Suspension Coil Spring and Rubber Insulators : *towards a methodology of global design*

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ABSTRACT

CF-Gomma & Allevard Rejna Autosuspensions have combined their know-how to asses a suspension coil spring & rubber insulator system design methodology. The particular aim is to identify a more robust optimisation criteria, while seeking a compromise between ride comfort, handling and NVH.

CONTEXT

Optimizing the vehicle suspension system has a major role in improving ride comfort, active safety and vehicle reliability. Car-makers are indeed constantly seeking to improve vehicle driveability and behavior.

This has to be achieved through solutions that allow a sufficient design margin and that take into account the multitude of parameters affecting ride comfort.

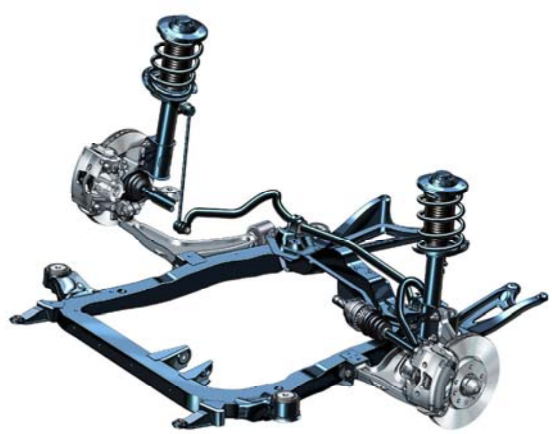
In this context, Allevard-Rejna, specialized in elastic suspension components, has joined forces with CF-Gomma, specialized in rubber insulators, to combine their know-how. This partnership is based on our on-going commitment to providing our customers with an optimized insulation-steering system for vehicle suspension.

INTRODUCTION

A good car suspension system should be perceptible by the customer in terms of vibrations and ride comfort. It should:

- ensure optimum tire performance,
- support the chassis,
- offer good standards of comfort, by minimizing the transmission of road surface irregularities to the body and also by efficiently filtering noise generated by the contact between the tire and the ground.

The MacPherson type suspensions studied here have some definite advantages, the main one being their good price-quality ratio.



Source: Opel

They nevertheless have some drawbacks, well known to car-makers, with regard to their road-holding qualities. In particular, we may mention the problem of friction and drift.

Friction has a direct impact on ride comfort. It is characterized by the lateral forces that develop at the end of the damper rod.

To minimize or even eliminate this problem, one solution involves tilting the suspension spring in relation to the damper. Due to limited space, this solution is not always feasible. Other solutions involve using particular spring geometries and/or interfaces to tilt the action line (side load) of the spring without tilting the spring itself and therefore leaving the packaging unchanged. Indeed, a parametrical study of the end coils of the spring shows that the action line is influenced by three parameters (offset, pitch and coiling radius).

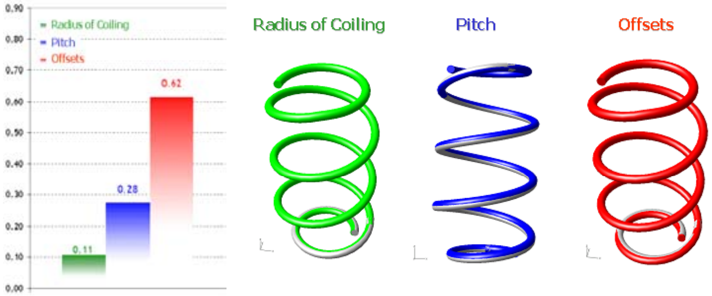


Fig-1: Classification of parameters influencing the action line.

Drift has the effect of pulling the vehicle towards the right or left when driving in a straight line on an ideal road surface. This has an adverse effect on steering comfort. It can be characterized by the difference in forces in the left and right hand steering rods.

The purpose of this study is to investigate the influence of the rubber in the spring insulator on the static and dynamic characteristics of the spring/insulator/strut bearing sub-system. The latter is represented by an ideal pivot joint.

For this purpose, finite element calculation models were created with validation tests using specific tools.

We will first present the role of the spring insulators and rubber mixes with regard to vibration comfort. At the same time we will consider the role of the spring in the steering function. The second part will examine a practical case in which we will demonstrate the advantage of using insulated cups and thus assess the robustness of our numerical models.

The results obtained enable us to conclude that it is possible to achieve a global compromise (between the spring and the insulated cup) that meets vibration comfort and road holding requirements.

VIBRATION COMFORT

Before describing the role of the spring insulator, it is important to describe the vibration behavior of the spring.

Spring vibration behavior

The spring behavior may be examined in terms of the transfer function in the frequency domain. In the present case, the transfer function is defined by the ratio between the load transmitted and the displacement injected.

The transfer function of a spring subjected to vertical loading is represented below (Fig-2).

The spectral density of a spring is very high. In the spring vibration behavior, it is possible to distinguish 2 zones separated approximately at the 150 Hz point.

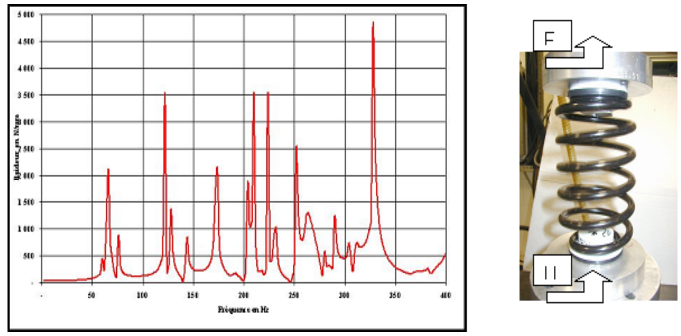


Fig-2 : Transfer function of a spring subjected to vertical loading

Low frequency resonance <150 hz

***Transversal modes*:**

The transversal modes of the spring have the lowest frequency and are excited either by offsetting the spring force or by the suspension kinematics that generate movement perpendicular to the spring axis. These are little absorbed and can cause the spring to knock against the axle or body of the vehicle (Fig-3).

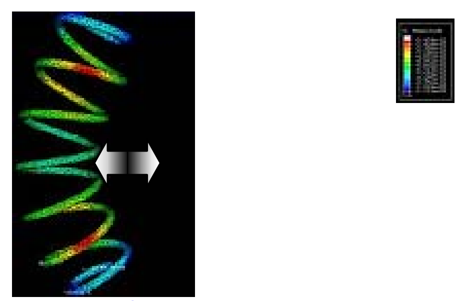


Fig-3 : Deformed shape of a transversal mode

***Axial or pumping modes*:**

The little absorbed axial coil modes generate very high peaks of force transmitted by the spring. When strongly excited (when driving on cobblestones for example), the coils may knock together due to the amplitude of these modes (Fig-4). Coil-to-coil contact is an important factor in acoustic comfort (source of noise) as well as in the spring service life as it can damage the anti-corrosion paint on the spring.

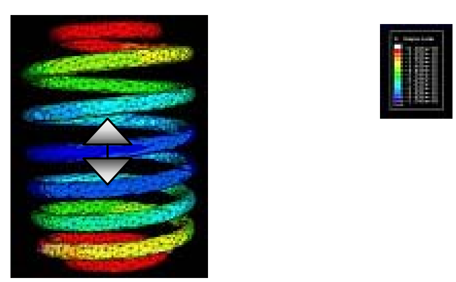


Fig-4: Deformed shape of an axial mode

Medium and high frequency transfer >150 Hz

All the spring modes (helical beam) are involved in this transfer. They are little absorbed and the transmissibility of the spring on its own remains high even at high frequencies. The vibrations of the spring cups on the arm or strut excite all the spring modes. The forces transmitted to the body can be high at medium frequency when the springs are not insulated.

Role of the spring insulator

The main function of the insulator is to improve vibration comfort by insulating the spring modes (Fig-5). This improvement is achieved here by increasing the thickness of the rubber insulator.

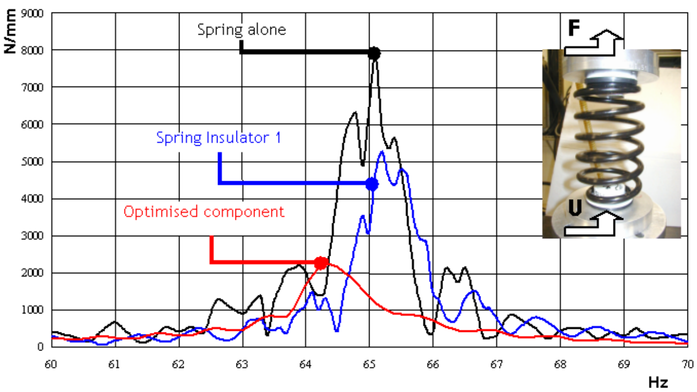


Fig-5: Insulating effect of the spring insulator.

The influence parameters of the insulator are its thickness (i.e. its stiffness) and damping properties. By increasing its thickness, its insulating effects are improved. The graph in figure 6 shows the improved behavior of a vehicle with insulated spring when running over an obstacle at 30 km/h.

The damping properties of the elastomer of the insulator reduce:

- the axial resonances of the spring
- the force transmitted to the body
- the amplitude of the vibration of the coils and therefore the risk of contact between the coils (endurance).

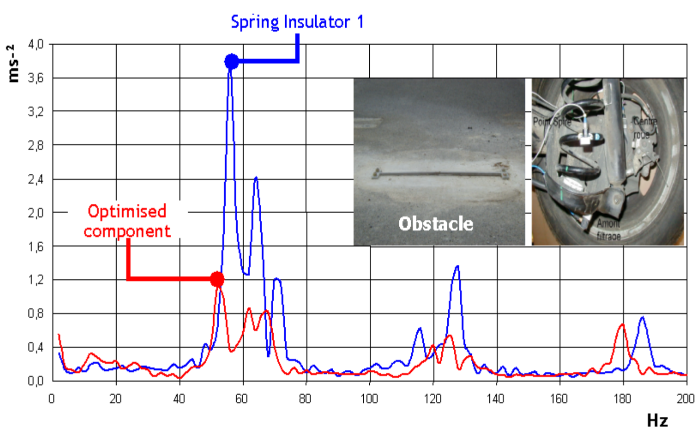


Fig-6 : The spring is excited axially by running over an obstacle generating a vertical movement of the wheel

Insulation can therefore offer an additional solution to the geometrical optimization of the spring.

PRACTICAL CASE: IMPACT OF THE INSULATOR ON FRICTION AND DRIFT

The problematic here is to both ensure optimal road-holding performance of the spring and low frequency noise comfort while insulating the spring modes. It is therefore necessary to assess the influence of the insulator on the functions required of the spring, particularly friction and drift in the case of the MacPherson suspension.

Design tool implementation : Numerical and Experimental

Numerical models and validation tests have been developed by the partners based on specific internal tools.

Figure 7 illustrates the coil spring design modules and evaluation of friction and drift. These modules are integrated into Allevard Rejna's VPN (Virtuel Prototyping Network) calculation software.

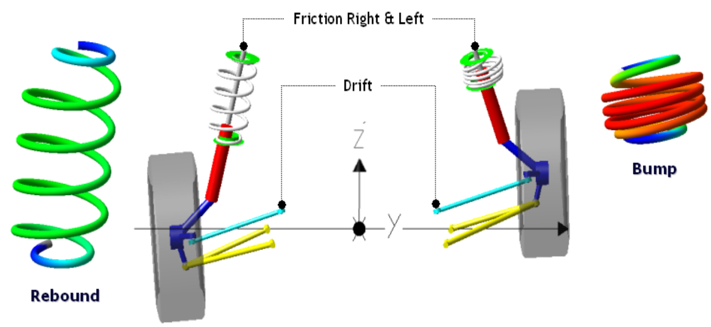


Fig-7: Evolution of torsional stress (bump and rebound) and definition of friction and drift

These models have been enriched by CF-Gomma in order to integrate a more robust modelling strategy with regard to a non-linear assembly, both in static and dynamic mode, namely:

- large strain of the rubber,
- large displacements of the coil spring
- contact between the components (Fig-8).

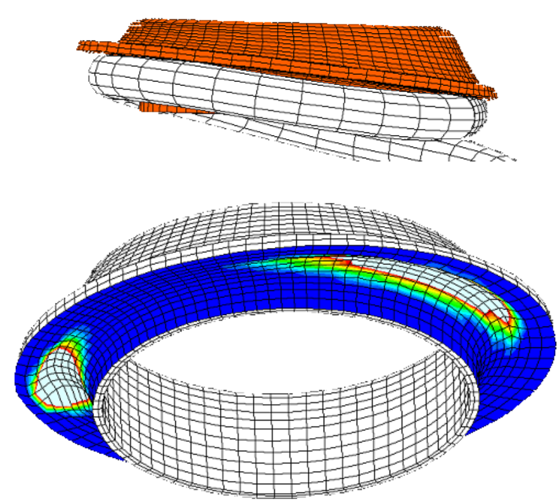


Fig-8: Distribution of contact pressure on the rubber insulator.

Results

Figure 9 represents the friction curve (load at the damper rod end) for the left and right hand suspensions respectively according to the spring compression height, from rebound to full bump position.

When we compare the friction curves obtained from a rigid cup (A), a mass produced rubber insulator (B) and a double thickness rubber insulator (C), we can see that:

- the curves begin to diverge from the rebound position.
- the curve obtained with the rubber insulator (B) and (C) is stable throughout the spring compression process. It is even more stable with insulator (C).

The friction is lower with a rubber insulator (B and C). This level of friction corresponds to the best compromise for the optimum performance of the damper. It is neither too low (instability of the damper rod in the vehicle body) nor too high (low comfort levels and premature wear of the damper).

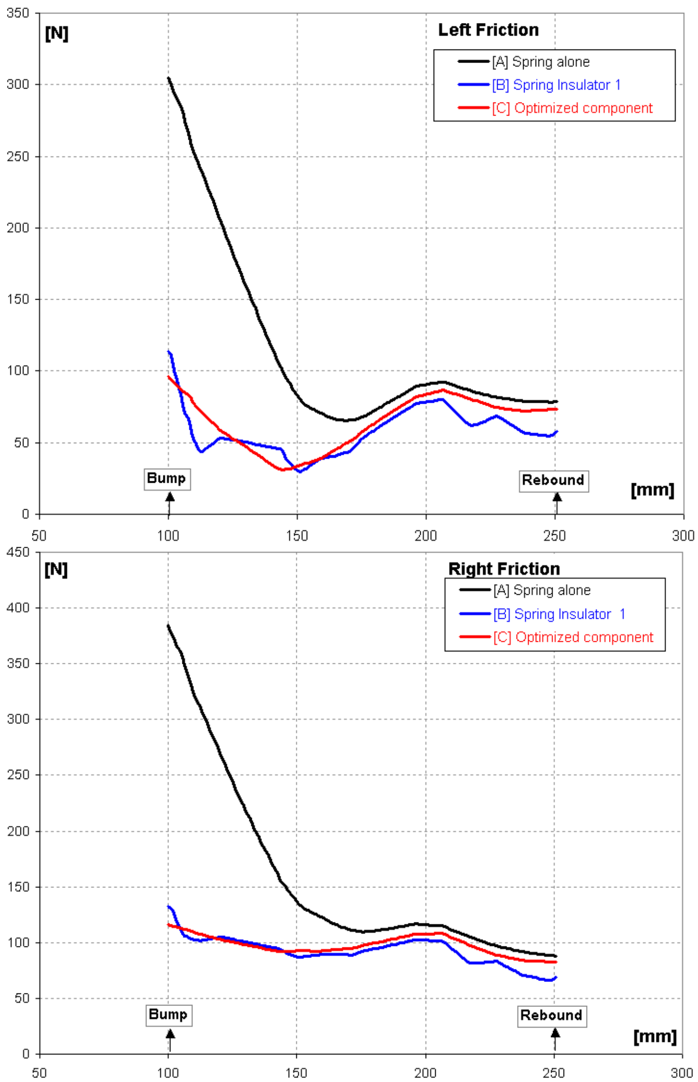


Fig-9 : Evolution du Frottement Gauche et Droit

We can draw the same conclusions with regard to drift which represents the difference in the load in the left and right hand steering rods (Fig-10).

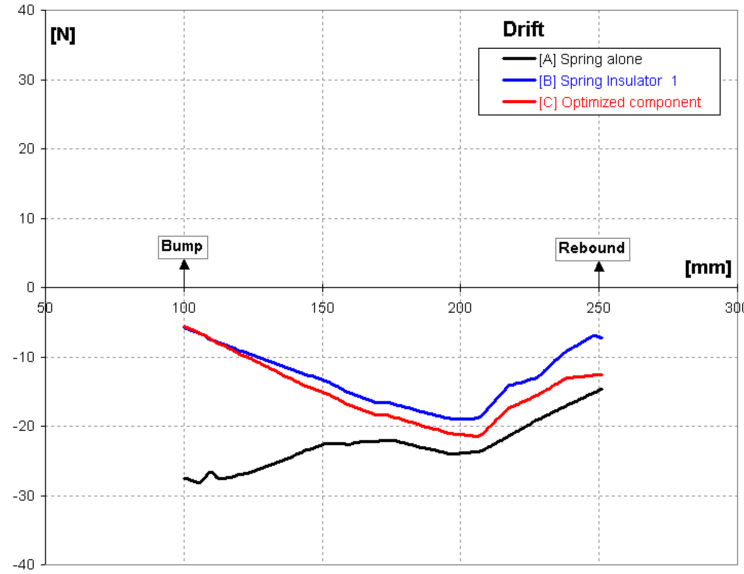


Fig-10: Drift curves

These results are confirmed by an analysis of the action line (centre of pressure) (Fig-11).

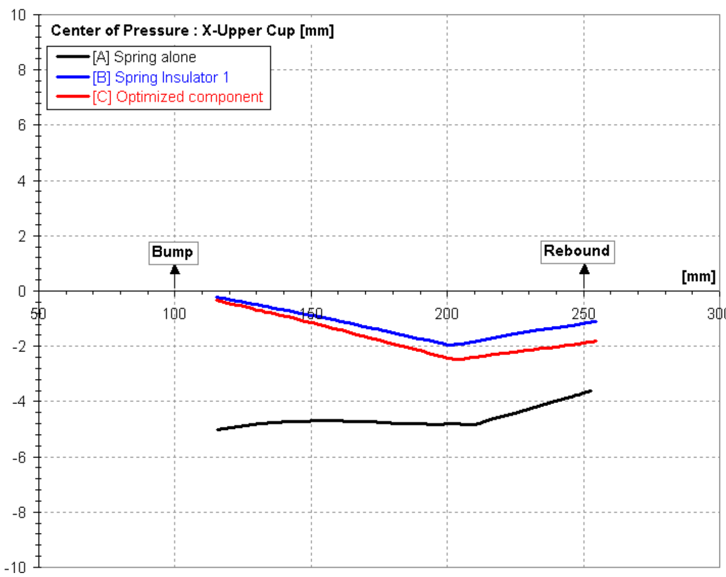


Fig-11Action line curves: (Center of Pressure Upper Cup)

This can be explained by the fact that the rubber insulators distribute the contact pressure more evenly.

Examination of the above results shows that use of a double thickness insulator (C) which provides better insulation (cf. Fig-5 and Fig-6) has no effect on steering compared to version (B).

Validation

The validation tests were conducted following a procedure to ensure repeatability of the measurement on a set of samples.

Figures 12 illustrate the correlation between the test and the design calculation in the case of the double insulator.

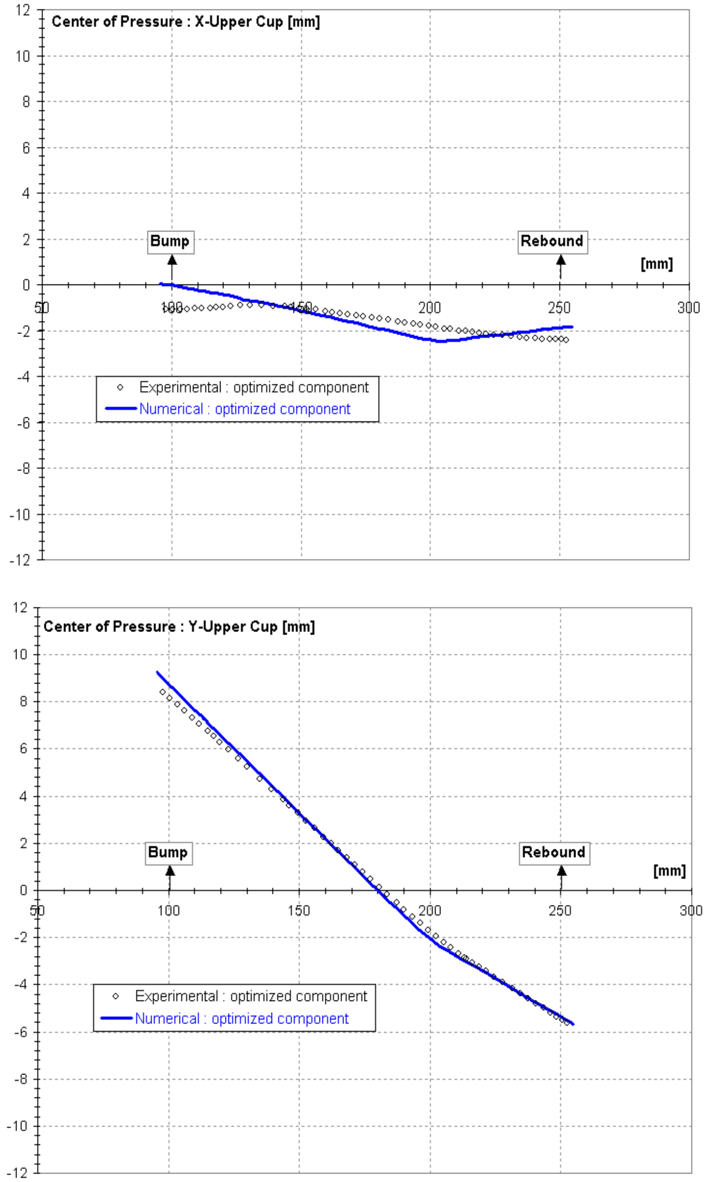


Fig-12: Action line test/calculation correlation (X & Y Upper Cup)

CONCLUSION

This partnership has entailed the creation of specific design tools correlated with physical measurements.

The results obtained underline the importance of integrating the rubber insulator for optimal spring performance with regard to road-holding qualities and low frequency vibration comfort, while filtering the spring modes such as friction and drift in particular in the case of the MacPherson suspension.

This study therefore has opened the way for CF-Gomma and Allevard Rejna to propose optimal solutions in terms of vibration comfort and endurance which apparently are not detrimental nor in opposition with steering functions.

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