ADAMS/View Powertrain Model

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Abstract

A system for defining a powertrain model is developed in ADAMS/View by Mechanical Dynamics Sweden. It is based on an ADAMS model developed by Ricardo Consulting Engineers for the Joint Research Committee. This model was originally designed for studying gear rattle but is currently used to study shunt and shuffle.

The system uses a complete handling model of a car, developed at Volvo Car, and adds a powertrain to that model. The powertrain model is created by simply specifying the numbers of cylinders of the engine, the number of gears and which predefined template to use. It is completely parameterized and the data of the components are changed either interactively with ADAMS/View menus and panels or by reading files from a database.

This model is used to study how different parameters influence the behavior of the car. This will reduce the need for building prototypes and performing expensive testing. It will also give us a deeper understanding of the phenomenon shunt and shuffle.

1.0 Introduction

The increasing demand for driving comfort has put some emphasis on the dynamics of the powertrain. In this context dynamic simulations can be of aid in several aspects:

- Possible sources of unwanted behavior of the system can be detected in early stages of the design process. This allows the designer to correct the design at an early stage and minimizes the need for expensive prototypes. It also makes the design process faster.
- Known problems can be analyzed and possible solutions can be tested in the simulation models. This leads to better solutions, faster treatment and minimizes the need for testing.
- Dynamic simulations lead to a better understanding of the behavior of the system. This knowledge can then be used in future designs to avoid possible problems.

The department of transmission design at Volvo Car found the need for a more general system for dynamic powertrain simulations. This led to the ADAMS/View Powertrain Model. It is developed by Mechanical Dynamics Sweden and is based on an ADAMS model developed by Ricardo Consulting Engineers for the Joint Research Committee.

Some areas of interest for the transmission department are:

- Shunt and shuffle, i.e., for and aft longitudinal oscillations of the car that might occur at transient changes of driver demand.
- Gear rattle.
- Clutch judder, i.e., vibrations that can occur when releasing the clutch at the start of the car.
- "Power hop", i.e., oscillation in the drivetrain, initiated by tire slip, at take-off of high powered front wheel driven vehicles.

Currently the model is used only to study shunt and shuffle but can, with minor modifications, be used to study some of the other areas.

2.0 Model Description

The ADAMS model of a complete car developed by Ricardo was developed for the study of gear rattle but could, of course, be modified for other studies as well. However, it was not at all parameterized and could not easily be modified to different types of cars. This led to the engagement of Mechanical Dynamics Sweden to make a fully parameterized system in ADAMS/View where arbitrary front wheel drive powertrains can be modelled.

The system uses a handling model of a car developed at Volvo Car. This model is presented in an other paper at this conference so it will not be described here. Starting with this handling model, the powertrain is created by simply describing the major topology of the powertrain, e.g. the number of cylinders of the engine, the number of gears, and a template file. Then the engine mounts are created with the aid of templates. The model can then be modified either by reading data from a component database or by modifying data with the aid of ADAMS/View menus and panels.

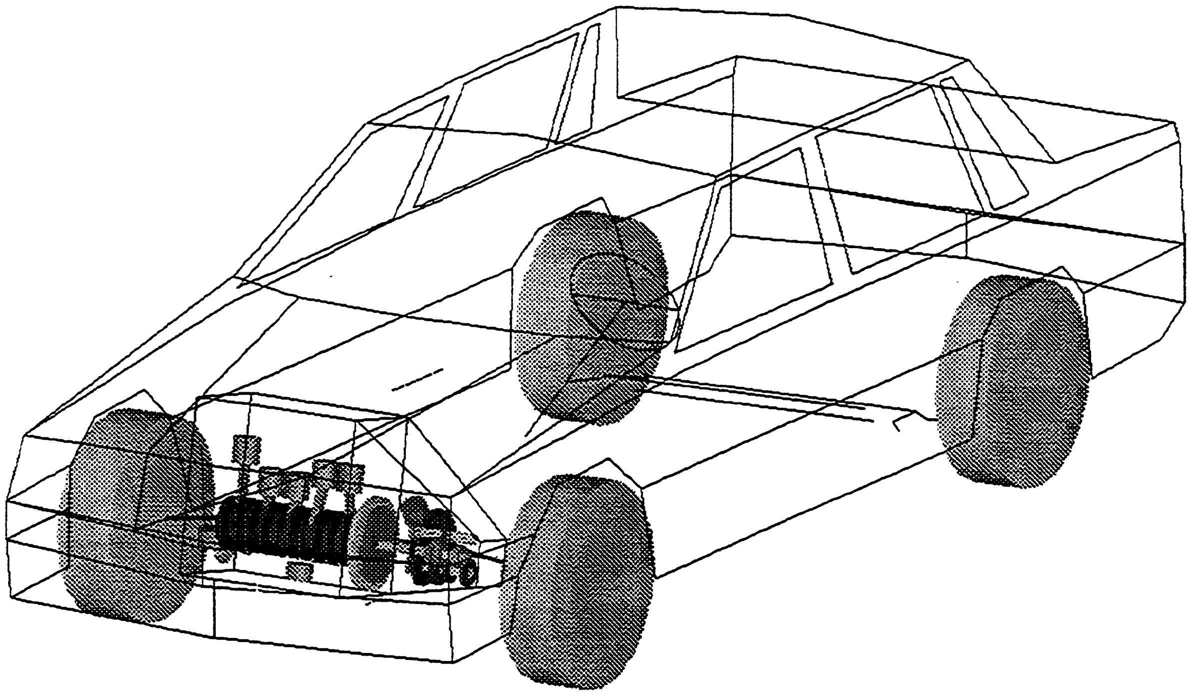

Figure 1. The graphical representation of the complete model

Some features of the model are:

- It is parameterized so it is easy to modify.
- Data can be received from and stored to a database.
- The engine can have up to nine cylinders.
- The gearbox can have five or six gears.
- The gearbox can have two or three (e.g. Volvo 850) shafts.
- The simulation can be started at any velocity.

2.1 Engine

The engine model is quite detailed. It contains pistons, connecting rods and crankshaft. It is driven by cylinder pressure measured at different engine speeds. This gives a good model of the variations of the engine torque which is important when studying gear rattle. In the shunt and shuffle study, however, this model might be unnecessarily comprehensive.

There also exist the possibility to use a theoretical model to calculate the cylinder pressure, but that model is currently not in use.

The crankshaft is modelled with a mass at each crank which are connected by spring dampers. The last crank is connected to the flywheel by a spring damper.

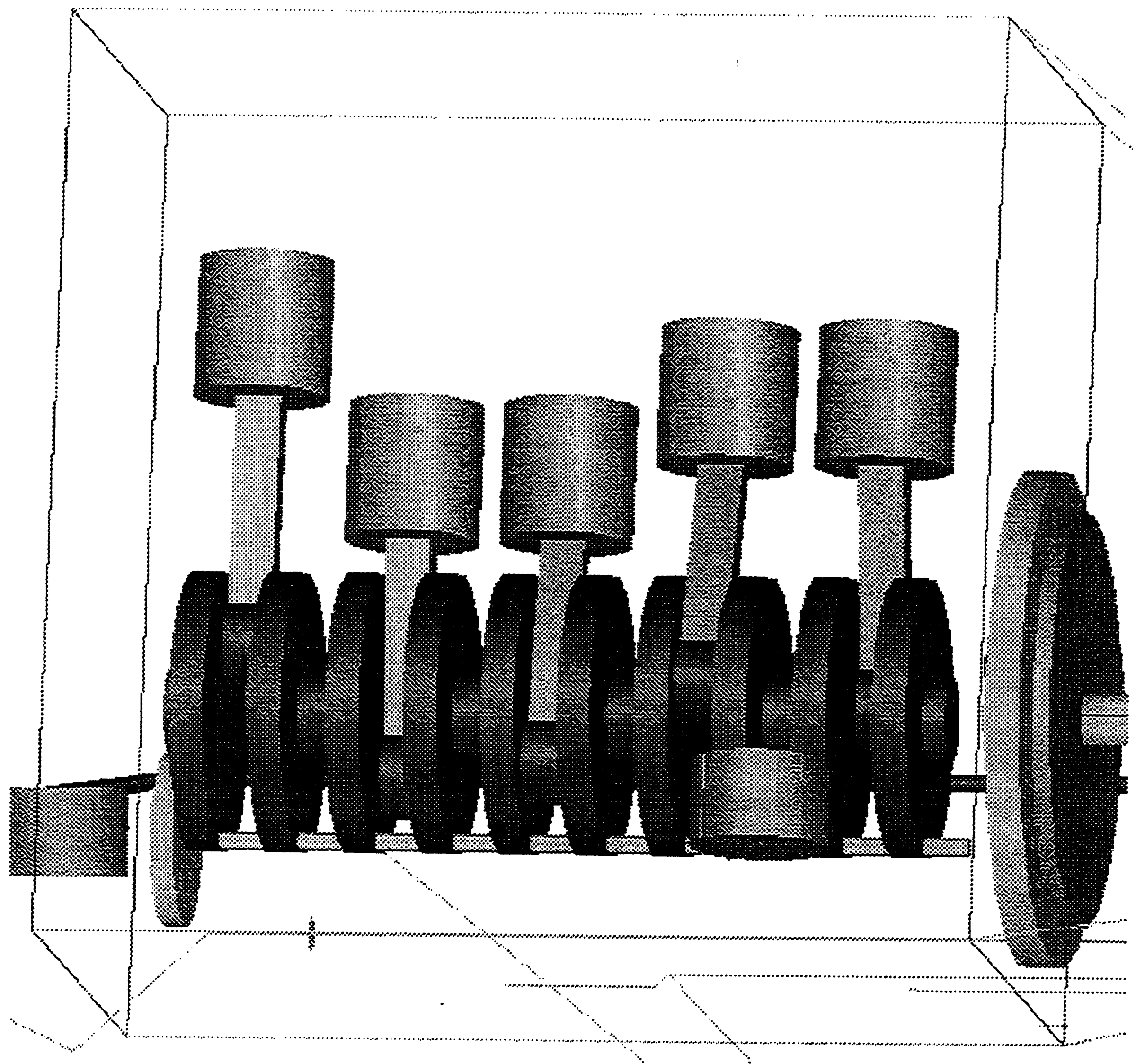

Figure 2. The graphical representation of the engine

2.2 Engine Suspension

The engine suspension can be modelled with two different components; torque rods and visco-elastic mountings. The torque rods consist of a spline for the non-linear axial stiffness and constant damping. The model of the visco-elastic mountings defines the response in both the axial and radial directions. It consists of a combination of splines for the non-linear stiffness and arrangements of springs and dampers. This makes it possible to tailor the response of each mounting to measured response. Originally this arrangement of springs and damper were modelled with separate springs and dampers connected by parts with negligible mass. This was rewritten to differential equations in order to avoid unnecessary high frequencies in the system.

2.3 Clutch

The clutch is modelled with two masses. The torsional stiffness of the clutch is defined by a spline since it is highly non-linear. The model also includes viscous and hysteretic damping. The hysteresis varies dependent on the torsion of the clutch.

2.4 Gearbox

The gearbox model consists of one input shaft, one or two output shafts, five or six gear mesh pairs, a final drive mesh and a differential. The gear meshes include backlash and linear stiffness and damping. The main gear meshes can be in three different states; synchronized to the input shaft, synchronized to the output shaft or engaged. Naturally only one gear at a time can be engaged. Which gear that is engaged can easily be changed between simulations, the engaged gear is marked with a different color in ADAMS/View. Bearing and churning drags are calculated for each gear. Both the gear forces and drag torques are calculated in Fortran subroutines.

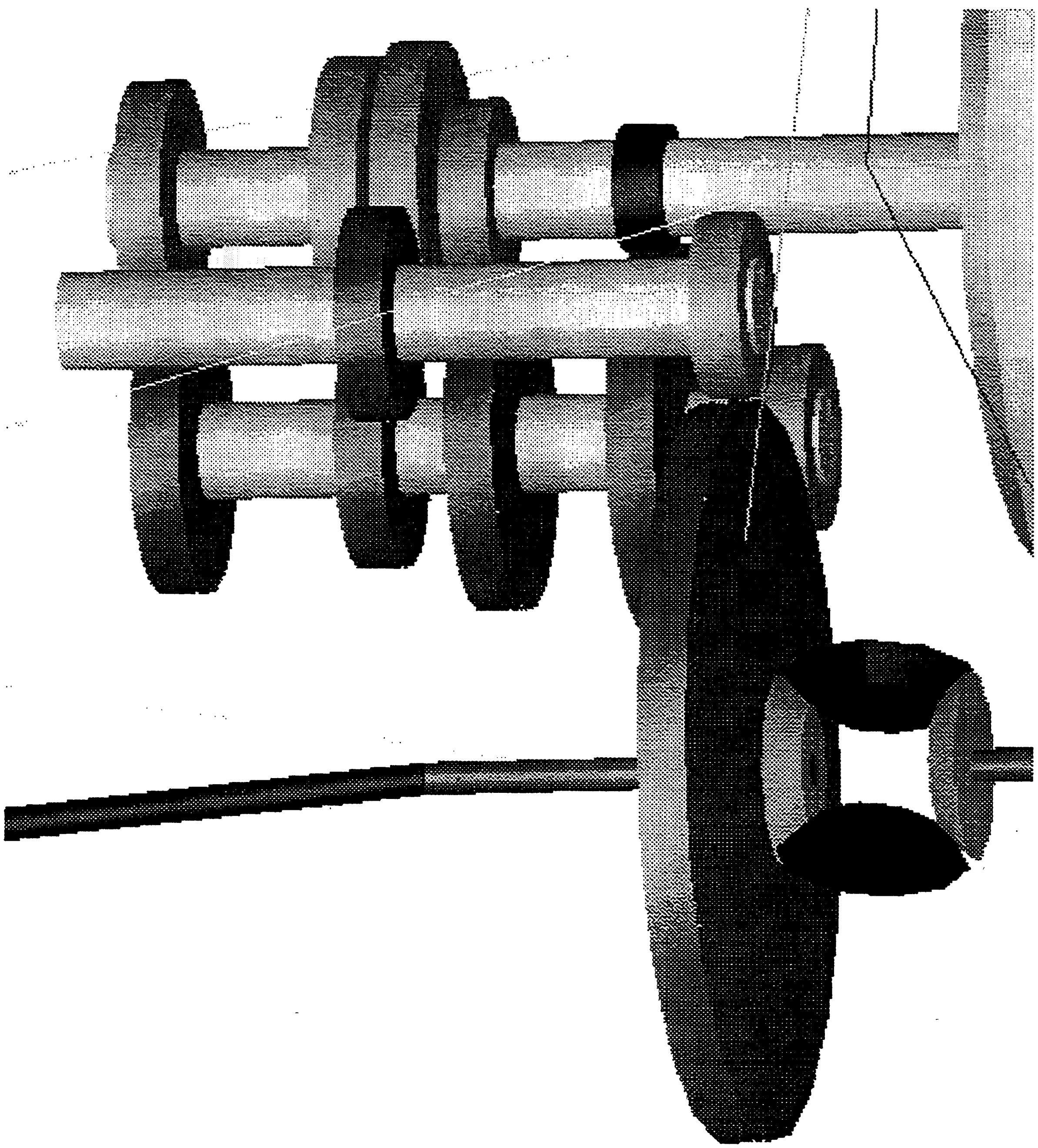

Figure 3. The graphical representation of the gearbox with final drive and differential

2.5 Driveshafts

The driveshafts are modelled with standard ADAMS elements. The flexibility is modelled as spring dampers connecting masses representing parts of the shafts. The CV joints are, naturally, modelled with constant velocity joints.

3.0 ADAMS/View Interface

One of the main reasons for the conversion of the original ADAMS model to ADAMS/View was to make the model more easy to modify and use. ADAMS/View provides a powerful environment for building dedicated simulation systems. In addition, this system provides a component database in order to minimize the work of entering data for different configurations of the powertrain.

The simulation environment consist of a number of additional macros to ADAMS/View that creates and modifies the model. These macros also defines the menus and panels that are needed for these additional tasks. The items of the main menu for the powertrain are:

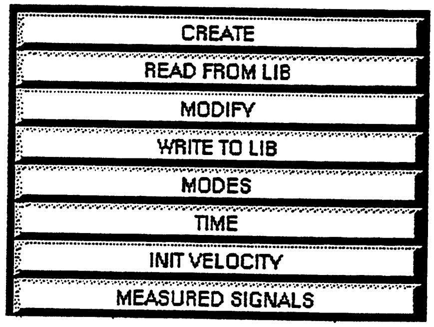

Figure 4. The powertrain main menu

CREATE	Create a powertrain or engine suspensions.
READ FROM LIB	Read data from the database, either a whole powertrain or different levels of components.
MODIFY	Modify data with the aid of panels
WRITE TO LIB	Write data to the database, either a whole powertrain or different.levels of components.
MODES	Perform a linear analysis and present the results.
TIME	Perform a dynamic analysis and generate pre-defined plots.
INIT VELOCITY	Set the initial velocity of the car and the components in the powertrain. The macro uses the gear ratio of the engaged gear to set the correct angular velocity of, e.g. the engine.
MEASURED SIGNALS	Additional functions customized for comparisons with measurements of shunt and shuffle; generates requests, creates plots and generates ASCII files for post-processing.

3.1 Creating a Model

The creation of a new powertrain model can be divided into 5 steps:

1. Load a handling model into the customized version of ADAMS/View.
2. Fill in the panel: transmission create model.

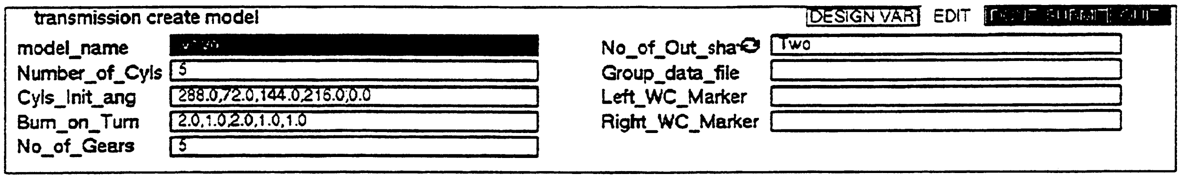

Figure 5. Panel for the creation of a powertrain model

The fields that are to be specified are:

Number_of_Cyls	Number of cylinders of the engine, up to 9.
Cyls_init_ang	Initial angular position of the crank of each cylinder.
Burn_on_turn	Specifies the firing order, 1 or 2 for each cylinder.
No_of_Gears	Number of gears in the gearbox, 5 or 6.
No_of_Out_shafts	Number of output shafts in the gearbox, 2 or 3.
Group_data_file	Which pre-defined template file to use.
Left_WC_Marker	The center marker of the left front wheel.
Right_WC_Marker	The center marker of the right front wheel.

The powertrain is now automatically created.

3. Create the engine suspension with the aid of predefined templates.
4. Modify components, either by reading data from the database or by modifying the data in the panels.
5. Modify the mass and inertia of the chassis to compensate for the mass of the powertrain.

The model is now ready for simulations.

3.2 Example of Input Panel, Gearbox Topology

The panel for modifying the gearbox topology is chosen as an example of the input panels.

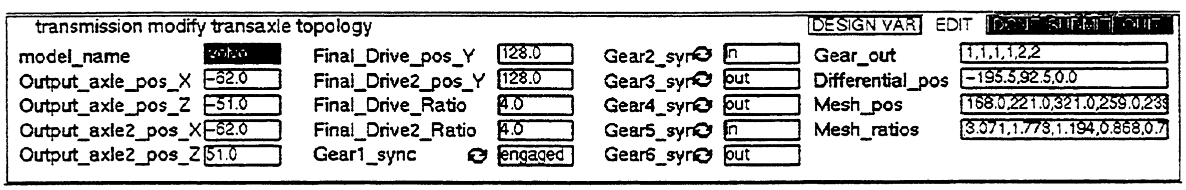

Figure 6. The panel for modifying the gearbox topology

This panel specifies the positions of the output shafts, final drive and gear meshes. It also specifies the ratios of the gear meshes. Gear_out specifies which output axle the gear meshes are connected to. GearX_sync specifies which shaft the gear meshes are rigidly connected to, i.e., input, output or both, in which case it the engaged gear. When the engaged gear is changed the constraints in the model are modified and the engaged gear mesh is marked with a different color.

3.3 Structure of the Database

The database consists simply of ASCII files that contains the data for the parameters in the model. The files have different extensions dependent on the type of data it contains. It is hierarchical and some of the files only refers to other files further down in the hierarchy.

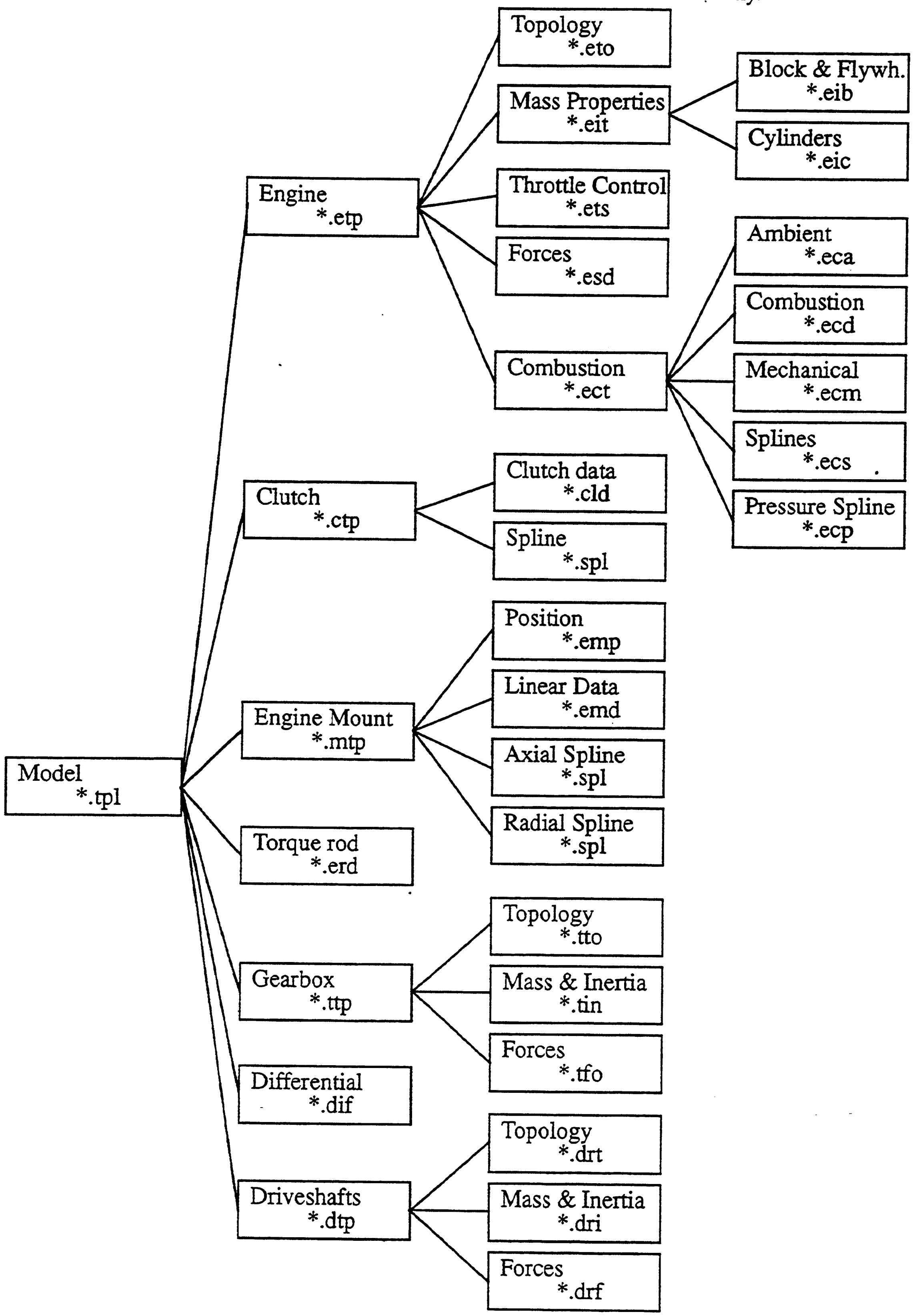

Figure 7. The structure of the database

4.0 Simulation Results

Some simulations have been performed with a model of a Volvo 850. The main subject was to study shunt and shuffle. The simulation cycle was 6 seconds starting with 2 seconds of retardation due to engine braking. After that tip-in to 7% throttle which is held to 4 seconds where tip-out is performed. The cycle was performed at a starting velocity of 6.4 m/s and with gear 1 active.

The most interesting result is the longitudinal acceleration of the car, since that is mainly what the driver experiences.

In the following figures simulation results have been plotted together with results from measurements of the tip-in phase performed at Volvo

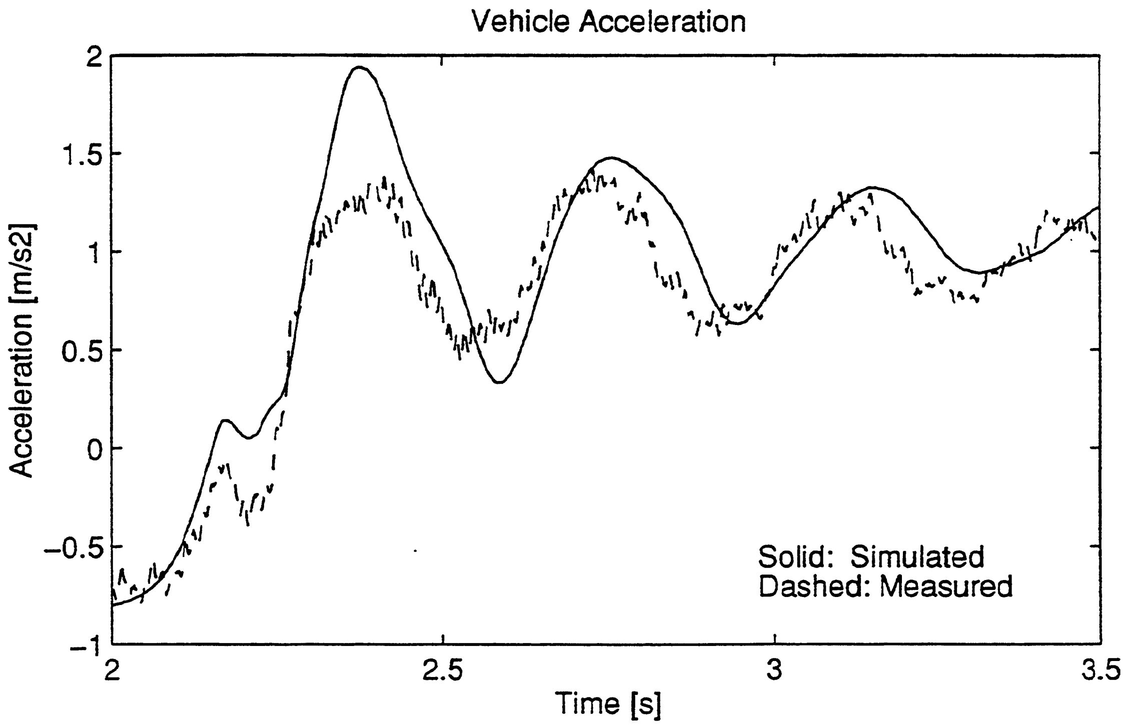

Figure 8. Vehicle acceleration, comparison between simulation and measurement

The simulations show promising similarities with the measurements. The major difference is in the amplitude of the acceleration of the vehicle. This difference is due to a too fast response of the engine in the simulation model. In the real car, the engine control unit has functions that controls the engine to avoid shunt and shuffle. However, the frequency and damping of the oscillations are quite similar.

In order to get a better approximation of the engine response the engine torque is to be measured for a tip-in and tip-out driving cycle. The measurement can then be used to get a better model for the engine torque. It is also possible to use the measured torque as direct input to the simulation model. Alternatively the cylinder pressure can be measured in the driving cycle and be used as input to the model.

The verification of the model is not completed. There is a project at Volvo studying shunt and shuffle and within that project a lot of measurements are performed. This will give additional input to tune the model to give good results.

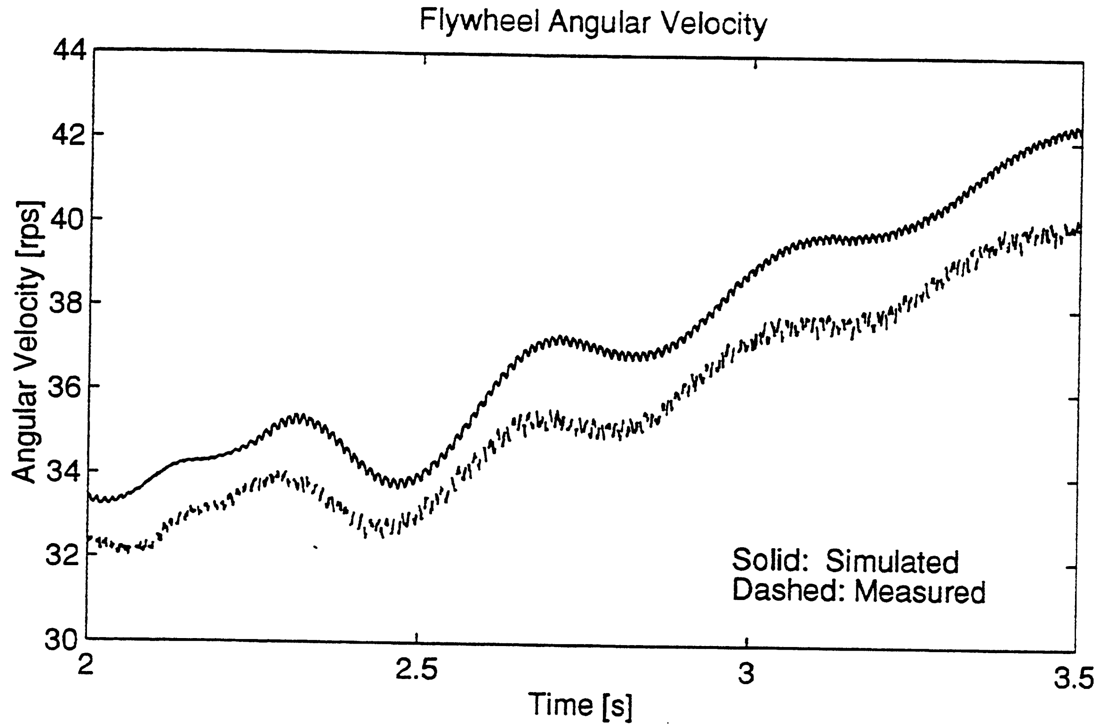

Figure 9. Flywheel angular velocity, comparison between simulation and measurement

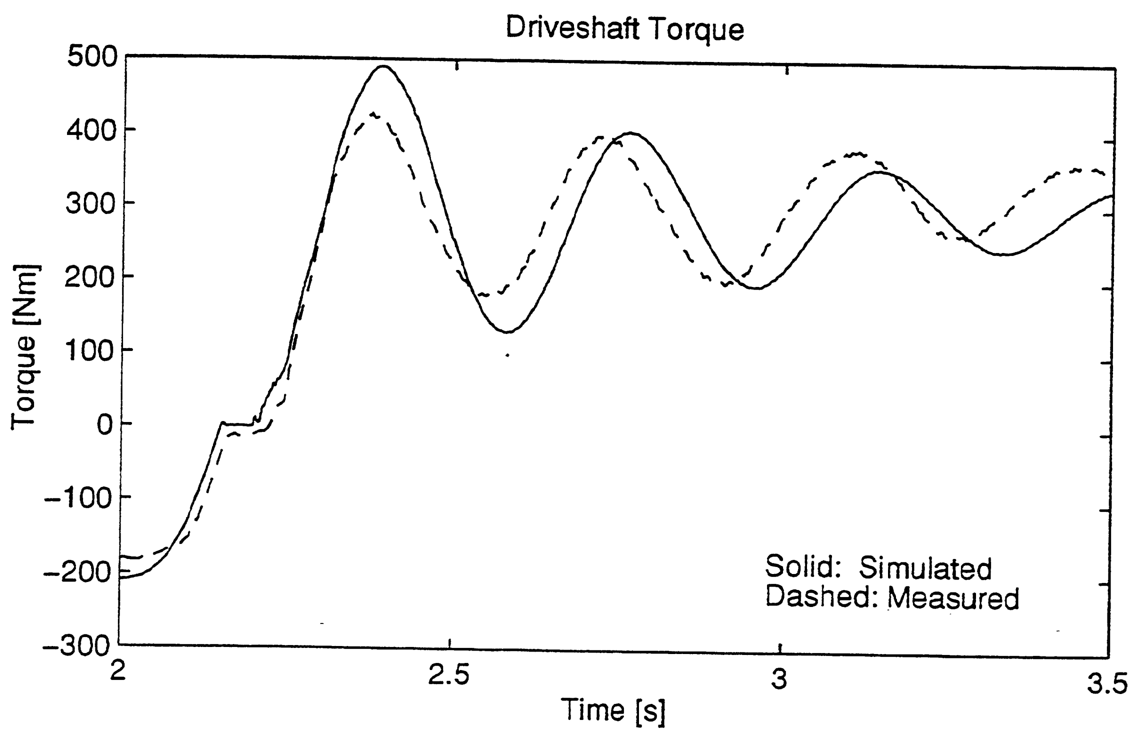

Figure 10. Driveshaft torque, comparison between simulation and measurement

4.1 The Influence of the Tire Slip

One objective of the shunt and shuffle project is to investigate what parameters that influence the damping of the oscillations. One of these parameters seems to be the tire slip. In order to study this simulations were performed with three different slip characteristics; one with real measured slip, one with very soft tires and one with very stiff tires. The simulations show that the tire slip has a significant influence on the damping. It should be noted that this only is a numerical study and that tires with these characteristics hardly exist.

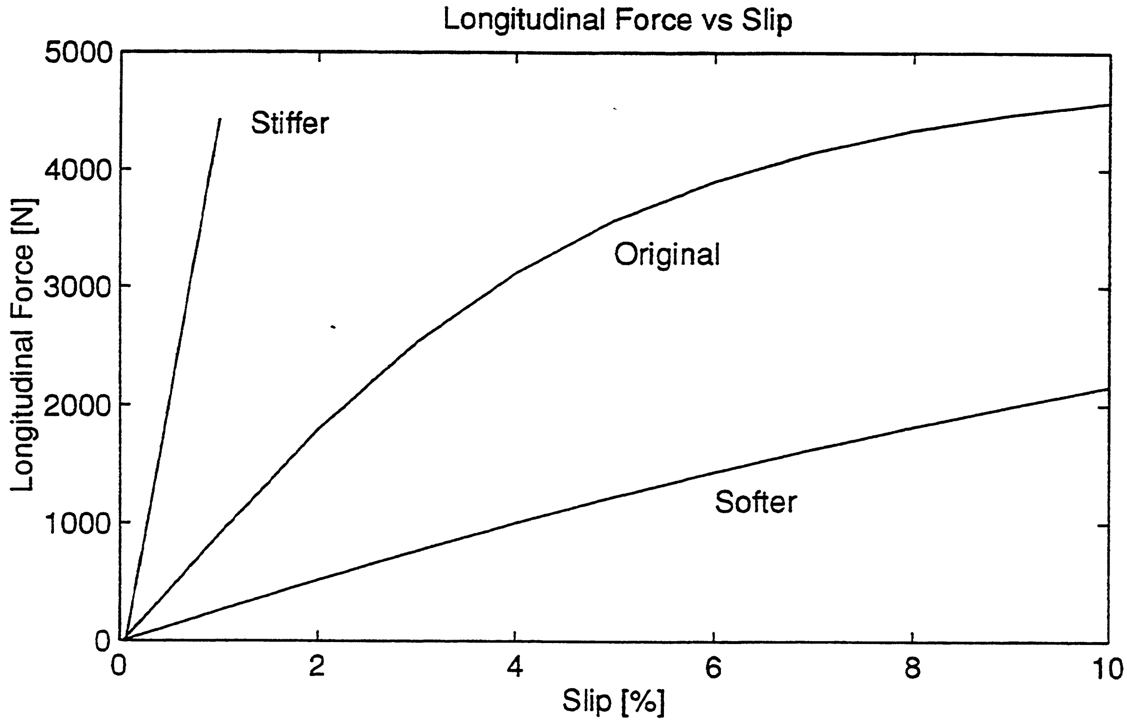

Figure 11. Three different tire slip characteristics

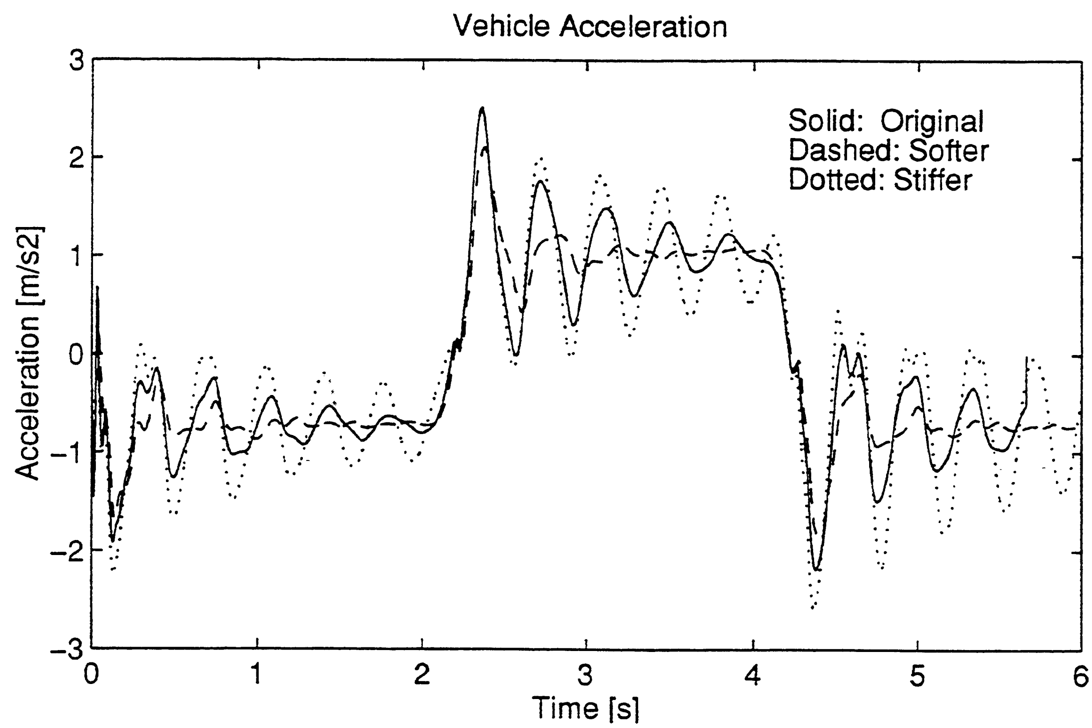

Figure 12. The acceleration of the car with different tire slip characteristics

5.0 Conclusion

Dynamic simulations can be of aid in several aspects of the design process of powertrains. They can be used for parametric studies which reduces the need for building prototypes and performing tests. Simulations can also increase the understanding of the dynamical behavior of the system. In order to perform these simulations a flexible and easy to use model is required. This led to the development of the ADAMS/View powertrain modelling system.

This system is a powerful tool for dynamic simulations of powertrains. The ADAMS/View interface makes it easy to create and modify different types of powertrains. The database included in the system makes it possible to store standard components which can be used in different models.

So far the model has been used to study shunt and shuffle. Some promising results have been obtained. However, some work remains to be done in order to tune the behavior of the system.