function of absorbing the impact energy produced by relative movement between two wagons. This device reduces force peak transmitted through the vehicle structure avoiding damage.

There are several kinds of shock-absorbing devices. It is possible to quote the type based in hydraulic cylinder and also rubber. However, the shock-absorbing device used in Brazil is the spring and friction wedges type which is the model used for the development of this work.

The shock-absorbing device is essentially a mechanic device composed by spring and friction wedge. The assembly is done in a rectangular metal case (item1) as in “Figure 2”. This figure shows the schedule of a shock-absorbing device of spring/ friction wedge type on free position (A) and compressed (B).

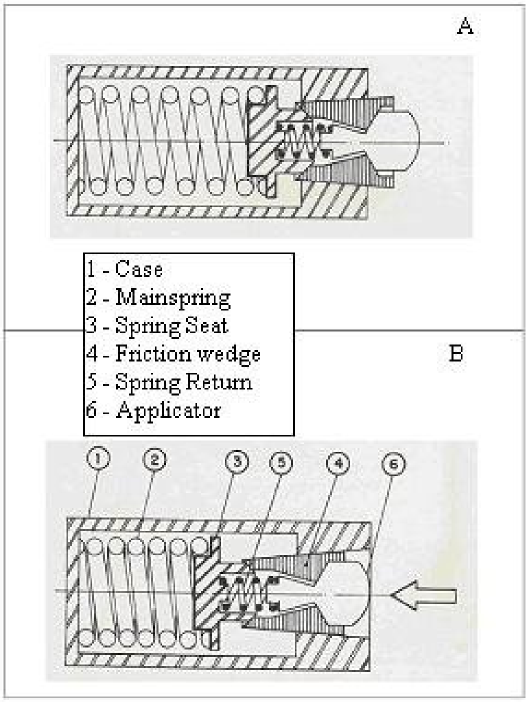

Figure 2. Shock-absorbing Device

The frontal part of the shock-absorbing device is composed of applicator (item 6) and spring seat (item3) that are the support to the main spring, when it is forced into the coupling by pressing the friction wedge (item4) against the internal side walls (item 1) producing dry friction and dissipating the impact energy (Barbosa 1993).

The friction wedges (item4) are split elements and these are pressed by an applicator wall (item6) and spring seat. When the compression force is released, the spring return (item 5) tends to separate the spring seat applicator thus releasing the pressure on the wedges, creating the hysteresis effect.

2.2. Transmitted Forces Through Shock-Absorbing Device.

"Figure 3" displays a schedule of an interaction where it is possible to observe the transmitted forces through the shock-absorbing device.

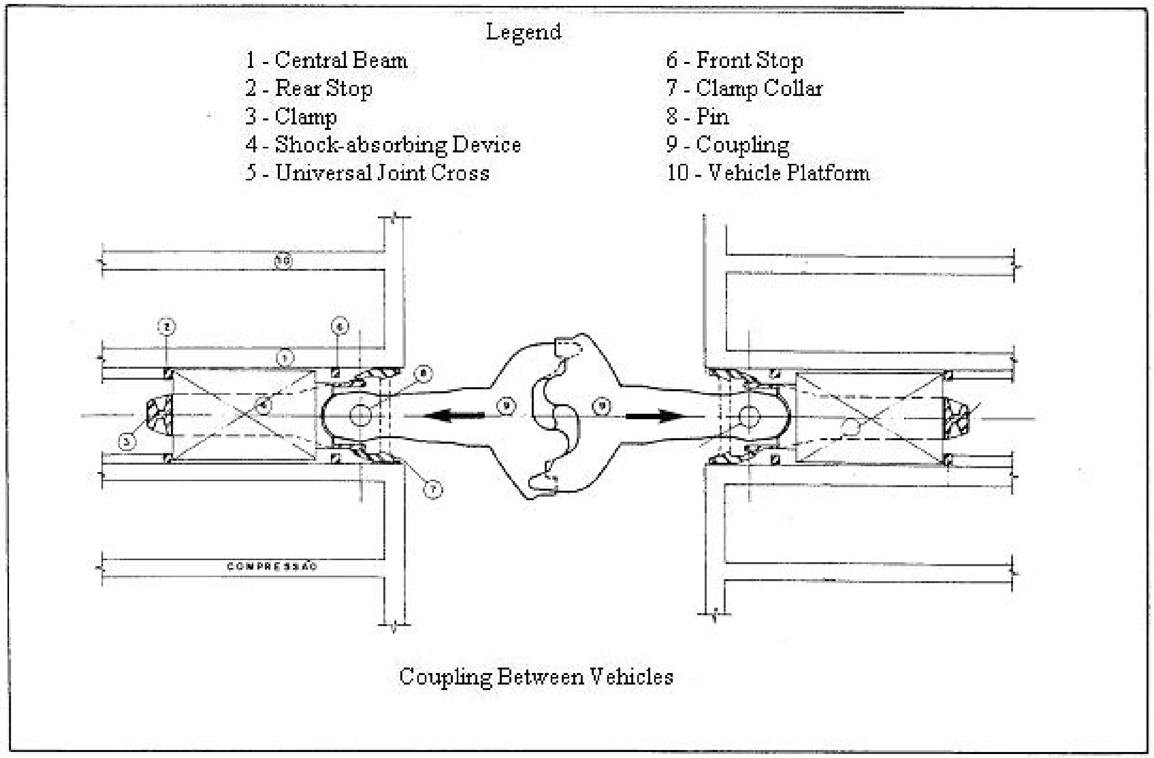

Figure 3. Coupling Between Vehicles

We observe above that couplings (9) are subject to compression forces. In this case it reacts through the coupling body directly over the shock-absorbing device front (4), which is attached to the vehicle rear stop (2).

For tension between vehicles the coupling pulls the clamp (3) which reacts over the rear part of shock-absorbing device attached to the front stop (6).

The shock-absorbing device will always compress because of the clamp (3) and the front stop assembly (6). When tension is applied the clamp pulls the shock-absorbing device, which leans its frontal part over the front stop. Each union between vehicles has two shock-absorbing devices in series and their link has half of shock-absorbing device stiffness. (Barbosa 1993)

2.3. Multibodys System

A Multibody System is defined as a mechanic system with many degree variations. Effectively, if the mechanic system has two or more bodies, it is considered as a MBS. The MBS movements are governed by mathematical expressions called dynamic movement equation. These mathematical equations are composed of a set of differential equations, eventually increased by some algebraic equations. The differential equations are physical law expressions (Newton's movement law) that describe the rigid body movements and the algebraic equations consider the restrictions imposed by system geometry or their movements, as a connection link between two adjacent bodies, or particular contact characteristics between two bodies.

The MBS technique model can be used to carry out the mathematical model conception of any mechanical system which can be modeled physically as a set of rigid bodies interconnected by joint, influenced by forces, directed by movements limited by restriction. Movement equations for these systems are complex and hard to write manually, even for a composed system by the reduced number of interconnected bodies. The possibility of development movement equations to MBS was a great advance.

3. METHODOLOGY

To make the simulation in MBS the railway coupling and the vehicles (wagons) were modeled. The measurements to model the coupling were directly collected of a coupling with the configuration described in previous items.

After developing models CAD 3D the Cosmosmotion software was used to generate Multibody models, following the definition of necessary parameters to simulate the breaking, based in data by Barbosa (1993).

3.1. Railway Coupling and Vehicle Representation

As presented in the bibliographic review above, the shock-absorbing device always receives compression since the coupling directly compresses it or when the coupling is pulled; then the armband compresses the shock-absorbing device. To represent the coupling behavior between two vehicles three parts were modeled as shown in “Figure 4”: coupling, shock-absorbing device and armband.

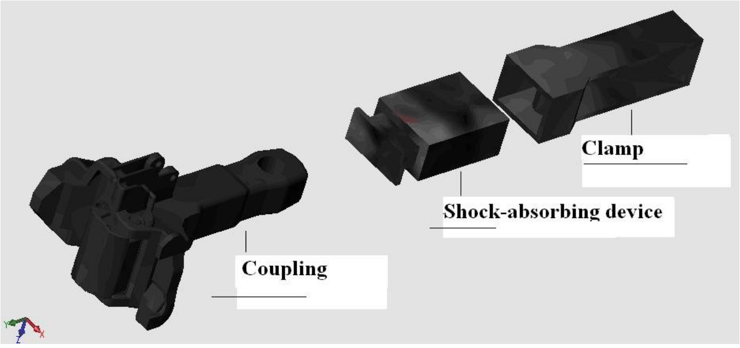

Figure 4. Tree parts representing the railway coupling

Simplifications were introduced in the model to represent the coupling behavior. This simplification does not modify the results and makes the processing faster. The longitudinal strength was evaluated in the study and it was fixed in coupling position to simplify the mandible. No rotation was allowed, as shown in “Figure 5”.

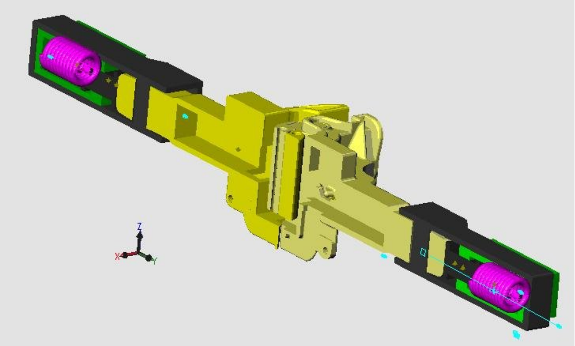

Figure 5. Coupling and shock-absorbing device assembly

The vehicles and rail were modeled as in “Figure 6”. There was no friction between vehicle and rail because the purpose was to study the coupling without energy loss with other components or operation conditions.

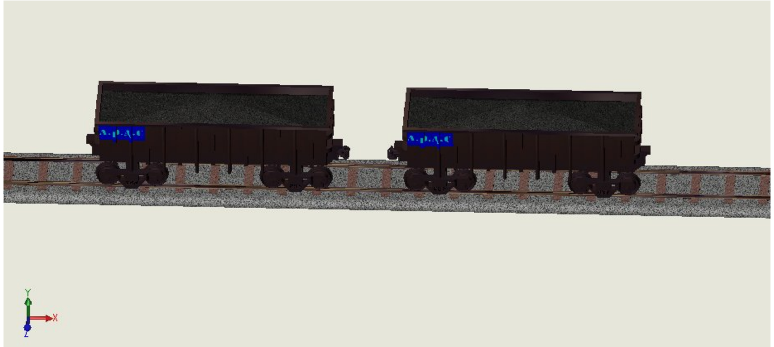

Figure 6. Rail and wagon assembly

Input data:

Initial Speed: 60 [km/h]
Final Speed: 0 [km/h]
Breaking time: 100 [seconds]
Vehicle mass: 120.000 [kg]
Shock-absorbing Device Stiffness: 10,5 E + 06 [N/m]
Shock-absorbing Device Damping: 80,0 E + 03 [Ns/m]

The vehicle reached 60 km/h (16700 mm/s) for breaking simulation, in order to obtain a force allowing for the evaluation of the behavior of the shock-absorbing device. To observe the coupling behavior the shock-absorbing device and damping stiffness were doubled.

For the simulation, only the driver vehicle had control over the deceleration when braking.

4. RESULT ANALYSIS

For the railway coupling dynamic study vehicle speed, coupling strength, and shock-absorbing device spring strength results were collected.

At the beginning of deceleration the driver vehicle induces the conducted vehicle deceleration through coupling causing speed oscillations that in time response pass to linear scheme as in “Figure 7”. This behavior is caused by shock-absorbing device and damping stiffness actions.

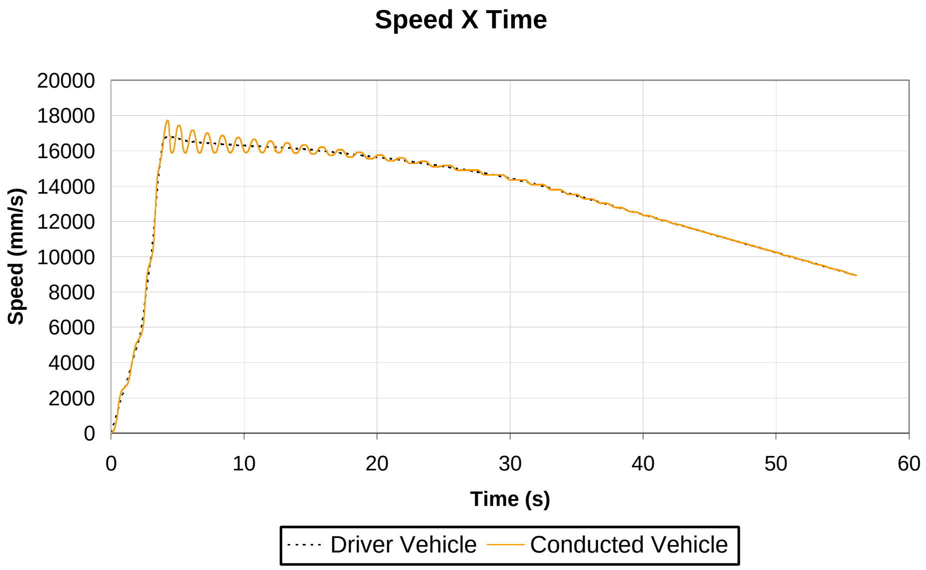

Figure 7. Driver vehicle and conducted vehicle speed

At the beginning of deceleration the coupling efforts reach values up to 1000kN. This value is directly linked to input parameters and model definition such as acceleration speed and time.

With the shock-absorbing device action the coupling strength as spring strength as in "Figure 8 - Figure 9" respectively, oscillates and loses amplitude because of the energy loss caused by damping.

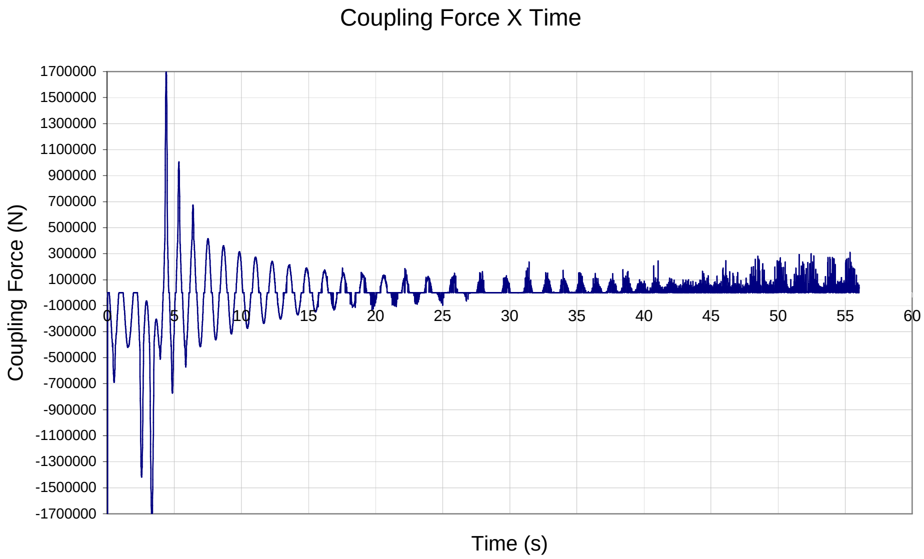

Figure 8. Coupling force in time response

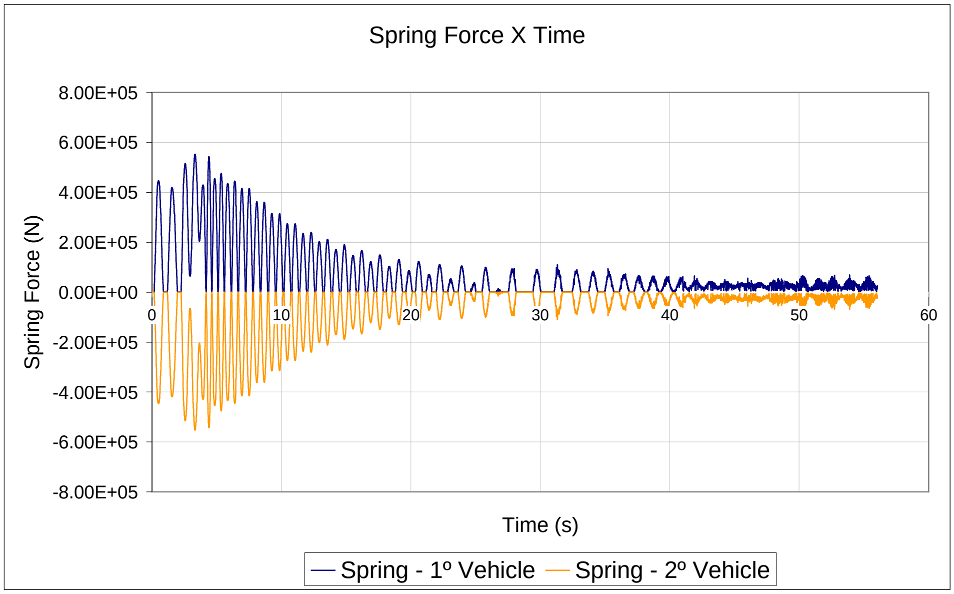

Figure 9. Spring force in time response

To evaluate the shock-absorbing device stiffness action a new simulation doubling the stiffness value was carried out. "Figure 10 - Figure 11" show a decrease in amplitude effort but a frequency increase. These results can be explained by Hooke law as in Eq. (1).

$$F = k.x \tag{1}$$

The stiffness increase caused high shock-absorbing device spring displacement decrease causing a coupling and spring efforts decrease as in “Figure 12”.

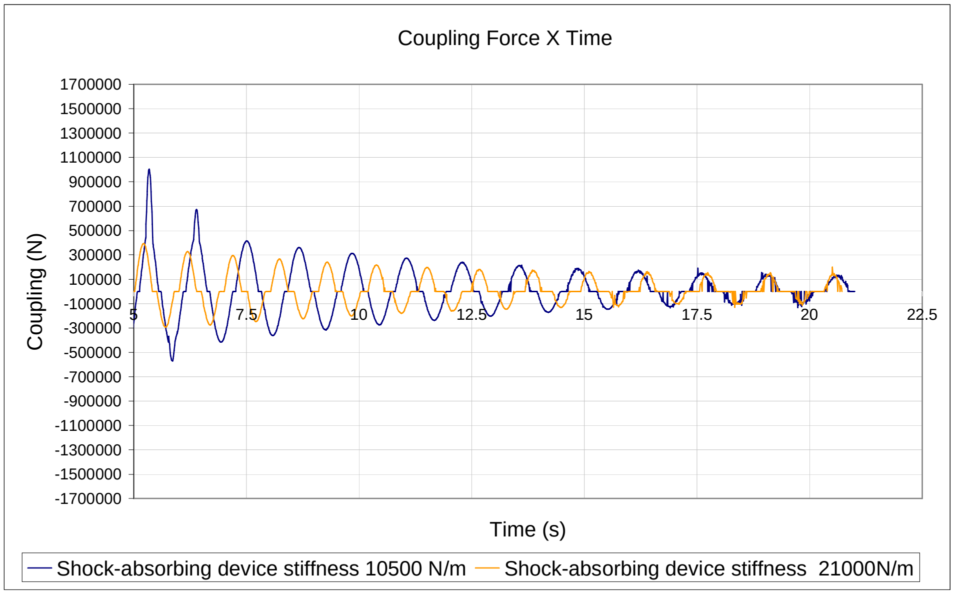

Figure 10. Coupling Force in time response. Efforts comparison ranging the shock-absorbing device stiffness.

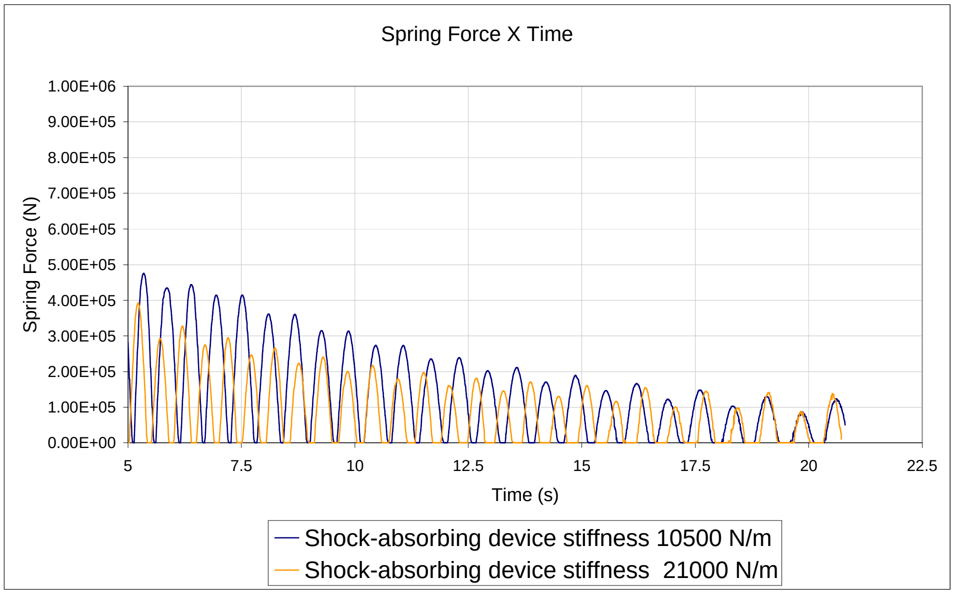

Figure 11. Spring force in time response. Efforts comparison ranging the shock-absorbing device stiffness.

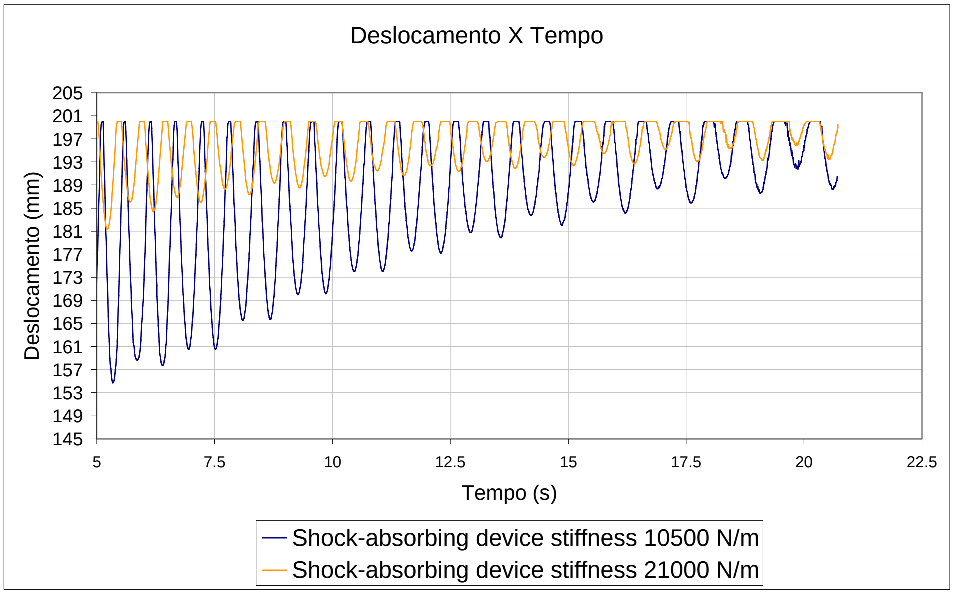

Figure 12. Displacement in time response. Efforts comparison ranging the shock-absorbing device stiffness.

The frequency increase caused by stiffness increase is explained by Eq. (2).

$$w^2 = k/m \tag{2}$$

5. CONCLUSION

The use of software makes it possible to show the importance of the shock-absorbing device in the railway coupling behavior. It was possible to soften the coupling shock due to the shock-absorbing device stiffness and damping, where energy was dissipated in time response with oscillatory motion. It relates the shock-absorbing device spring stiffness influence with strength, displacement and natural frequency amplitude changes. It will be possible propose improvements with more refined analysis in future studies.

This work shows the use of simulation software in dynamic study. Cosmosmotion has many tools allowing good result analyses. Using CAE will be important to develop mechanic devices and work improvements.

6. NOMEACLATURE

F – Force.
k – Stiffness.
m – Mass.
x – Displacement.
w – Natural Frequency.

7. REFERENCES

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8. RESPONSIBILITY NOTICE

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