Vehicle Dynamic Simulation Using A Non-Linear Finite Element Simulation Program (LS-DYNA)

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INTRODUCTION

The reason manufacturers invest their time and money in order to improve the performance of dynamic characteristics, fatigue stiffness, NVH and crash safety during the process of vehicle development is directly linked to their competitiveness. Due to the rapid development of the computer CPU and application software, it is possible to perform dynamics analysis and durability design using CAE tools before making a prototype vehicle to reduced time and money in testing and developing a vehicle. In this paper, we create a united CAE environment by (1) developing the virtual proving ground approach that can produce every output needed using only one model, one analysis program, and one process. (2) The means in which we can dramatically reduce the time and individuals involved in constructing the model that will be used to perform the analysis such as vehicle dynamic analysis, quasi-static stress analysis and fatigue analysis. (3) The analysis technique which is able to perform a vehicle dynamics analysis using the same dynamic stress analysis model which will improve the virtual proving ground approach in its accuracy. Figure 1 shows the flow chart of analysis using the virtual proving ground approach.

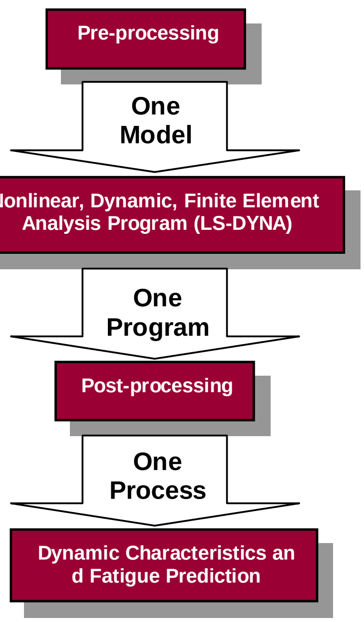


Figure 1. The Routine for Vehicle Dynamic and Fatigue Strength Evaluations Using VPG Approach

APPROACH

Distinctions from previous analysis approach

In the analysis vehicle, the front suspension system is double wishbone type and the rear suspension system is an axle suspension type having four independent links. We choose the simulation type as follows:

First, the vehicle moves forward and then changes lanes from left to right at the spot where the distance from the start line is 30m with a speed of 80km/h. This simulation type is used to predict the dynamic response characteristics such as lateral displacement, lateral acceleration, roll angle, yaw angle, roll rate, and yaw rate at the point of the vehicle's mass center of gravity while it is changing the lane from left to right. Until now, vehicle dynamic analysis using a multi-body dynamic analysis program have had many difficulties in using finite element models which were constructed for stress, NVH, and crash analysis. Recently, flexible multi-body dynamic analysis has been introduced that can assign flexibility for each part through the exchanges of data between the multi-body dynamics analysis program and the finite element program. Prior to this development, both were treated as a rigid body, but calculations still have to be performed in a separate program for both finite element model and dynamics analysis model. Therefore, there exist two different mathematical models that have different characteristics. As it is shown in Figure 2, the previous way of performing the analysis made it impossible to perform an analysis using the same software for vehicle dynamics and quasi-static stress analysis. The cost and time consumed for the data interface between two different software programs was very high.

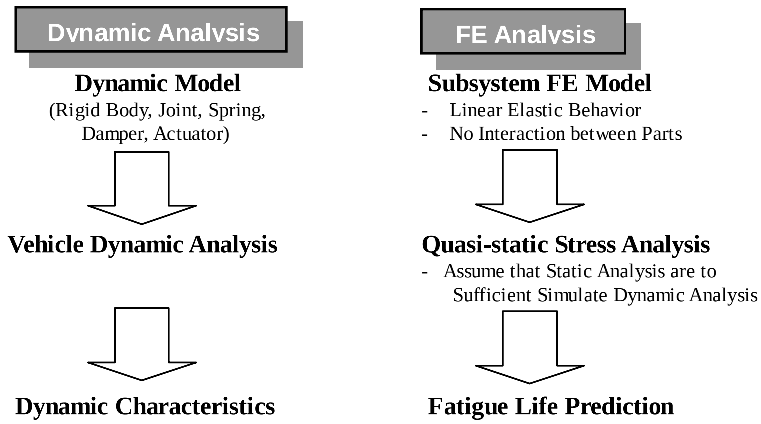


Figure 2. Current Methods and Assumptions

In the virtual proving ground analysis approach, one can perform the analysis at the same time for both dynamics analysis and stress analysis, which can lead to cost reduction in the analysis. Figure 3 is a flow chart consisting of the basic concepts in the virtual proving ground analysis approach.

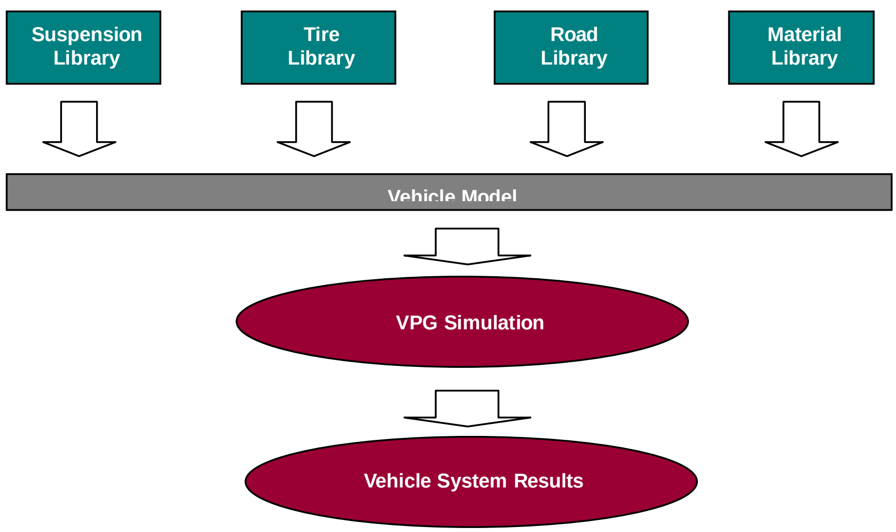


Figure 3. The VPG Concept

Vehicle dynamics analysis model
The target vehicle will be a jeep type passenger vehicle with a frame included. To reduce the computation time, all other parts except the tires and frame are assumed to be rigid bodies. The tires attached to the wheel rim are rotating, absorbing impact energy from the ground and creating friction to enable the vehicle to drive, steer, and brake. In this paper, we used thin shell and solid elements to make a much more realistic tire. For the suspension system, joints, springs, dampers and actuators have been modeled the same way as in dynamics analysis using general dynamics analysis programs such as DADS or ADAMS. Figure 4 shows the front and rear suspension systems, as well as the tire FE model. Rubber characteristics have been considered in the tire and the links in the axle and suspension system have been modeled as rigid beams. Figure 5 shows the entire model.

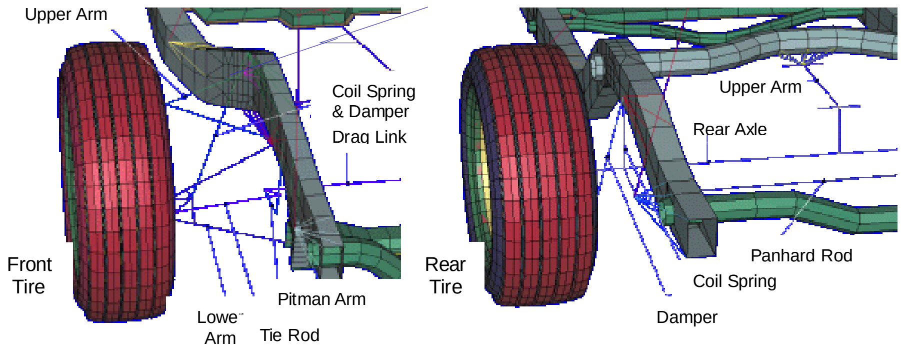


Figure 4. Tire and Suspension Model

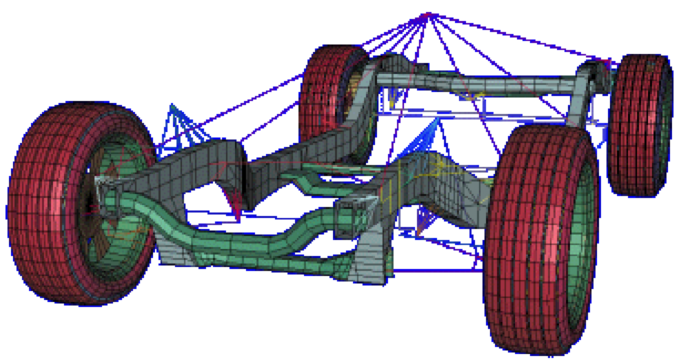


Figure 5. 80km/h Lane Change Simulation Model

Simulation for changing lane at 80km/h
Simulation has assumed the situation as follows:

The vehicle, having a velocity of 80km/h, is driving on a flat paved road with a couple of rubber cones lying on the road at a distance of 30m each. The vehicle changes lanes in the rubber cones.

It was assumed that vehicle has the maximum amount of passengers and tire pressure was given as a standard value of a target vehicle with a dry road condition. The steering angle, which is the most important parameter, was not given directly to the steering wheel. The angle was inputted to the gearbox and then transferred to the knuckle to steer the wheel. In other words, from the steering wheel to the gearbox input part were omitted for convenience sake. Figure 6 shows the output vehicle path through 80km/h changing-lane analysis using virtual proving ground analysis.

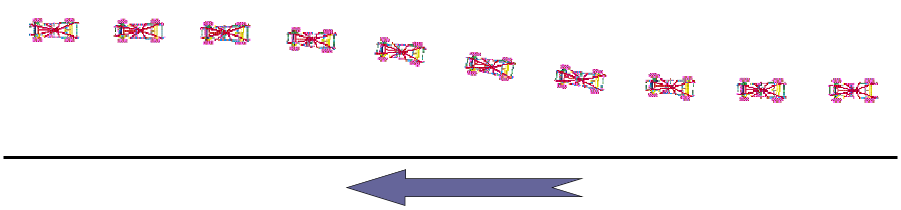


Figure 6. 80 km/h Lane Change Simulation

Figures 7~14 shows the lateral displacements, lateral acceleration, roll angle, yaw angle, roll rate, yaw rate, and wheel center from the C of G of the vehicle. In all figures, lane change occurred at 1sec and we did not present the result before 1sec.

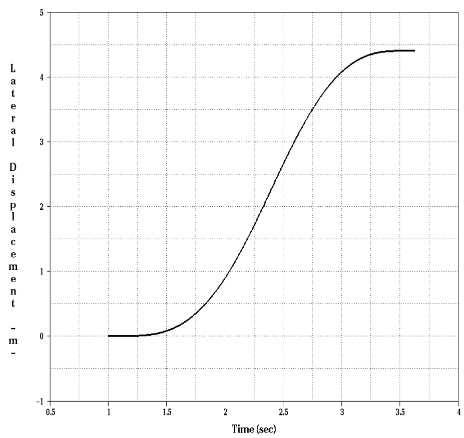


Figure 7. Lateral Displacement

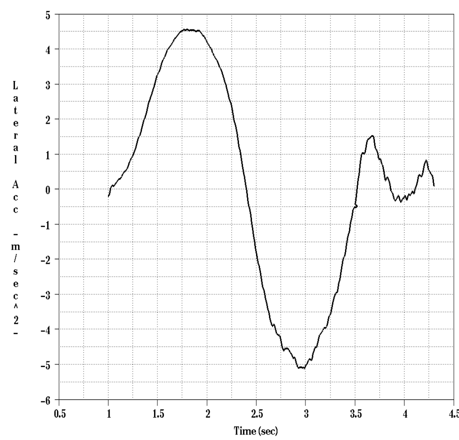


Figure 8. Lateral Acceleration

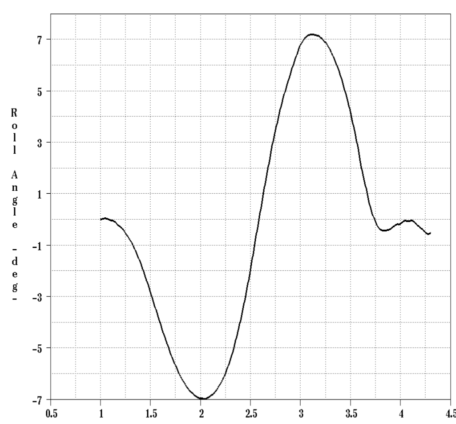


Figure 9. Roll Angle

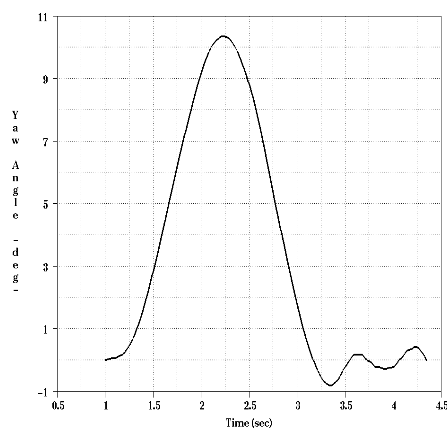


Figure 10. Yaw Angle

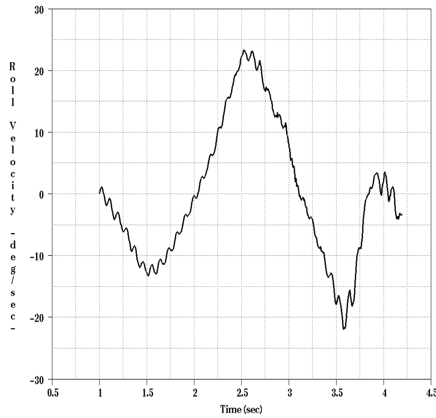


Figure 11. Roll Rate

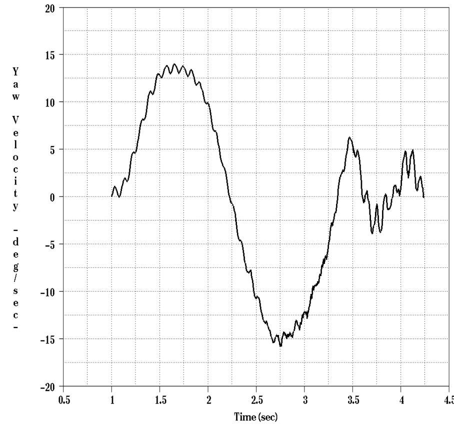


Figure 12. Yaw Rate

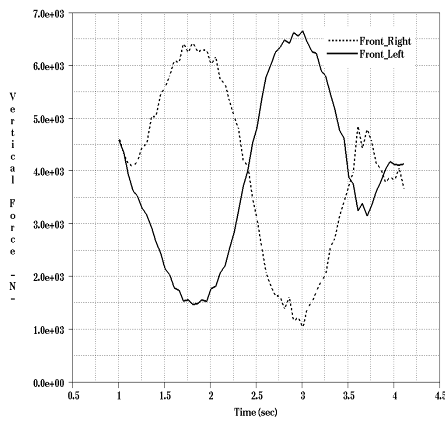


Figure 13. Wheel Center Load History (FRT)

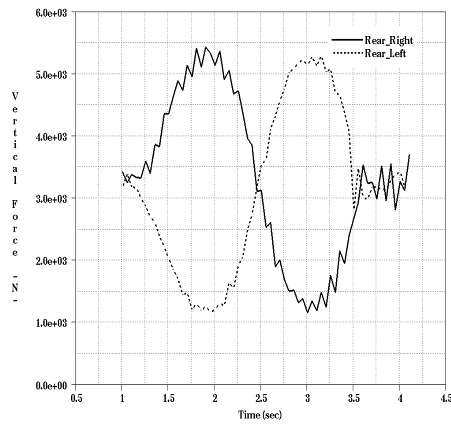


Figure 14. Wheel Center History (RR)

DISCUSSION OF RESULTS

Comparison between analysis and test

The results show that the dynamic response characteristics from the CG of the vehicle while changing lanes at a speed of 80km/h was similar in its trend and magnitude with no large significance. To verify the analysis results, we tested the same vehicle with the same conditions as the target analysis vehicle. Figures 15~18 show the comparison between test and analysis (lateral acceleration, roll angle, roll rate, yaw rate, etc…) There is some significance in the roll rate compared to the other results. It seems that the paved road test performed was not flat so the vehicle initially had some inclination and started changing lanes then ended up with not difference. In the figure of roll rate and yaw rate comparison, time interval difference in data recording made the analysis result look more irregular than the test result. If the time interval in the test was the same, as in analysis, the test curve would result in the irregular pattern much the same as in the analysis curve.

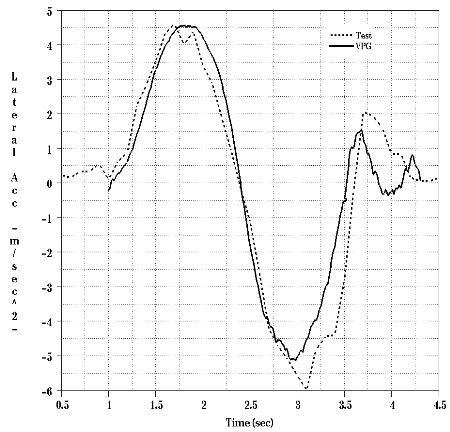


Figure 15. Lateral Acceleration

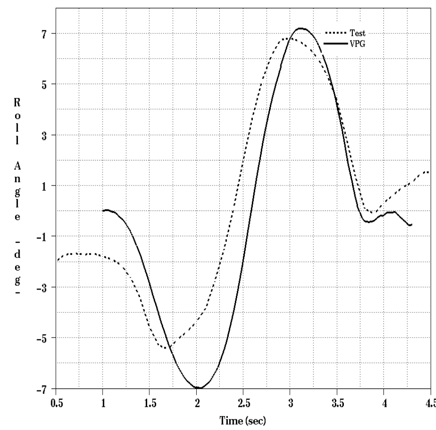


Figure 16. Roll Angle

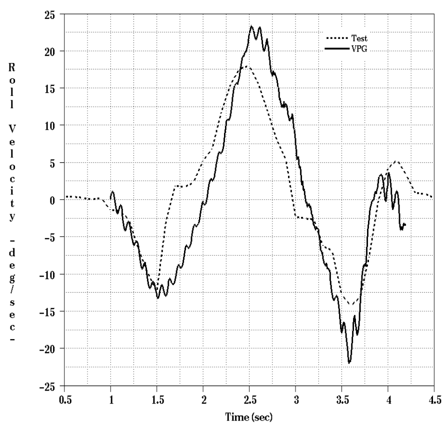


Figure 17. Roll Rate

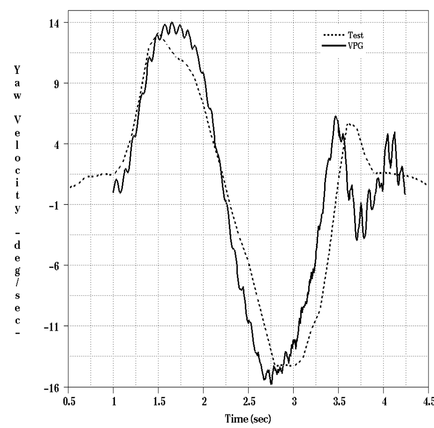
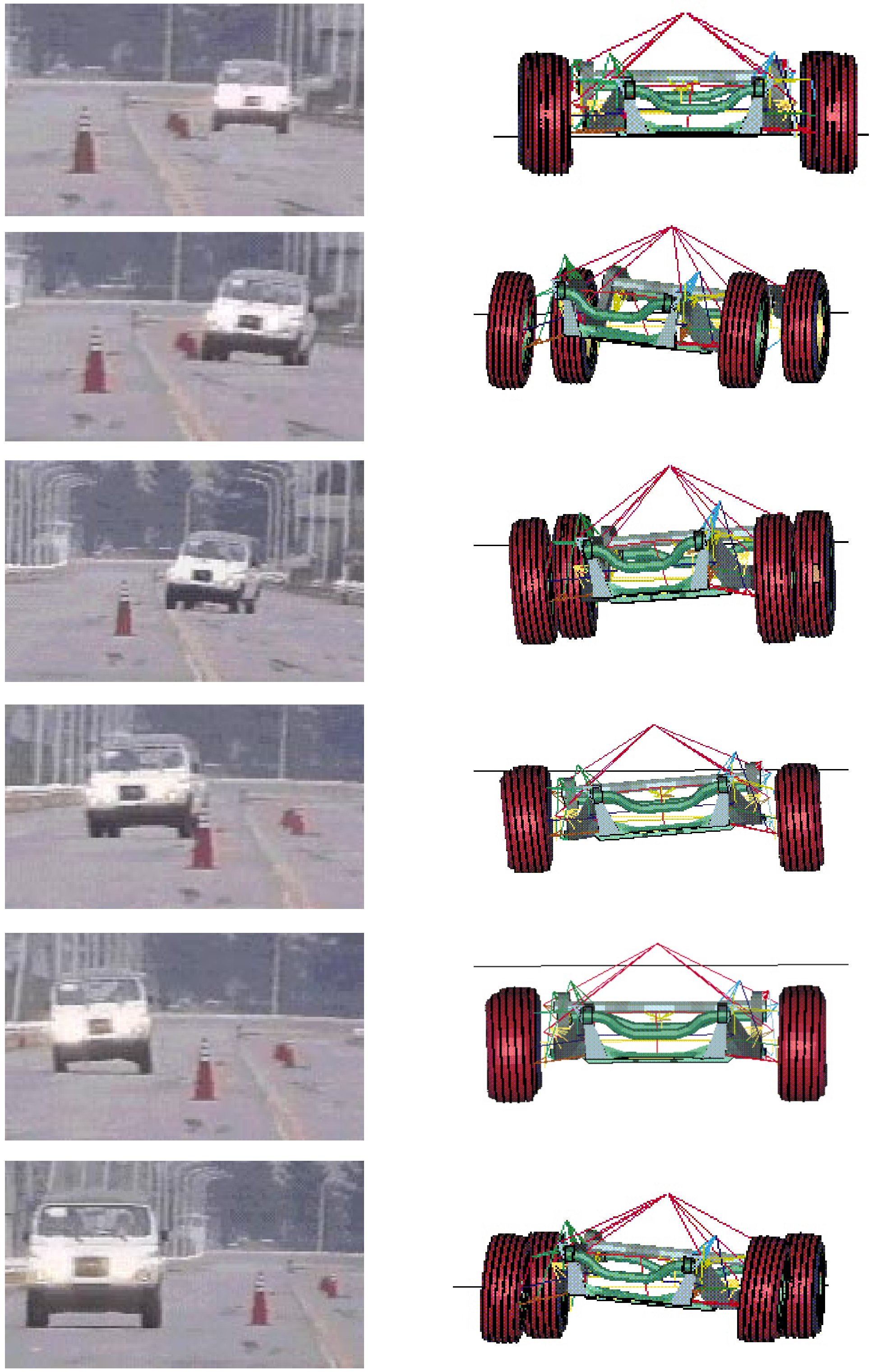


Figure 18. Yaw Rate

Figure 19 shows the comparison of front view of the test and analysis while it is changing lanes. It also shows the similar movement between the test and analysis vehicle.



(a) Test (b) VPG Analysis

Figure 19. Comparison of Vehicle Motion between Test and Analysis

CONCLUSIONS

This study was performed to build a united CAE environment that would give us every output result to evaluate vehicle performance. Using the VPG approach to generate real road driving conditions, the outputs resulted from using only one analysis model and one application software from crash analysis to vehicle dynamics and fatigue analysis.

(1) We developed a virtual proving ground approach which could save money and reduce the number of individuals involved compared with previous dynamics analysis techniques.
(2) Due to the benefit of being able to use the crash analysis FE model, we could save the modeling time by up to 90%.
(3) We provided the base that one could do CAE analysis if it was needed in the middle of vehicle development under the united environment.
(4) Proposed VPG analysis approach in this paper can be utilized not only in the crash, vehicle dynamics and fatigue analysis, but also in the link analysis of the suspension system.