AnTriebsStrang (ATS) – An A–View Userinterface to Model and Simulate Parametric Car–Powertrains

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Abstract

The ADAMS/Car compatible user–interface AnTriebsStrang (ATS) has been developed to calculate powertrain based problems, such as mass balance, flywheel definition or forced torsional vibrations. Additional aspects of car longitudinal dynamics can be described by implementing the ATS model in full–vehicle multibody systems. The setup of the powertrain is designed in a modular way. The result is a completely parametrized model, which the user can simply modify via ATS–panels. The application of ATS at Volkswagen includes compartment problems as well as noise and vibration problems, examples will be shown.

1 Introduction

Present full–vehicle models for simulation of car–driveability mostly include simple powertrains. The more complex ones are based on a given car, and what is more, modification is difficult.

To meet the future requirements of judging driving comfort, a detailed specification of the powertrain as well as efficient modelling tools for rapid virtual prototyping are necessary.

Apart from the decrease in modelling time and the improvement of full–vehicle models the creation of a unique database and datastorage was the main intention to implement this project. The project definition was drawn up by CAE–partners of different departments of Volkswagen, all involved in powertrain simulation. With ATS they all use the same database, so work can be divided and complete models can be merged faster.

2 ATS at Volkswagen

The success of a new software tool in industrial practice can be measured by the frequency of use. Taking that into account, we had to solve two tasks.

Firstly, the new software had to be embedded in the presently applied tools of the whole Volkswagen Group. Therefore, we made ATS compatible with ADAMS/Car, the A/View customisation for full–vehicle models, supported and presently tested by AUDI. Consequently, ATS serves as an interface between car and engine multibody systems (Fig. 1).

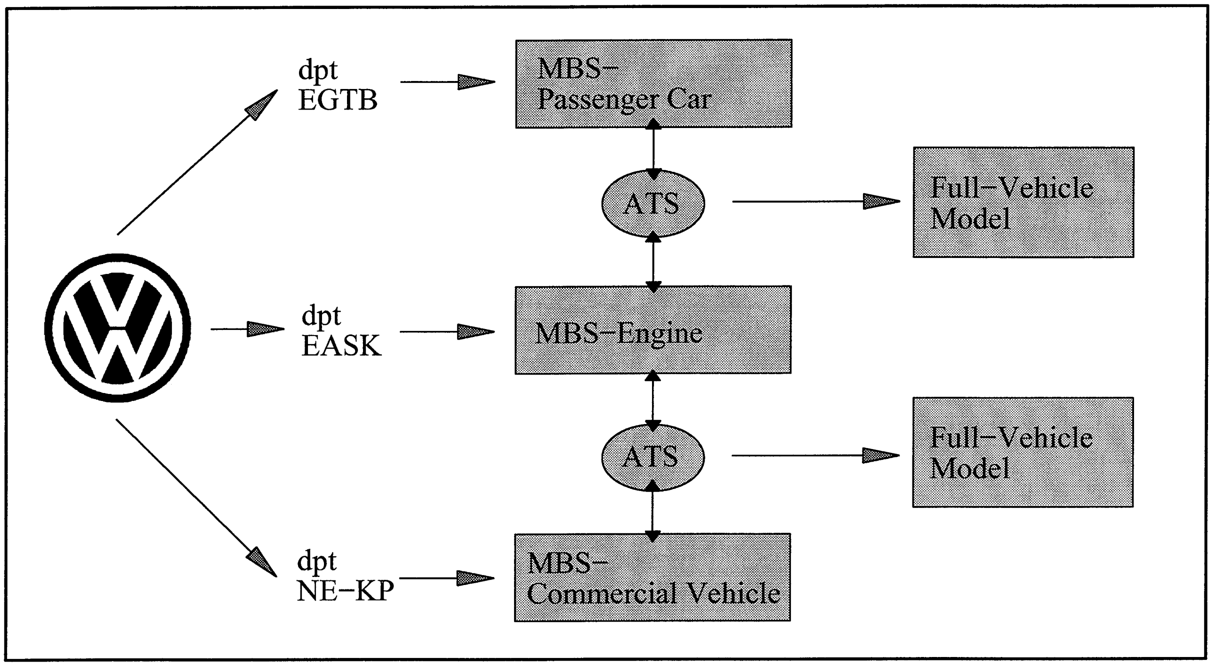

Figure 1. Full–Vehicle Simulation at Volkswagen

Secondly, the new software was to have different levels of use. That was the reason to execute ATS in two different modes. The experienced ADAMS users working in the CAE departments of Passenger cars and Commercial vehicles or in the Engine Department are able to generate templates representing a new model. The non–experts execute ATS in acar–mode. In this mode only parametric studies can be conducted. There are already first examples of doing simple calculations in the design departments. The influence of mass tolerances in the balancing system of 3–cylinder engines is checked by a designer who has never dealt with ADAMS before using a simple 3–cylinder engine template.

3 The ATS Modules

The modular setup of the entire powertrain enables tailoring the models to the needs of a given application.

The ATS modules are:

–the engine
– the engine mounts
– the clutch
– a simple gear–box
– and the driving shafts (Fig. 2).

The *engine* itself is a rigid body and receives its mass properties from measured data. In order to have all exciting forces inside the model, the crankshaft, the conrods and the pistons are parts of the system. Cylinder pressure can be added from measured data or is calculated in a sforce–subroutine. The user can implement balancing shafts for 3– and 4–cylinder engines.

The *engine mounts* have to be modelled carefully because of their dominant influence on most applications of powertrain simulation. Therefore, simple spring–damper and, additionally, hydraulic mounts are implemented. They all can have non–linear stiffness.

The *clutch* is either a conventional one or a clutch with a two–mass flywheel. A simple torsional connection from the engine to the gear–box can also be used. To simulate misuse of the clutch, the user can define the time–step to reach the maximum torque of the clutch.

The *gear–box* module models the transmission of power from the engine to the driveshafts by using one gear statement for the connection of input and output gear–shaft and a coupler statement for the definition of the differential output. The user has the choice of modelling a stiff or an elastic connection with backlash of input and output gear–shaft.

The *driveshafts* are represented by two parts connected by a rotational spring–damper and a revolute joint. A constant velocity joint attaches one part to the differential output which is connected to the gear–box via a cylindrical joint. A cv–joint attaches the second one to the spindle, mounted to the wheel carrier by a revolute joint.

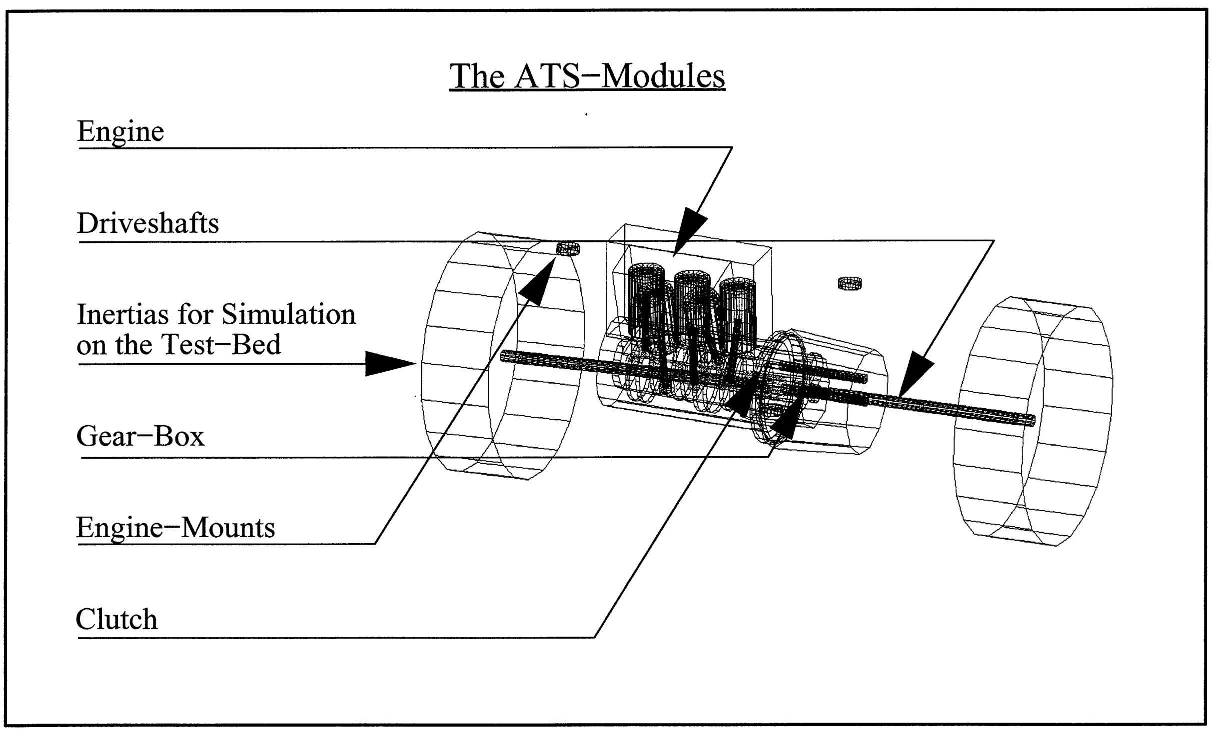

Figure 2. The Modules of the Powertrain

4 The Setup of a Model

To setup a new model, the expert user starts ADAMS/Car, applying the ATS macros in template–builder mode. The user is presented with a customised A/View for the interactive input of all values representing the powertrain. Inside the template–builder mode, only the system description is drawn up. The values chosen may be dummies. With the template, the expert tailors the model to the application. For instance, the template for idle shake investigations only describes an engine with the mounts. A full–vehicle template describes all ATS modules and defines and uses connectors and communicators to integrate ATS into a car model.

By generating a subsystem from a template, the dummy values are replaced by real system data. You get your virtual prototype description. A panel for the definition or modification of system data is shown as an example in Figure 3.

The last step which will provide an ADAMS data set for simulation is the assembly phase. Here, all subsystems are merged and property files for mount stiffness, combustion pressure or bearing friction are read.

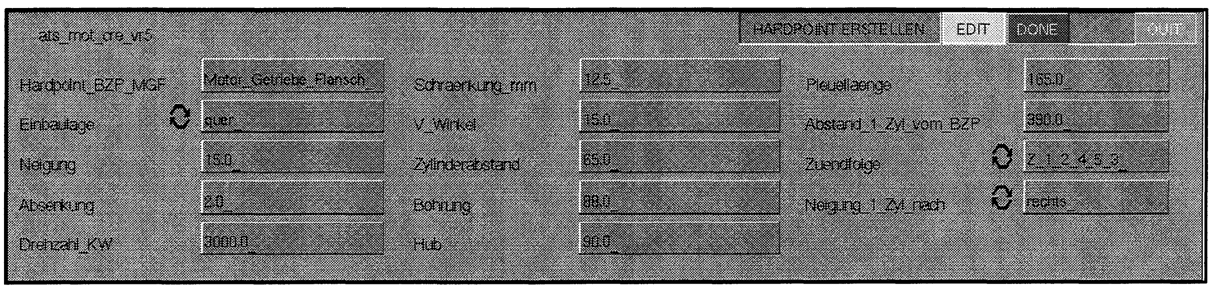

Figure 3. Input Panel to Describe the Engine (Subpanel)

5 Application of ATS at Volkswagen

As mentioned above, the ATS project has been initiated by three departments of Volkswagen Research and Development: the Engine Development, the Passenger Car and the Commercial Vehicle Development.

The Engine Development deals primarily with the components of the engine itself and therefore simulates the engine on a test rig. Major topics are the mass balance and the flywheel definition to obtain minimum noise and vibration excitation. The forced torsional vibrations of the crankshaft are presently simulated using rigid bodies, torsional spring–dampers and a special force statement for the clutch. A future goal is the implementation of bending of the crankshaft in order to calculate the bearing loads. ATS will be the basis for these simulations. An ADAMS model of the 5–cylinder TDI engine is shown in Figure 4.

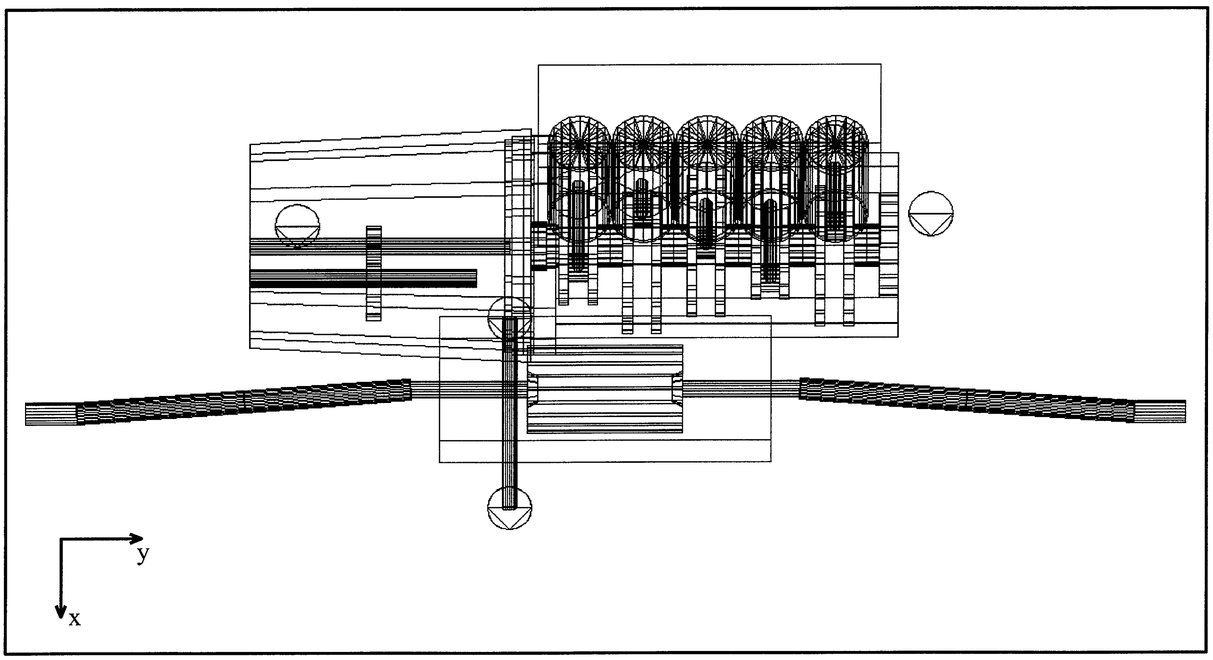

Figure 4. 5–Cylinder TDI Engine

The other two departments, the Passenger Car and the Commercial Vehicle Development, are more interested in full–vehicle simulations. Figure 5 shows an ADAMS model of the Volkswagen Transporter with the 5–cylinder TDI engine, generated with ATS. The full–vehicle model is mainly used for the design of the engine mounts, where we have conflicting aims. On the one hand, mounts with low stiffness are preferred because of better sound insulation. On the other hand, we need high stiffness to keep the engine movements as small as possible to avoid compartment problems. For a well balanced definition of the mount stiffness we investigate the load cases shown in Figure 6.

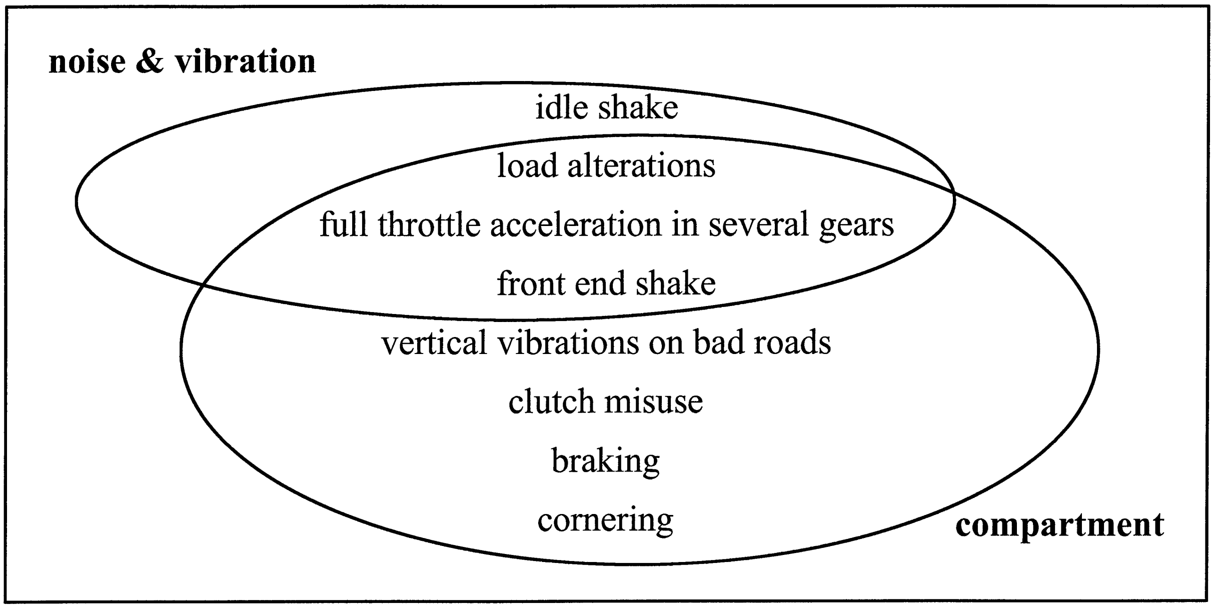

Figure 6. Load Cases for the Engine Mount Design

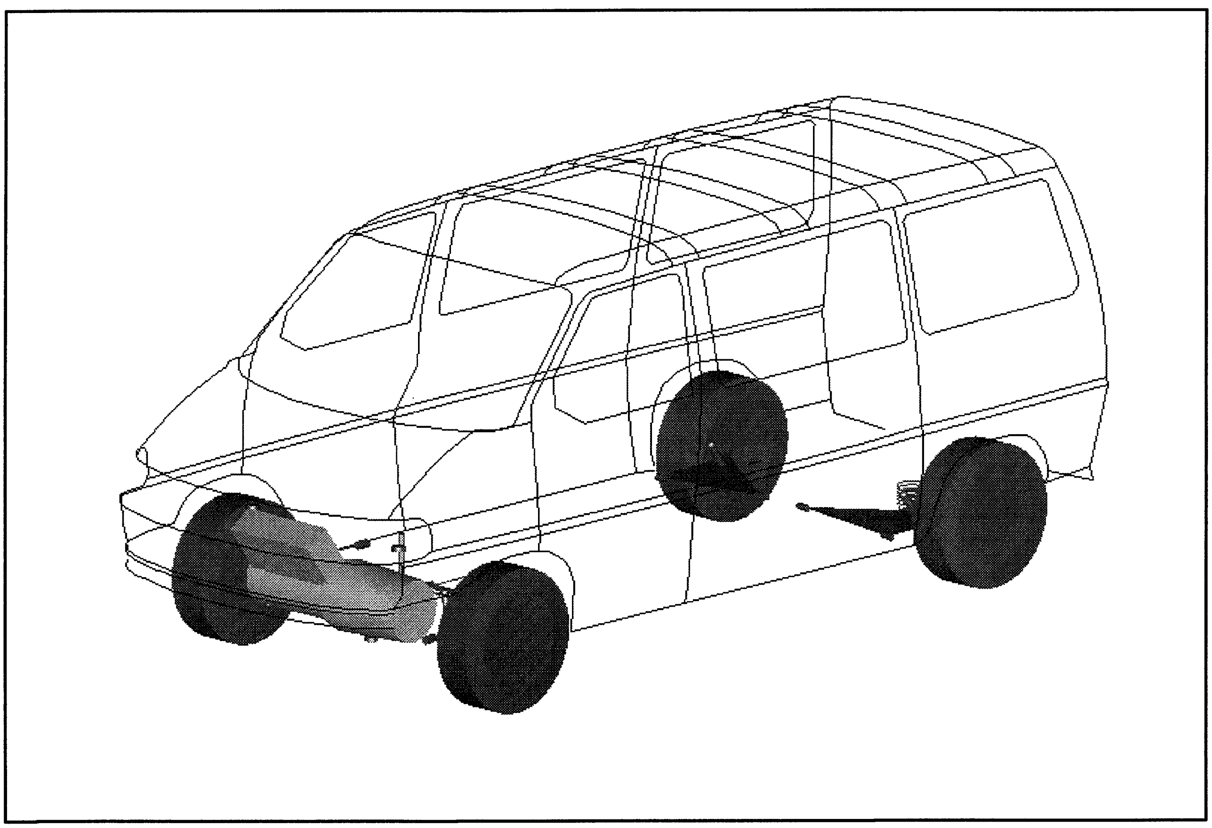

Figure 5. Volkswagen Transporter with the 5–Cylinder TDI Engine

Some of these load cases are relevant only for comfort or the engine movements, others for both fields. The results of the engine movement load cases are later used to determine the design space of the engine. Figure 7 for example shows the envelope of a moving engine. This envelope can be generated from the engine CAD data and the simulation results and it can be retransferred to the CAD system. Now the design engineer is provided with information on the volume that must be reserved for the engine. Furthermore, it is possible to use the bearing forces especially of the compartment load cases for fatigue life estimations of the neighbouring structure.

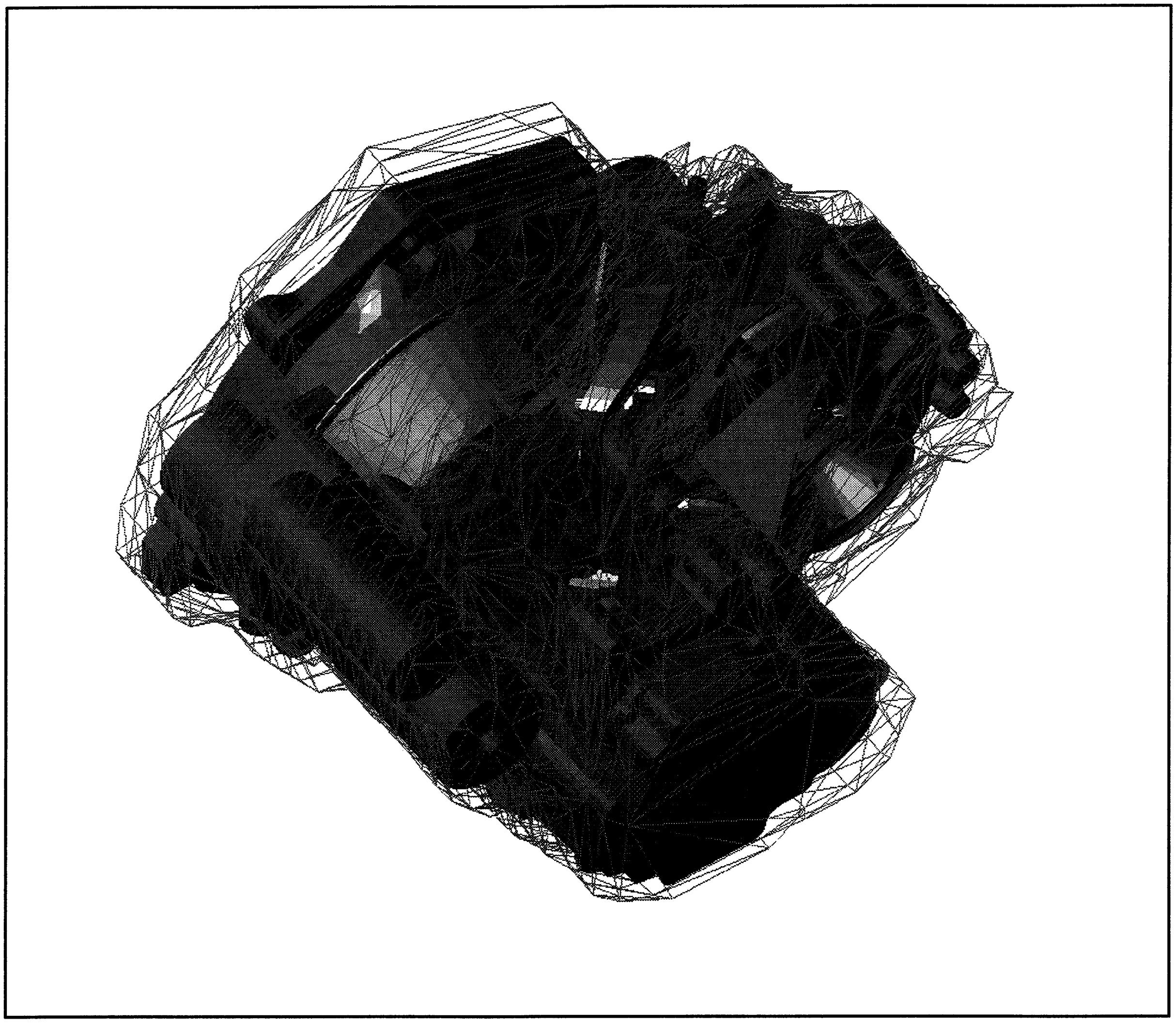

Figure 7. Envelope of a Moving Gear–Box

6 Examples
6.1 Front End Shake

The front end shake is a vertical vibration of the car front end, that occurs when the engine is running at very low revolutions, usually after engaging the clutch too fast. In order to assess measures against this phenomenon, the engine in the full vehicle is run at 600 r.p.m., the car velocity is kept constant and the body vertical acceleration is investigated in the middle of the front axle. For the start configuration (curve in Fig. 8) high peaks for the 2.5th and the 5th order excitation at 25 and 50 Hz, lower peaks for the 3.5th, the 7.5th and the 10th order excitation at 34, 75 and 100 Hz are evident. In the second simulation the stiffness of the lower engine mount was decreased by 10 % in comparison to the original one in the start configuration. The acceleration of the body is reduced by 5 % for the 2.5th order excitation. In the third version the slope of the lower mount strut was cut down to zero (horizontal strut). Due to the uncoupling of the rotational excitation around the car lateral axis and the vertical reaction forces in the engine mounts the body vertical acceleration at 25 Hz was reduced by 7 %. In order to retain Fig. 8 as clear as possible, only one curve is shown. The results of the two remaining simulations are listed in the following table:

	2.5th order	5th order
Basis	100 %	42 %
Reduced Stiffness	95 %	40 %
Horizontal Strut	93 %	39 %

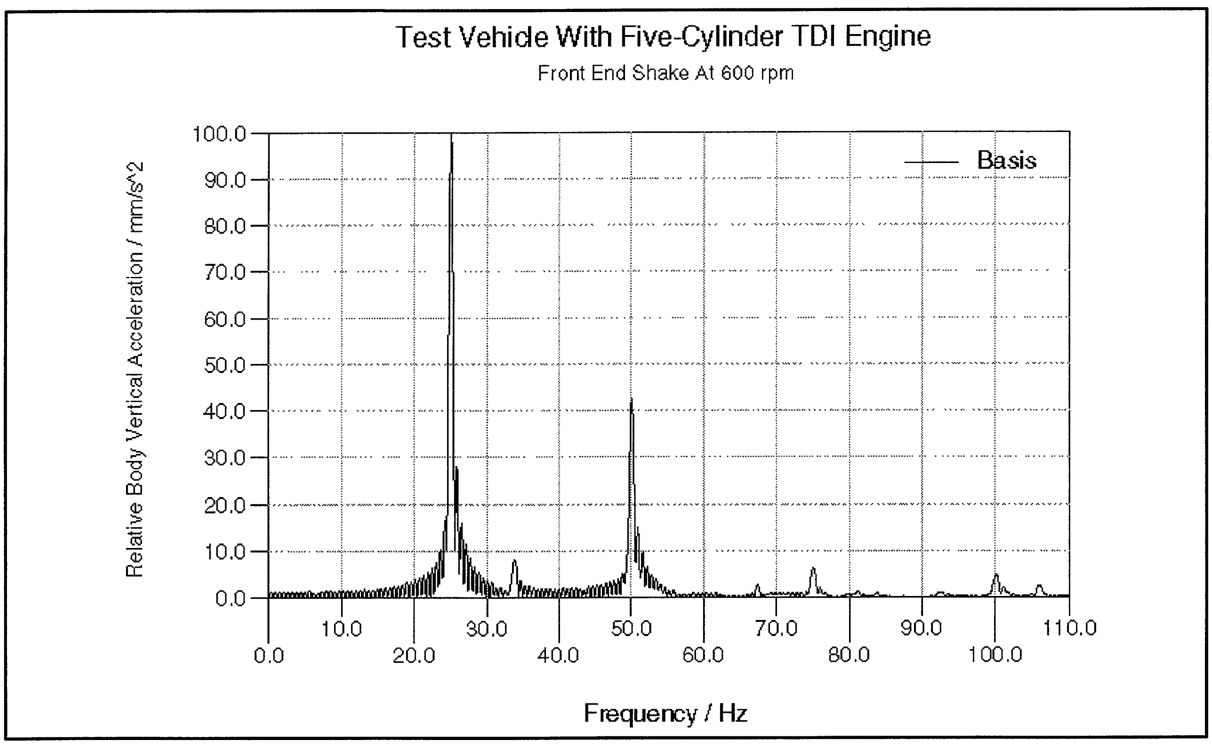

Figure 8. Front End Shake of a Test Vehicle

6.2 Load Alteration

Load alteration has been investigated on the full–vehicle model shown in Figure 5.
The simulation starts with an initial velocity of the transporter of 10 kph. That corresponds to an engine speed of 700 r.p.m. and second gear engaged. Now combustion forces accelerate the car until an engine speed of 3000 r.p.m. is reached.
To model the load alteration, the combustion forces are multiplied by a double ADAMS step function (Fig. 9). This means that the cylinder pressure is first reduced to zero and than reset to the initial level, both in a given period of time. While the pressure is changed, losses increase and decrease simultaneously.

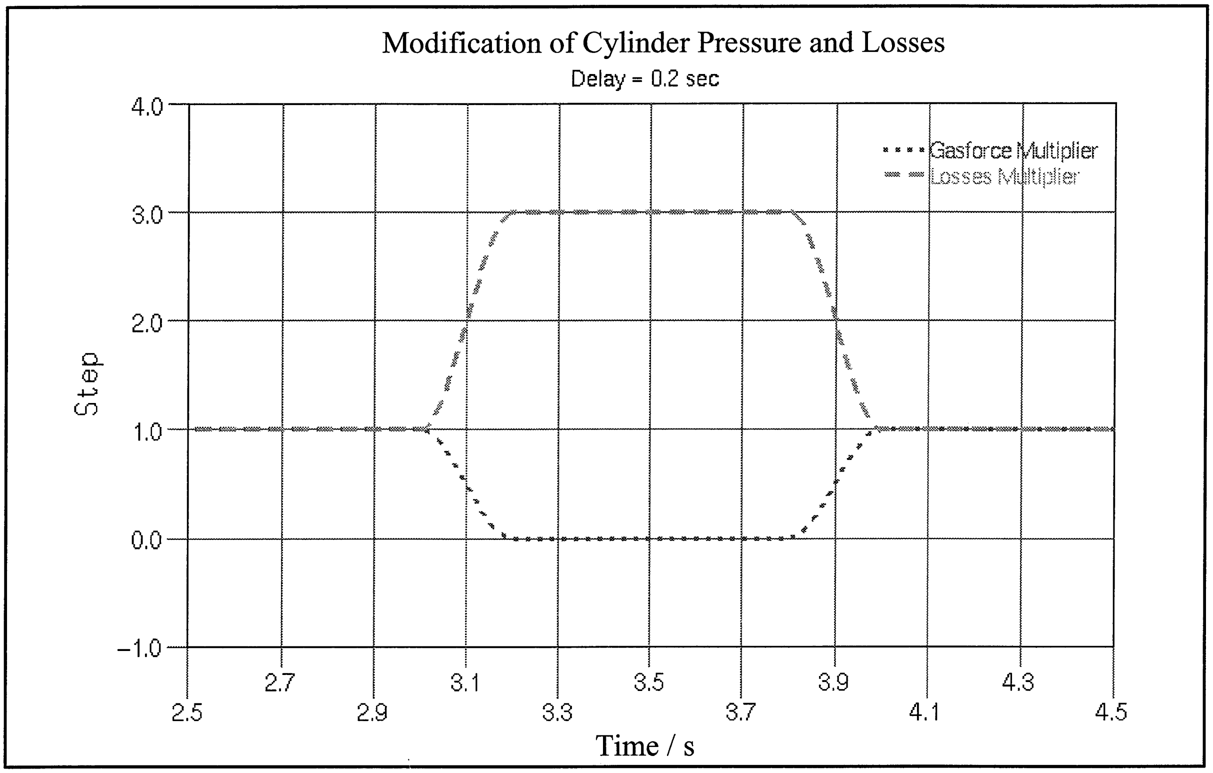

Figure 9. Modification of Cylinder Pressure and Losses for Load Alteration

The influence of the load alteration on the tire forces, the engine displacement, the car acceleration and additional simulation results have to be analysed. Figures 10 to 12 show some of the items named. Looking at the car–acceleration it can be seen that an increasing time delay from 0.1 to 0.3 s strongly reduces the acceleration peaks. A growing delay from 0.3 to 0.4 s does not result in further improvement.
To find an optimum delay for the reduction of cylinder pressure, it is nessecary to define objectives. Considering driveability they can represent different car–behaviour, for instance sporty or comfortable.
The results help to define the controlling of throttle–back to full–throttle change.

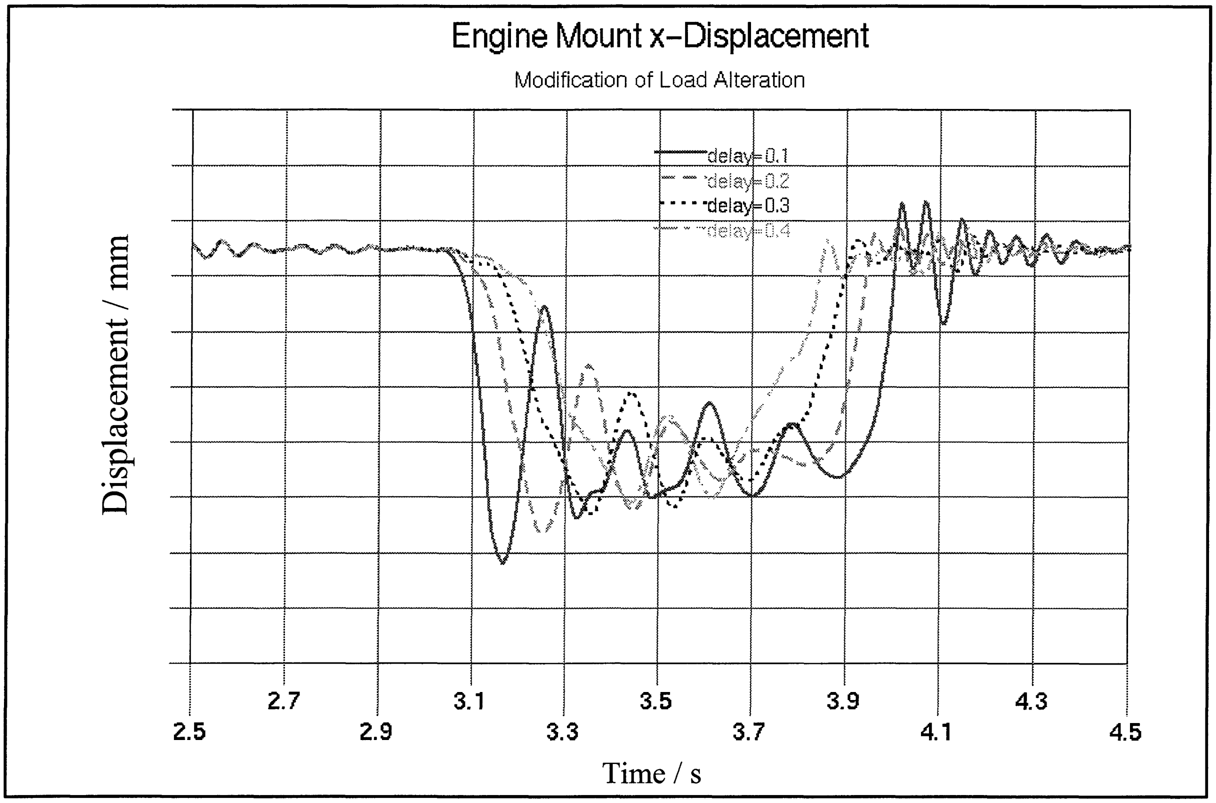

Figure 10. Engine Mount x–Displacement during Load Alteration

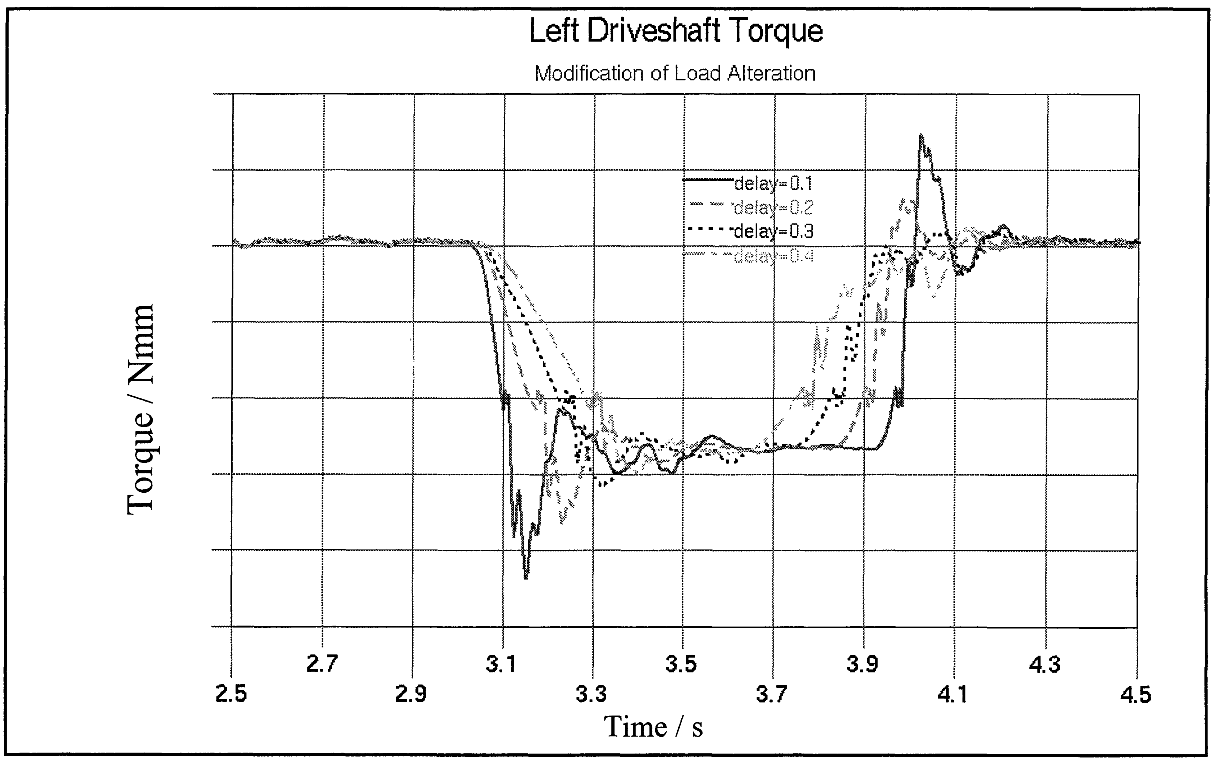

Figure 11. Driveshaft Torque for different Load Cases

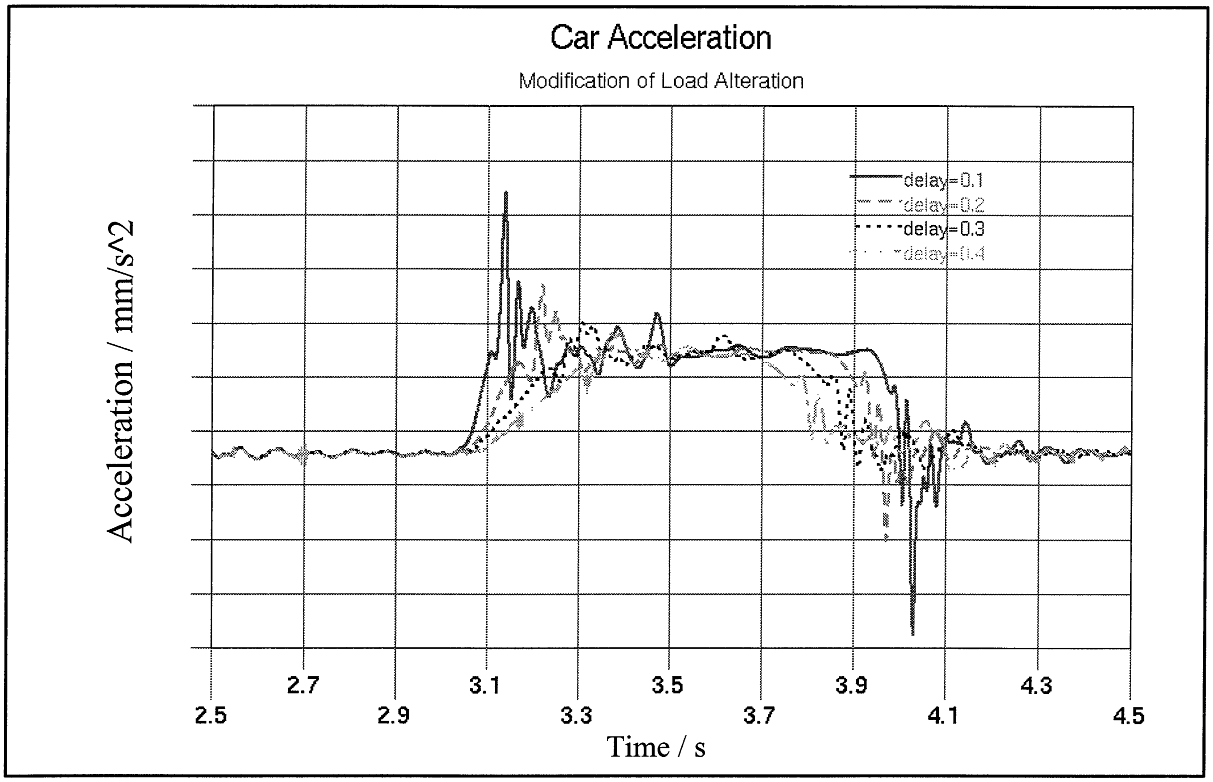

Figure 12. Car Acceleration for different Load Cases

6.3 Clutch Misuse

In a first step this load case has been simulated on the test bed. The equivalent of the car mass was added to the tire rotational inertia. In the simulation the initial engine speed was 3000 r.p.m.. The clutch was engaged in a time step of 0.2 s.

Figure 13 for example shows the x–displacement of a point at the valve cover during the clutch misuse. A good correlation to the measured data, which are also shown in the plot, has been obtained. Analysing the displacement of certain reference points is another way of checking the moving engine for collisions besides the creation of an envelope.

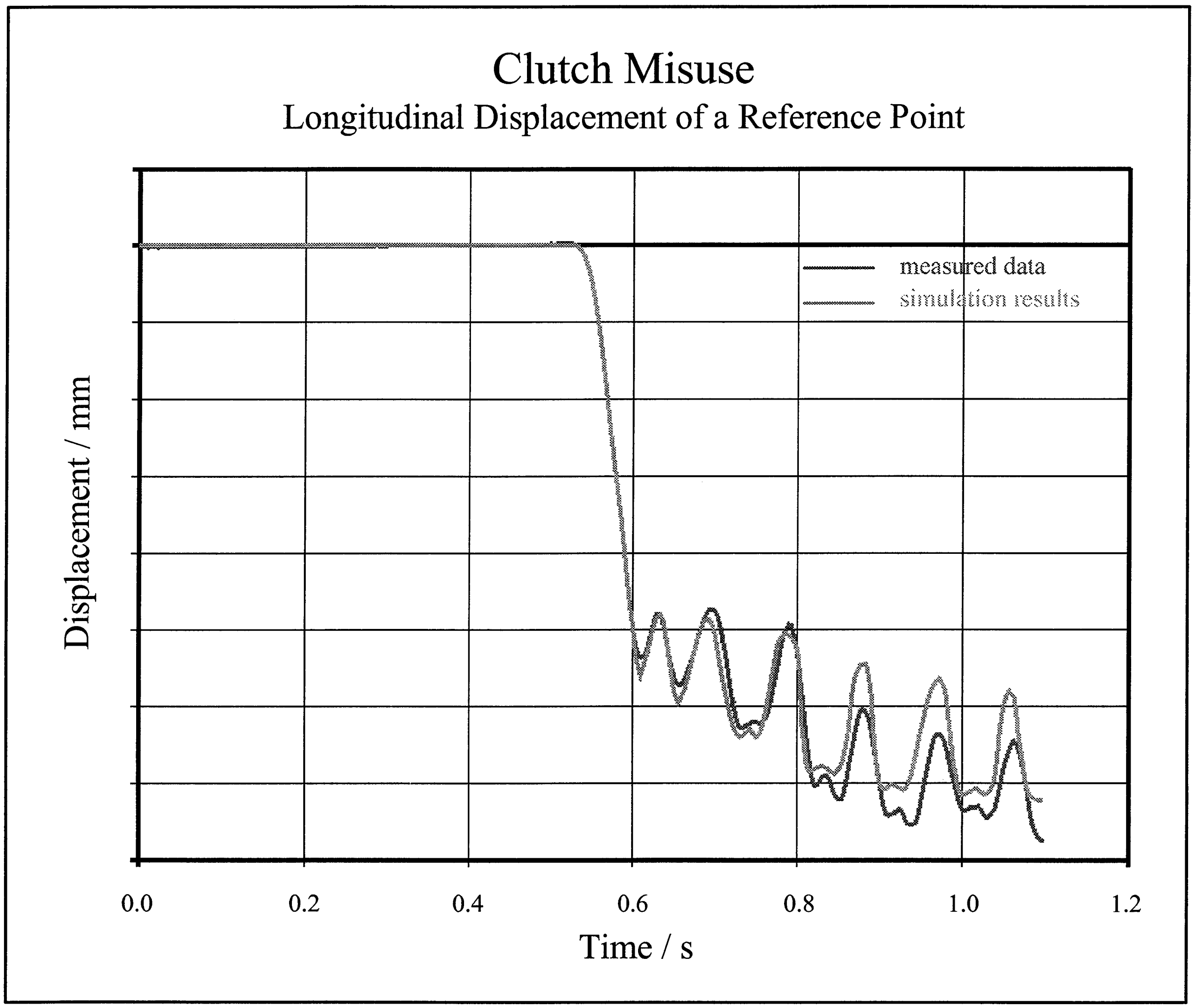

Figure 13. Clutch Misuse

7 Summary

With ATS a new preprocessor for the simulation of engine–related load cases has been created. We expect a faster preprocessing, higher accuracy of the simulations and easier data–transfer between departments of Volkswagen Development.
We hope to be able to satisfy the growing demands and expectations not only regarding the compartment problems but also regarding the noise and vibration excitations.

Thanks to Mr. M. Hache (Passenger Car Development), who made his results of the clutch misuse simulation available for us.

Also many thanks to Mr. A. Hamann, who kindly provided us with the FEM–model of the Transporter, that we used for the animation.