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Virtual Prototype: A New Concept in the Development of Mechanical Projects

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ABSTRACT

The present work carries out static and kinematical studies of front suspensions of a Brazilian medium sized passenger car. The concept of virtual prototyping with the use of multibody system modelling techniques is employed by ADAMS, a package developed by Mechanical Dynamics Inc.. The concept of virtual prototyping allows vehicle development without the need of physical prototype construction. ADAMS uses the description of the geometric suspension, inertia parameters from its parts and how the parts are connected to generate a full model of the system. The type of analysis which can carry out include vertical and steering behaviour (in the case of a front suspension). These analysis are generated in graphical as well as an animation. The results include among others: toe-in angle, camber and caster angle, ride rate, and so forth. The use of the virtual prototyping concept, has made easier the modelling and analysis of this type of mechanism. This indicates the possibility of shortening product development time or altering product behaviour with a small effort.

INTRODUCTION

Amongst new concepts in engineering, Simultaneous Engineering has been one of the most that has been causing larger impact in terms of improvement of quality, reduction of costs and increase of productivity in the design of new products.

One of the pillars that has been facilitating this success is the significant reduction in development time and cost of products through computational simulation. Those techniques facilitate to evaluate the final product in its various different aspects, such as:

- mechanical properties;

- design of the product;

- kinematic and dynamic properties;

- ergonometrics;

- ease of assembly ,etc.

Those evaluations are accomplished without the need of a physical prototype, may be simulated in computer.

These simulations may be made by compatible tools with the desired capability, obtaining in this a way virtual prototype of the product.

Through these tools it is possible to introduce and to test modifications very quickly in the prototype and at reduced cost, resulting this way in a project near the desired one.

MULTIBODY SYSTEM (MBS) - A multibody system is defined as a system with several degrees of freedom. The movement of a MBS is governed by dynamic equations of movement that are composed of differential and algebric equations. The differential equations are expressions of classic physical laws of the movement (laws of Newton) that describe the movement of the rigid bodies and the algebraic equations take into account the restrictions of the geometry of the system or of its movement, such as bars connecting adjacent bodies or characteristics of the contact among the bodies.

Modelling technique with MBS can be used for the analysis and the study of projects of any mechanical system that it can be modeled as a series of rigid bodies interconnected by joints, under the influence of forces, with pre certain movements and limited by joints. The equations of the movement of those systems are very difficult to generate by hand, even for systems composed of a small number of rigid bodies. The equations of the motion for a MBS can be generated through programs in that the data of the rigid bodies (geometric data and inertial properties) and of its interconetions (joints and laws of force) they are given as arguments for the program.

ADAMS - MBS PROGRAM - ADAMS (Automatic Dynamics Analysis of Mechanical Systems) it is a program that was developed to generate the analysis and projects of multibody systems.

The construction process and analysis of virtual prototypes involves three different phases (figure 1): preprocessing, solution of the equations, postprocessing.

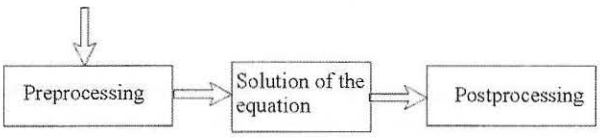

Figure 1 - Construction process of virtual prototping

1 - Preprocessing - Phase in which it is defined the topology of the multibody system that is, how many rigid bodies compose the system, how are them interconnected to each other and which are the type of these interconnections. The inertial parameters (mass, moment of inertia) should also be supplied.

In this phase it can be associated a geometry to the elements of the multibody system, in such a way that it has the appearance of the real physical system. For this reason, ADAMS has resources of edition of CAD (ADAMS-View) or it can import drawings in iges or step format from another CAD programs.

2 - Solution of the equations - Starting from the definition of the system showed in the first phase, the solution of the equations of the movement is generated and supply the necessary data for the next phase, the postprocessing.

3 - Postprocessing - With daa obtained from phase 2 it is possible to visualize the simulation results of the system.

Wiht the information supplied by the simulation you have:

- characteristics of perfomance of the system;

- output of the system in operation conditions.

With the results of the simulation, project parameters can be adjusted to increase the perfomance of the system.

MODEL DEVELOPMENT

The preprocessor ADAMS/Vehicle possesses a menu and a program base that serves for the creation and modification of ADAMS vehicle suspension models.

The models built in the preprocessor ADAMS/Vehicle are used for the analyses of the statics and vertical kinematics and in the study of the steer system of the suspension.

FRONT SUSPENSION - The front suspension of this vehicle is a McPherson Strut. The model generated in ADAMS/Vehicle is shown in the illustration 2.

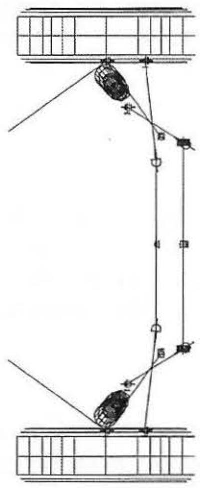

Figure 2 - Macpherson front suspension

TOPOLOGICAL MODEL – The front suspension topological model is shown in figure 3. In the topological model you can see the bodies and the joints.

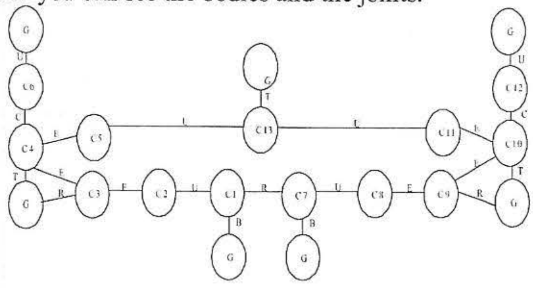

Figure 3 - Topological model

The table 1 shown the description of the bodies.

Table 1 - Body description

Description	Body
Left sta-bar half	C1
Left sta-bar link	C2
Left lower a-arm	C3
Left spindle	C4
Left tie rod	C5
Left strut rod	C6
Right sta-bar half	C7
Right sta-bar link	C8
Right lower a-arm	C9
Right spindle	C10
Right tie rod	C11
Right strut rod	C12
Steering rack	C13

Table 2 shown the description of the joints

Table 2 - Joint description

Description	Joint
Universal	U
Cilindrical	C
Sferical	E
Translational	T
Revolution	R
Bushing	B

RIDE ANALYSIS

For the analysis of the suspension behavior in the ride analysis, the results of the variation of the camber angle, toe angle and ride rate of the suspension were generated, as function of wheel center vertical travel.

Camber angle is defined by ISO 8855 and DIN 7000 standard as the inclination angle of the wheel plane in relation to the vertical measured in the front view. It is shown in figure 4.

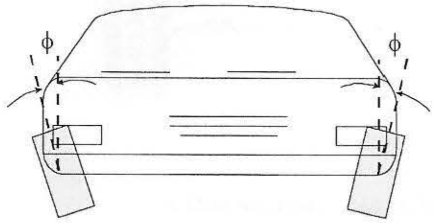

Figure 4 - Camber angle

Toe angle is also defined by ISO 8855 and DIN 7000 standard as the angle between the central plane of the vehicle in the longitudinal direction and the line of intersection of the wheel plane with the road plane.

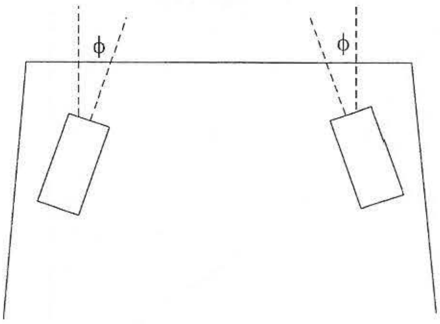

Figure 5 - Toe angle

The ride rate, given by the association in series of the stiffness of the suspension (considering its geometry) and the tire stiffness, is given by the equation:

Where:

RR = Ride rate.

Ks = Suspension stiffness.

Kt = Tire stiffness

In the analysis of the behavior of the suspension in the ride, the wheel center travel in the vertical direction is ∀ 80mm. The animation of the analysis in ADAMS/View can be visualized in the figure 6.

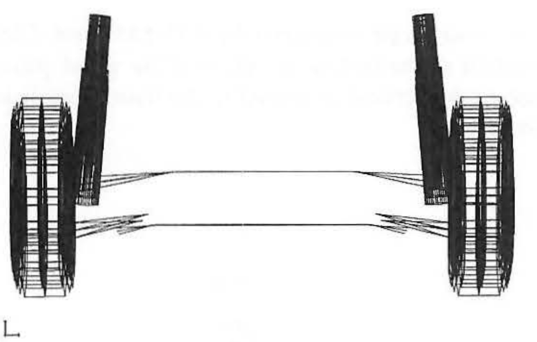

Figure 6 - Vertical displacement animation

The variation of the camber angle versus wheel center travel is shown in the figure 7. The variation of the camber angle of this vehicle is within the range of normal design values [2].

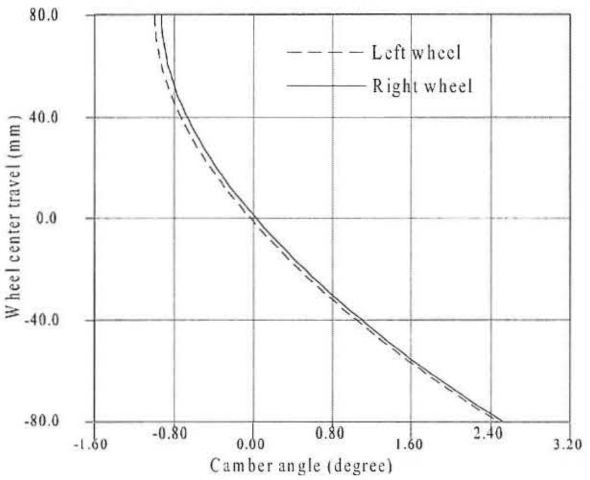

Figure 7 - Camberl angle x wheel center travel

Figure 8 exhibit the variation of toe angle. The variation is also within the range of usual design values.

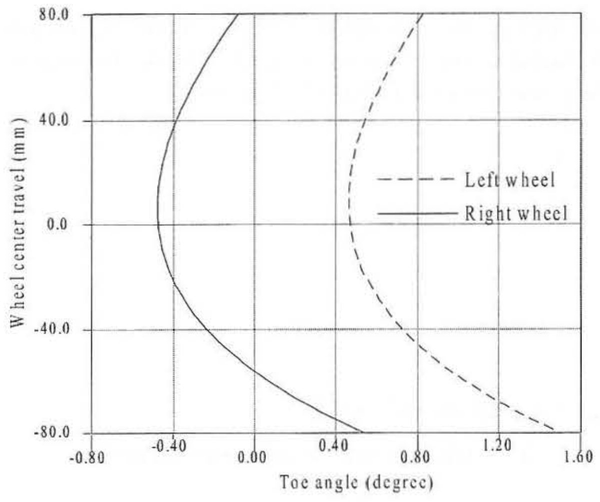

Figure 8 - Toe angle x wheel center travel

The variation of ride rate shown in the figure 9 demonstrates that the suspension possesses a progressive stiffness, that is, it increases with the displacement of the suspension in the vertical direction..

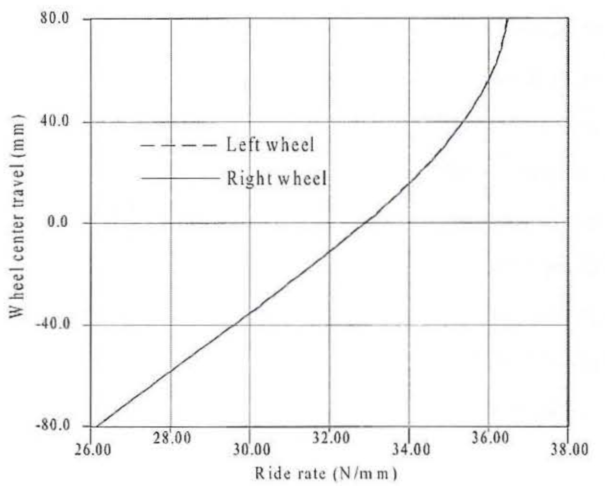

Figure 9 - Ride rate x wheel center travel

ROLL ANALYSIS

The roll center of the MacPherson suspension is shown in the figure 10.

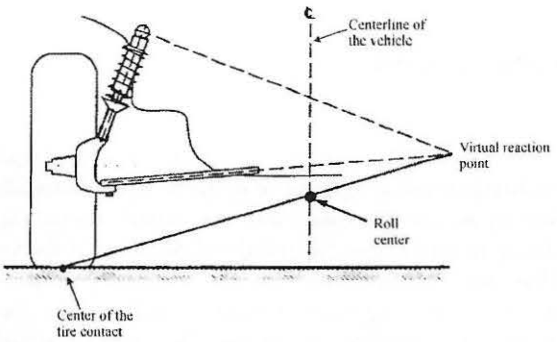

Figure 10 - Roll center of the MacPherson suspension.

The virtual reaction point must lie at the intersection of the axis of the lower control arm and a line perpendicular to the strut. The roll center is located at the centerline of the vehicle at the intersection with the line from the center of tire contact to the virtual reaction point.

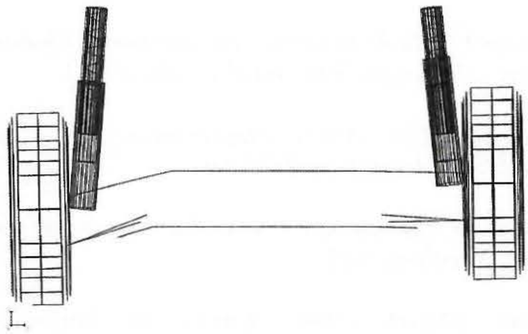

Figure 11 - Roll animation.

In the roll analysis, the graph of the variation of the roll center height as shown in the figure 12.

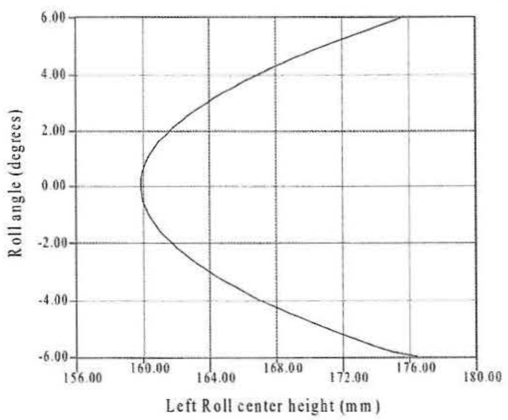

Figure 12 - Roll center height x roll angle.

STEER ANALYSIS

In an ideal steer geometry the wheels steer without slip. The arithmetic average of the steer angle the left and right wheels is known as Ackerman angle. The deviation of the steer angle in relation to the Ackerman angle is of great influence in the tire wear.

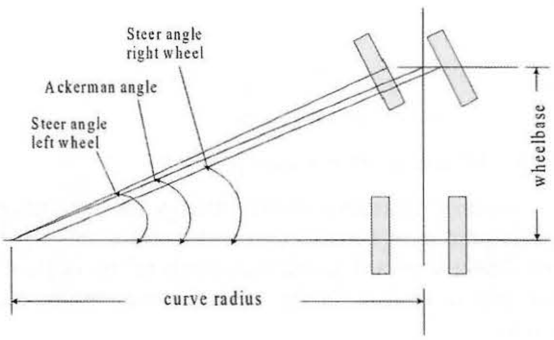

Figure 13 - Steer geometry

The figure below shows the animation of the steer analysis. In this analysis there was a variation of ∀50 mm in rack travel.

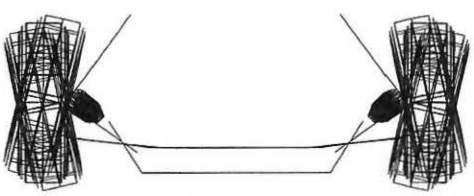

Figure 14 - Steer animation

The plot showing the deviation of the steer angle in relation to the Ackerman angle is shown in the figure 15. The maximum deviation is equal of 5 degrees, what is in the range of the normal values of this suspension.

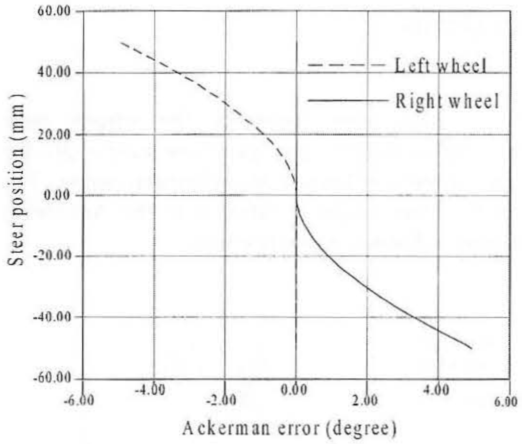

Figure 15 - Ackerman error x steer position

Another parameter is the variation of the caster angle during the steer. Caster angle is defined by ISO 8855 and DIN 70000 standard as the inclination of the angle of the steer axis in relation to the vertical, measured in the lateral view.

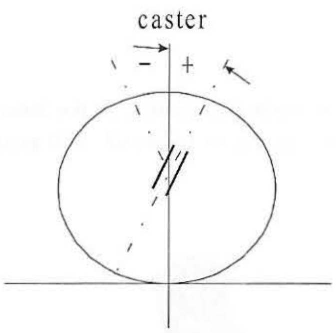

Figure 16 - Caster angle.

The plot of the variation of the caster angle is shown in the figure 17.

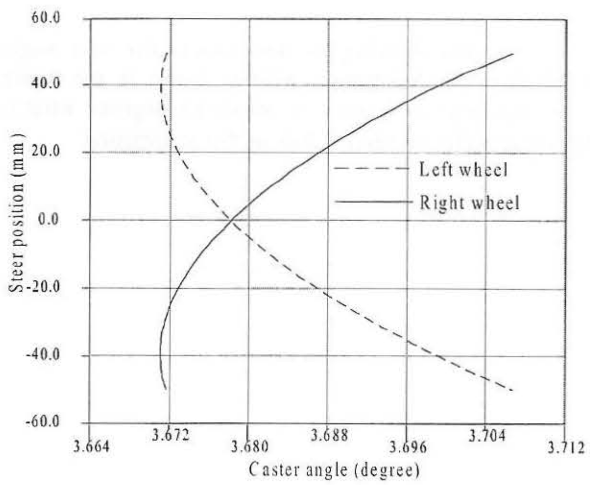

Figure 17 - Caster angle x steer position

CONCLUSIONS

The analysis using the concept of virtual prototype facilitates the development of projects. A lot of simulations had to be accomplished and the model altered for the closest to arrive possible of the real behavior of the system. That was accomplished in an extremely short time, allowing the diagnosis of defects and its fast location through the graphic simulation. The graphic simulation showed to be a very big aid to know the behavior of the suspension, because it is much easier to visualize the behavior of the suspension than to analyze numeric results.

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