Advantages of the modelling and simulation

Multi Body Simulation inside FEA
Application to different vehicle components

1 Introduction

Numerical simulation becomes more and more important in the vehicle development process. It is then crucial to have high accuracy of results in order to obtain good predictions and reduce prototyping costs.

Multi Body Simulation (MBS) is nowadays considered as an acceptable tool to develop concepts for vehicles suspensions, steering wheel, powertrain parts or other components of vehicles. MBS models used for these applications include rigid components, kinematical joints and possibly Super-Elements. Using only rigid components in the model of a multi-body system has been proven to be too conservative and not reliable enough. Flexibility is an important contributor to the dynamics of the system and can consequently no longer be neglected.

2 The use of numerical simulation

2.1 Vehicle Dynamics

As mentioned above, MBS packages are representing most of the components of a vehicle suspension as purely rigid, or using equivalent linear stiffnesses. This can be enhanced to create better models that will produce results that are closer to reality.

Properly taking into account flexibility of some components is of critical importance when modelling complex suspension/steering systems. Bushings that isolate the chassis from external disturbance, for instance, feature a locally nonlinear behaviour due to the material it is made of. The rear suspension beam can also be the source of nonlinear deformation. Classical MBS software does not have the capability to represent such structural non linearity. Using Super Elements can initially be seen as a good solution to include flexibility. This approach shows however important limitations such as the assumption of linearity and the limited frequency range in which it gives proper results. Super Elements are therefore not sufficient in a lot of cases: contact (pothole or curb strike), pre-stresses (assembly), friction (steering or suspension), nonlinear material behaviours (bushings), nonlinear geometric behaviours (rear beam suspension) or complex interaction with control systems (ABS system on a bumpy road).

This creates the need for an advanced solution procedure complementary to pre-existing methods. This new solution must be able to take into account the current modelling approach but also all these nonlinear phenomena previously described. This new solution must also be easy to use and capable of providing a reliable solution in a reasonable computation time.

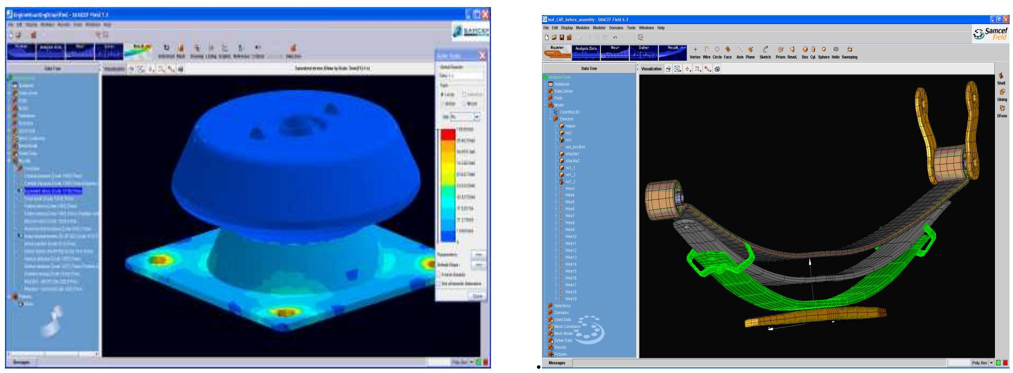


Figure 1: Bushing and leaf spring examples having large deformation to take into account

Models presented here are linked to an original car called **Imperia GP.** This car is equipped with a hybrid engine and is developed by the Belgian company Green Propulsion. Those models were built using SAMCEF Mecano. These models are typically derived from a Master Model based on MBS simulation only and then improved with super elements and eventually local nonlinear parts. Once tuned, the models can then be used to simulate more complex manoeuvres and to design the components. Some results are given on Figure 2.

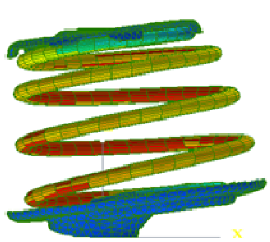
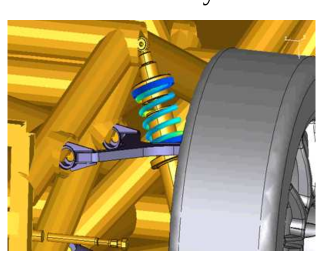
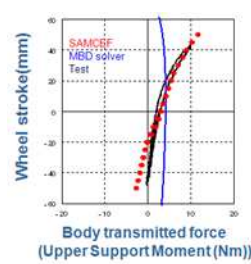
Local analysis	Global analysis	Global results
		

Figure 2: Meshed spring included and comparison with classical MBS (Green Propulsion)

2.2 Powertrain parts

The term **powertrain** refers to the group of components that generate power and deliver it to the road surface, water, or air. This includes the engine, transmission, drive shafts, differentials, and the final drive.

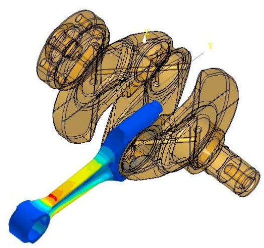


Figure 3: Meshed connecting rod inside a rigidly modelled engine

Competitiveness drives companies to engineer and produce powertrain systems that over time are less expensive to produce, with higher product quality and reliability, higher performance and longer in life expectancy.

The purpose of developing an MBS approach based on Finite Elements ("Motion in FEA") is clearly linked to the generality of the solution procedure, the fidelity of the model and therefore to the accuracy of the results.

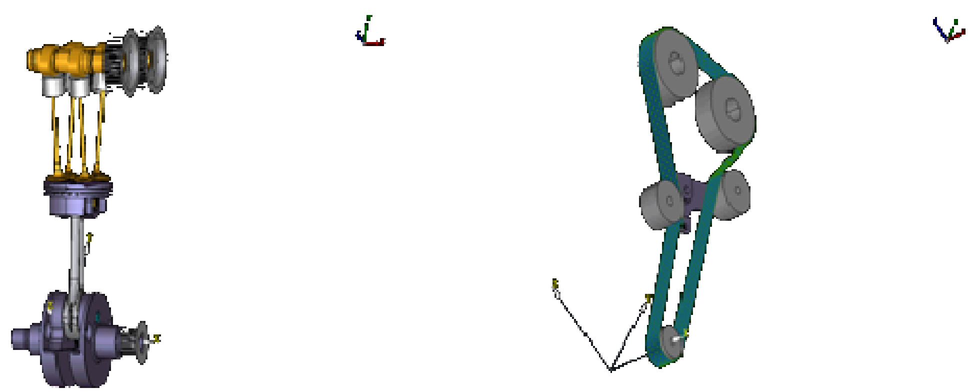


Figure 4: Transmission from flexible belt taken into account in MBS (Evolve Powertrains)

The advantages of this approach will be shown on different components of the powertrain like the engine, the differential and the clutch.

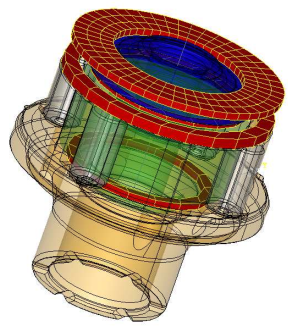


Figure 5: Differential managing gears system and contacts with variation of friction (JTEKT Torsen)

2.3 Other components

For other automotive applications, the MBS approach based on Finite Elements ("Motion in FEA") is also clearly adding value to the fidelity of the model, therefore to the accuracy of the results. Their importance in the global design process is obviously increased. Let's show an air conditioned as an example.

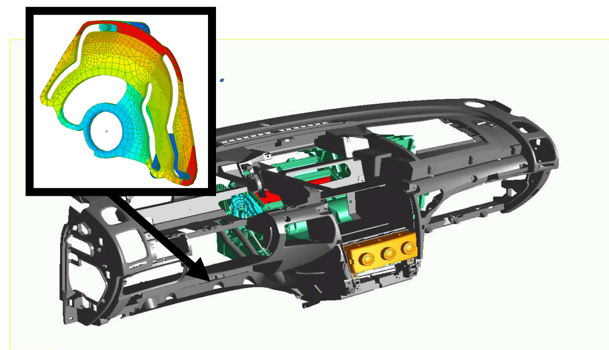


Figure 6: Cam system (DELPHI)

Air conditioning systems are designed to allow the driver and or passengers to feel more comfortable during uncomfortably warm, humid, or hot trips in a vehicle. It is tuning directly by the driver through system including the lever acting on a cam. The idea is to make sure that the force or torque to be applied by the vehicle driver on the lever has to be constant and acceptable from one end to the other. The path along which the pins move in the cam are optimized to minimize the stresses due to extra contact pressure and friction at some given points. It's very important to make analysis using FEM to be able to observe the variation of stresses in the different holes of the cam.

Figure 7: Air ventilation mechanism (DENSO)

A scroll compressor is a device for compressing air or refrigerant. It is used in air conditioning equipment, as an automobile supercharger and as a vacuum pump. These devices are known for operating more smoothly, quietly, and reliably than conventional compressors in some applications but need to be able to manage large deformations, large rotations and large displacements for simulations.

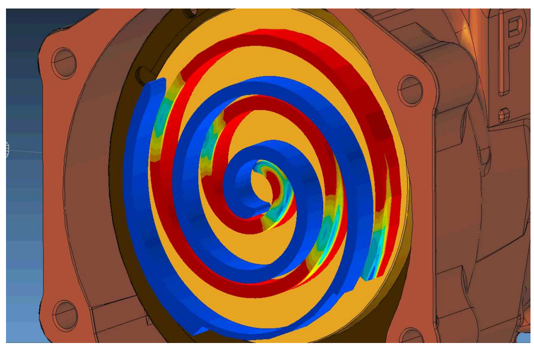


Figure 8: Scroll compressor (DENSO)

3 Conclusion

In the last few years, vehicle manufacturers have been trying to reduce the 'time to market' as well as the development cost mainly through a reduction of the number of prototype's cycles. Advanced modelling and simulation tools are for sure one of the tools to achieve that goal.It is then crucial to have high accuracy of results allowing to have good prediction and to reduce costs of prototyping. For several cases, this accuracy will be reached only if using the MBS approach based on Finite Elements.

During the presentation, the advantages of using the "Motion in FEA" for transport simulation are demonstrated using relevant vehicle examples. The "Motion in FEA" approach describes all the nonlinear effects present in the vehicle in a physical way and not with an empirical approach.

With respect to the engineering process efficiency, the “Motion in FEA” model also eliminates unnecessary iterations when merging local separate mechanical models as the MBS capabilities are embedded within the FEA environment.

4 Some References

HYUNDAI TOYOTA PSA PEUGEOT CITROËN BMW RENAULT

DAIMLERCHRYSLER *DENSO* TATA Daewoo PORSCHE