STUDY OF THE LIFECYCLE OF RUBBER SUSPENSION ELEMENTS FOR OPTIMISED MAINTENANCE AND SAFE DYNAMIC BEHAVIOUR

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ABSTRACT

Transport industry and, more specifically, railway industry, is confronted with a permanent need of improvement of its products. The competitiveness of rolling stock does not come only from low-cost production, but also from well-calculated lifecycle costs. Nowadays, many contracts for railway operators include not only trains, but also maintenance services throughout its lifetime, which may reach 30% of global costs. Hence, deep knowledge about the system's ageing is a strong asset to assess a good performance, both on quality of service and financial costs.

Rubber parts are widely used on railway technology because of their material properties, providing both mechanical stiffness and, to a certain extent, additional damping and vibration filtering. Contrary to metallic parts, whose mechanical characteristics remain relatively stable, rubber's properties can change throughout a lifecycle, due to service loads and environmental influence. Such changes might have an impact on the system's behaviour and lead to undesirable scenarii. For a given bogie model, we search to estimate the stiffness variation on some rubber parts, which are deemed relevant for safe operation.

1 SUMMARY

The works on our project are carried out with a partnership with a rolling stock manufacturer. The article will explain briefly the current safety norms and constraints which apply to rolling stock. The link between safety assessment and mechanical characteristics will be addressed, outlining the need of thorough knowledge on the evolution of rubber's mechanical characteristics. Ageing mechanisms will be described, as well as a strategy to study the impact of these changes on the pieces' global characteristics. Finally, a recall on maintenance objectives will be outlined.

2 SAFETY ASSESSMENT ON RAILWAY ROLLING STOCK

Railway industry has to meet several safety norms to obtain the homologation of its products, allowing the exploitation of rolling stock on one or more networks. Compliance is assessed according to each country's or operator's legal frame, but a common basis is set up by UIC (French initials for "International Railway Union") and EN European norms.

Accordingly to UIC 518 and its European transposition EN 14363, we carry out simulation tests on derailment aptitude, roll coefficient of the vehicle and safety assessment for dynamic behaviour. We use the MBS calculation software SIMPACK. Each test demands to meet several performance indexes, whose value depends on the mechanical characteristics of the system and which are limited by the norms stated above [6,7]; among this indexes one can find:

- ratio of lateral and vertical loads over a wheel, Y/Q [a-dimensional], lower than 1.2 ;
- wheel lift, Δz [mm], lower than 5 mm;
- roll coefficient of the carbody, S_R [a-dimensional], depends on the train (e.g. trains with a pantograph must be below 0.21);
- shift forces over an axle, ΣY [kN], given by the Prud'homme formula;
- acceleration levels in both vertical and lateral directions in several positions, $\ddot{y}$ and $\ddot{z}$ [m/s^2].

3 RUBBER SUSPENSION ELEMENTS

The use of composed rubber parts on train suspensions began on the 1960's and 1970's. The main interest on this parts is that they can handle loads as good as a metallic part would do, with the additional advantage of an inherent damping behaviour. This parts play a key role on providing both structural strength on the system, as well as filtering properties for vibration purposes. Their structure can be very different, depending on the desired role: first examples came as stacked layers of rubber and steel (e.g. Figure 1, 2^{ary} suspension on SNCF BB 22200), evolving to more complex forms like stacked-layer chevrons or conical rubber-metal springs [1] (e.g. Figure 2, 1^{ary} springs on Renfe CIVIA).

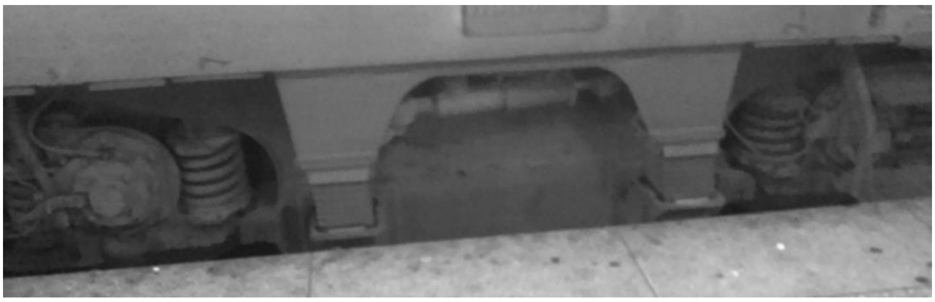
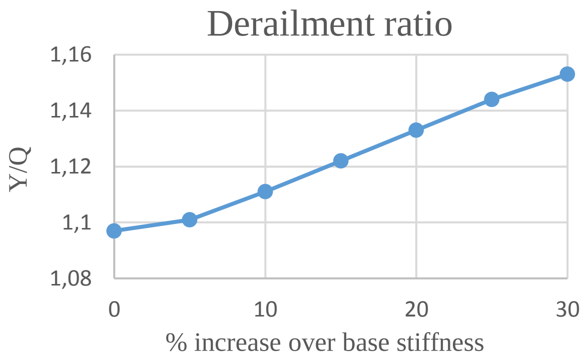


Figure 1. Motor bogie on SNCF BB 22000, 2^{ary} suspension with stacked metal/rubber layers.

Figure 1. Bogie featuring primary rubber elements [6].

The bogie which we have chosen has several metallic-rubber parts. We are mainly interested on two rubber-based elements: a primary rubber spring, shaped as an inversed conical rubber layer bonding two metallic frames, and an auxiliary spring which supplies additional stiffness when the secondary suspension is deflated.

The knowledge from our partner states that rubber elements might increase their stiffness up to 30% during their lifecycle. Thus, we have performed a large amount of simulations varying the characteristics of this elements, from +5% to +30% homogeneously over a whole train. The obtained results show that an increase of stiffness has an influence on the vehicle's derailment aptitude, leading to higher values on the Y/Q ratio (see Graphic 1). Hence, we can state an upper boundary on the element's stiffness to prevent the risk of non-compliance with safety norms.



Graphic 1. Evolution of the derailment coefficient depending on the increase of stiffness.

4 EVOLUTION ON MECHANICAL CHARACTERISTICS

4.1 Mechanical and environmental ageing

It is well-known that rubber is subjected to several phenomena which can affect its properties throughout time. In the case of railway applications, we can expect either an increase or a decrease of stiffness, which may come from faulty manufacturing (un-bonding with metallic frames, bad vulcanisation…) or from changes within the rubber itself. Inherent changes might come from two sources: degradation due to mechanical loadings and chemical degradation due to environmental aspects (UV radiation, heat/cold cycles, humidity, grease, etc.).

On our train suspension elements, environmental degradation and mechanical loading occur simultaneously. It has been proved that the effects of these two phenomena can be counter-effective [2,3], as shown on Figure 2. Thus, mechanical fatigue would tend to soften the material (loss of stiffness), while rubber ageing would make it progressively stiffer. Accordingly, the primary springs and the auxiliary springs would soften, then harden by the end of their lifecycle.

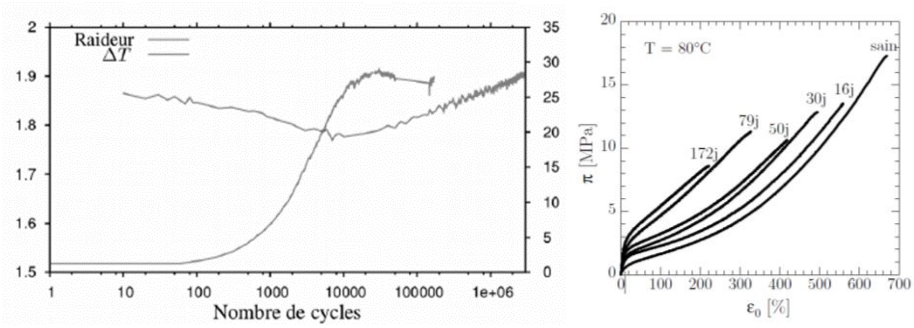


Figure 2. Thermomechanical ageing over a rubber sample [2] (left) and stress-strain curves for aged rubber [3].

4.2 An inverse approach to determine the element's stiffness along a lifecycle

Rolling stock manufacturers do not always have an access to their products once the warranty period is over. Furthermore, since the element's lifecycle extends up to ten years, feedback on suspension performances can also be scarce. Hence, gathering information about worn out components becomes soon a major challenge. Nevertheless, obtaining samples of the material from the suppliers is much easier and can be used as a starting base.

As the exploitation limits of some suspension organs lay far from the design stage, we aim to provide a basic tool that can perform predictive guesses on the evolution of certain elements' behaviour. This tool would be based on FE analysis and a study on the material's mechanical properties, coupled with current expertise from our partners.

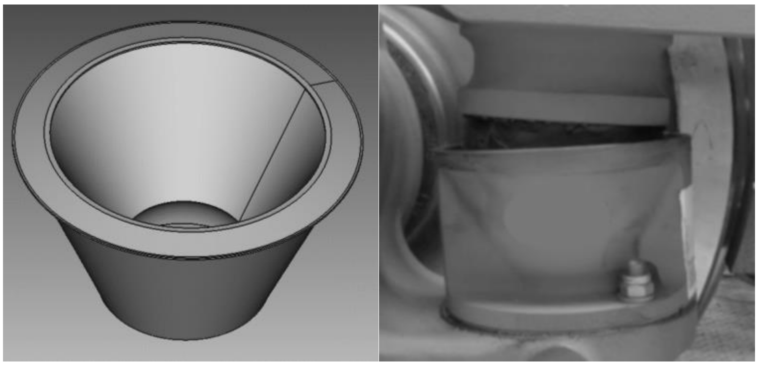


Figure 3. CAD design of the rubber layer within the rubber spring (left). Primary rubber spring on position; the rubber lays between the metallic frames, inside the lower part (right).

5 CONCLUSION

Maintenance optimisation depends, among others, on the suspension element's lifecycle. As it has been explained, it is possible to provide tools with a certain accuracy, which can provide some predictive assessment to complete the empirical expertise on lifecycle behaviour of rubber parts. Coupling the expected stiffness evolution of rubber parts with the operation boundaries of the system may show that overhaul delays can be extended accordingly with safety norms.

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