12th European ADAMS Users Conference

Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller for Improved Simulation of the Vehicle / Powertrain Interaction

by

Dr. Peter Redlich

Vehicle Systems and Concepts Development

Ford-Werke AG

&

David G. Ellis

Powertrain Attribute Integration

Ford Motor Company Limited

Abstract

With the increasing demand on driveability the interaction between the vehicle and the engine controller is also becoming more important. In addition the complex movement of the powertrain in its mounts relative to the vehicle body has to be taken into consideration.

Combing the strength of ADAMS for multi body simulation with the strength of MATRIXx for engine controller design, the integration of the two software tools enhances the overall computer simulation prediction capability.

This paper presents the successful integration of a MATRIXx powertrain with an ADAMS full vehicle model. First the background information warranting the exercise is outlined. Further discussion describes the integrated solution and provides details of the MATRIXx drivetrain model and the ADAMS full vehicle model. Specific features of the software enabling the integration of the simulation software packages are outlined. Attention is given to the extended post-processing capabilities of the combined system.

Background

It is recognised that the simulation of FWD powertrain mount systems within MATRIXx has limitations, Figure 1. For systems which employ simple elastomeric components (as opposed to hydraulic components) and do not use torque restricting links, the current MATRIXx models available at Ford are more than adequate. With the increasing number of vehicles with complex powertrain mount systems the requirements on the driveline simulation increase. Furthermore, the manner in which the vehicle sprung-unsprung compliance is simulated within the MATRIXx model is grossly simplified. For these reasons, it was suggested that ADAMS should be employed to simulate all vehicle elastomeric bushings, including powertrain mounts, and the consequent rigid body interactions between driveline and vehicle. For this purpose an ADAMS full vehicle model, already available for vehicle dynamic simulation, is well suited. One solution would be to perform the whole simulation in ADAMS. Unfortunately ADAMS has limitations as well, Figure 2. To combine the benefits of both software tools, integration of both models was chosen as the best solution to simulate the interaction between full vehicle and powertrain.

MATRIXx SystemBuild powertrain model overview

The SystemBuild top level Superblock is illustrated in Figure 3. It comprises of an engine model and a four mass driveline model, Figure 4. The input to the engine model is throttle plate angle as a function of time. The engine model generates torque on the crankshaft/flywheel assembly as a function of time. The torque forms the input to the four mass driveline model. The transfer function of tractive force to vehicle mass is assumed to be unity. Powertrain mount effects are not included. The primary output from the MATRIXx model is the simulated driver's seat track longitudinal acceleration. The model is driven with closed throttle for the first three seconds of the simulation followed by a tip-in to 40°.

ADAMS full vehicle model overview

The ADAMS full vehicle model is illustrated in Figure 5. It comprises of non-linear elastic front and rear suspension, the steering system including the power assist, and a tyre model with combined longitudinal and lateral force calculation, originally built for vehicle dynamic simulations. In order to simulate the powertrain behaviour a rigid powertrain with non-linear powertrain mounts and sideshafts is added to the model. The ADAMS model is driven by equal torques applied to each sideshaft. The powertrain block reacts the sideshaft torques through the powertrain mount system. Overall, the ADAMS model processes 102 kinematic degrees of freedom.

Interface details

In principle three approaches are possible to combine MATRIXx and ADAMS models, Figure 6. Out of these 3 approaches the parallel run of ADAMS and MATRIXx was chosen because this approach does not limit the ADAMS model to be linear and does not limit the MATRIXx model to the blocks supported by AUTOCODE. Additional reasons are summarised in Figure 7. The whole directory structure required to run both models in parallel is shown in Figure 8. In the MATRIXx and ADAMS model directory first the environment variables have to be specified in the C-shell scripts xmath_adams and start_adams. In addition an ADAMS executable containing the reqcall.f and varcall.f subroutines, which define the input/output variables to the ADAMS model, has to be generated. The whole coupling is controlled by the admusr.f user subroutine in MATRIXx. This subroutine opens the pipes for the data exchange and starts ADAMS at every time step. In addition to the output passed from ADAMS to MATRIXx the standard ADAMS outputs are stored in the ADAMS model directory. During the simulation, MATRIXx and ADAMS take simultaneous time steps. Each package independently computes the solution for their respective models. At the beginning and end of each step, the two packages exchange input/output signal data.

An expanded view of the drivetrain SystemBuild superblock is shown in Figure 9. Torque from the engine model forms the input to the powertrain superblock. This block generates the tyre contact patch tractive force which, in turn, dictates the acceleration and velocity of the vehicle. An intermediate output of the powertrain superblock is sideshaft torque in Nm. The engine, clutch and transmission in the SystemBuild model consist only of one rotational degree of freedom each. In the original SystemBuild model the next part is the wheel/tyre model which is then directly connected to a simple full vehicle model.

As best interface intersection the sideshaft was selected. This enables the coupled model to cover the effect of the tilted angle driveshafts. In the ADAMS model the driveshaft torque is applied as action/reaction torque between each driveshaft and the powertrain block, Figure 10. The gain of 500 converts the MATRIXx sideshaft torque in Nm into two equal sideshaft torques in Nmm for the ADAMS model. Because the engine, clutch, and transmission rotational degree of freedom is already covered by the MATRIXx model, the whole powertrain block in the ADAMS model is simulated as a rigid body. Nevertheless, due to the reaction torque between driveshaft and powertrain block in the ADAMS model, the reaction forces in the powertrain mount system are correct. This enables the user to simulate and graphically display all powertrain displacements in ADAMS. To close the feedback loop, the transmission block in SystemBuild uses the driveshaft angular velocities calculated in the ADAMS model and integrated in System/Build as input, to calculate the torque based on the angular difference of the inner and outer driveshaft angle and the combined sideshaft stiffness.

First simulations did not find stable solutions to solve the combined model. The problem was that MATRIXx uses very small time steps. Consequently ADAMS was forced to the same small simulation time steps causing integrator problems in ADAMS. These problems were solved by limiting the minimum stepsize in MATRIXx or using an integrator with constant stepsize.

Combined simulation results

The combined model is subjected to a part throttle tip-in from closed throttle. Figure 11 depicts the torque input in the driveshaft and the body longitudinal acceleration as simulated by MATRIXx and the combined model. Basically both models show the

same result. The powertrain mounts in the combined model reduce the natural torque oscillation frequency of the combined system and increase the overall damping. The movement of the powertrain relative to the body effects the longitudinal acceleration as well because additional eigenfrequencies of the powertrain are excited.
The combined model enables engineers to animate the full vehicle model during acceleration and to analyse the interaction between powertrain and suspension during acceleration. In Figure 12 the powertrain mount displacement and the displacement of the rear A-arm bush of the front suspension is shown.

Conclusion

After some initial difficulties a successful link between MATRIXx and ADAMS was achieved. The chosen concept of the parallel run of both packages is most efficient as already existing powertrain and full vehicle models could be used. The coupled model has shown additional prediction capabilities due to the better simulation of the interaction between powertrain and suspension.
Additional investigations are necessary to reduce the required CPU time for the combined model either by reducing the complexity of the ADAMS full vehicle model or by tuning the MATRIXx integrator. A fully integrated simulation in one software tool might be more efficient in terms of required CPU time, but the proposed solution does not require additional CAE models because the ADAMS and MATRIXx models already exist within Ford.

Limitations of the MATRIXx Model

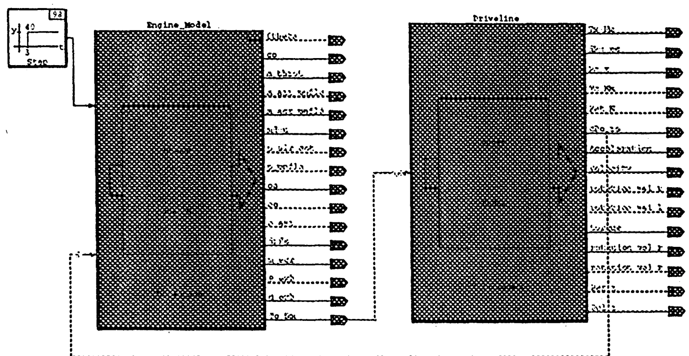
- **Driveline with only 1 rotational DOF**
  - 3 dimensional movement of the engine neglected
  - driveshaft angles not correct
  - maximum engine displacements not correct
- **Elasticities in the suspension neglected**
- **No graphic output available**

Limitations of the ADAMS model

- **Engine Controller exists only in MATRIXx**
  - No controller optimization possible
- **Gear shift not possible**
- **Autocode not available**

MATRIXx Full Vehicle Model

Continuous SuperBlock	Inputs	Outputs
Simple_Vehicle	0	31

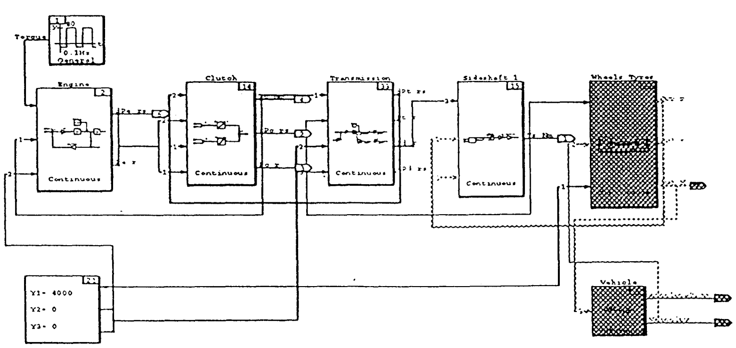


AVT Vehicle Systems
& Concepts Europe

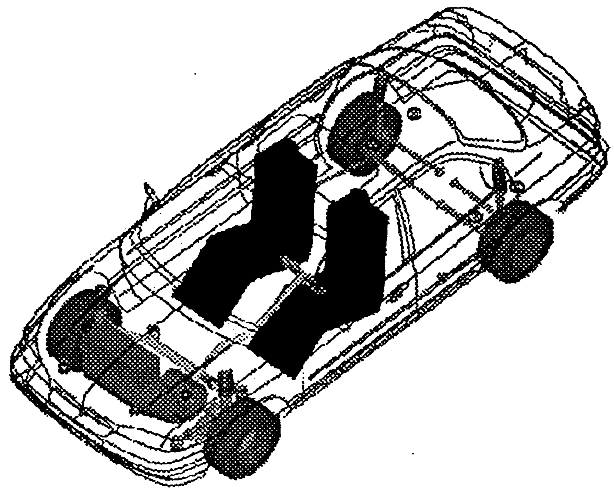
Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller
for Improved Simulation of the Vehicle / Powertrain Interaction
12TH EUROPEAN ADAMS USERS CONFERENCE
18. & 19 NOVEMBER, 1997

MATRIXx Driveline Model

Continuous SuperBlock	Inputs	Outputs
Driveline	0	8



ADAMS Full Vehicle Model



AVT Vehicle Systems
& Concepts Europe

Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller
for Improved Simulation of the Vehicle / Powertrain Interaction
12TH EUROPEAN ADAMS USERS CONFERENCE
18. & 19 NOVEMBER, 1997

Interface Possibilities

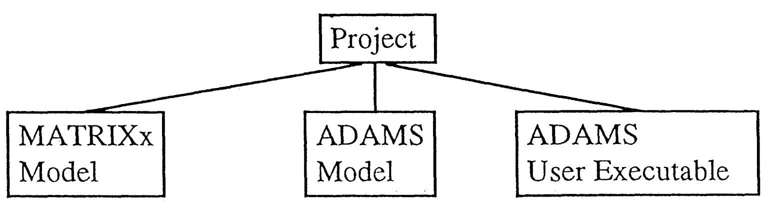
- **ADAMS as master**
  - Integrate an Autocode MATRIXx model as user subroutine in ADAMS
- **MATRIXx as master**
  - Linearize the model in ADAMS and integrate the linear full vehicle model in MATRIXx
  - Run both models from the MATRIXx user interface in parallel

Reasons to choose MATRIXx as Master Program

- **User already familiar with MATRIXx**
  - no detailed knowledge of ADAMS necessary
  - postprocessing in MATRIXx
- **Controller optimization possible**
- **Full MATRIXx content accessible**
  - Autocode does not support zero crossing block

AVT Vehicle Systems
& Concepts Europe
Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller
for Improved Simulation of the Vehicle / Powertrain Interaction
12TH EUROPEAN ADAMS USERS CONFERENCE
18. & 19 NOVEMBER, 1997

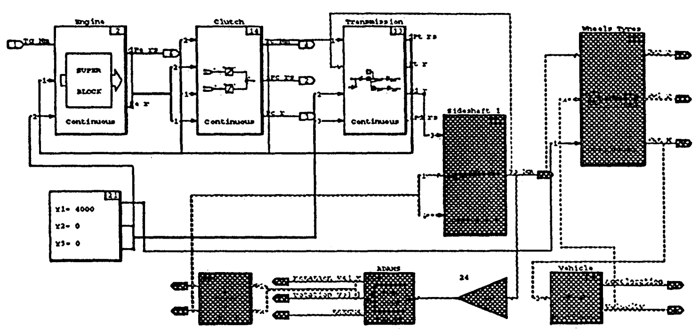
MATRIXx <=> ADAMS Interface
Directory Structure



MATRIXx Model	ADAMS Model	ADAMS User Executable
xmath_adams (by MDI)	start_adams (by MDI)	makefile_82_call
engine.model	CALL_ADM	call_adm.f (by MDI)
admusr.f (by MDI)	model.adm	reqcall.f
tire.cof	killadm (by MDI)	varcall.f
IDfile.com	mkpips (by MDI)	other usr.f
fromxm	rmpips (by MDI)	
toxm	adams.out	
simexe.lnx		

MATRIXx <=> Adams Driveline Model

Continuous SuperBlock	Inputs	Outputs
Driveline	1	15

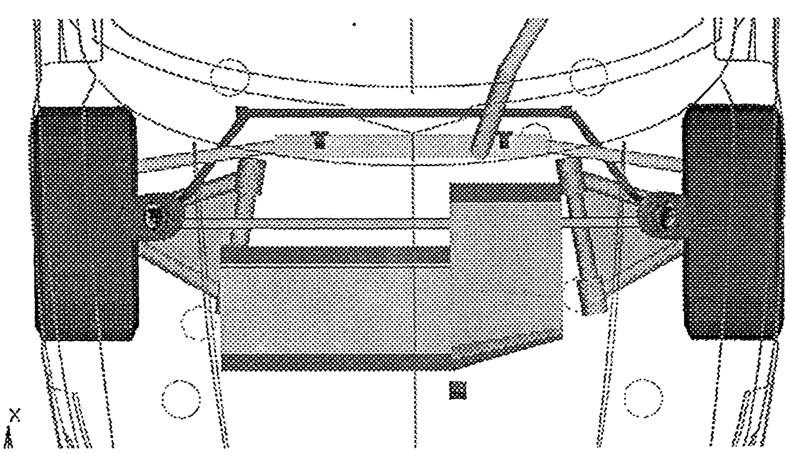


9

AVT Vehicle Systems
& Concepts Europe

Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller
for Improved Simulation of the Vehicle / Powertrain Interaction
12TH EUROPEAN ADAMS USERS CONFERENCE
18. & 19 NOVEMBER, 1997

Engine - Driveline Interface



10

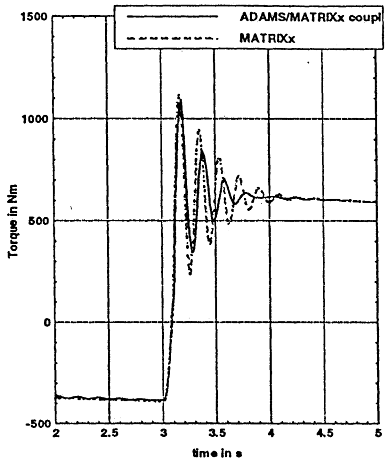
AVT Vehicle Systems & Concepts Europe

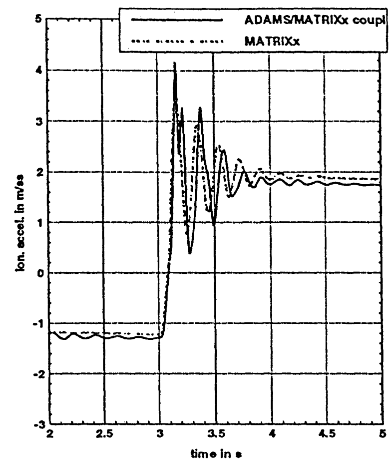
Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller for Improved Simulation of the Vehicle / Powertrain Interaction

12TH EUROPEAN ADAMS USERS CONFERENCE

18. & 19 NOVEMBER, 1997

Comparison of the Results





11

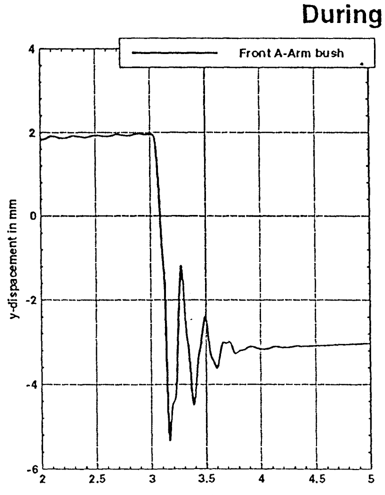
AVT Vehicle Systems & Concepts Europe

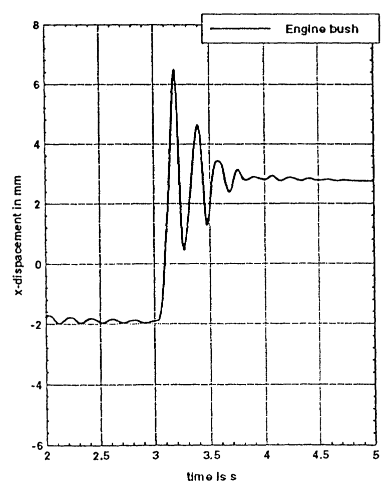
Integration of a Full Vehicle ADAMS Model and a MATRIXx Engine Controller for Improved Simulation of the Vehicle / Powertrain Interaction

12TH EUROPEAN ADAMS USERS CONFERENCE

18. & 19 NOVEMBER, 1997

Engine and Suspension Mount Displacements During Acceleration





12

Conclusion

- **MATRIXx & ADAMS Integration was successful.**
- **Combined model offers additional analysis possibilities.**
- **Optimize the ADAMS model to reduce required CPU time**
  - current CPU time on HP 9000
    - combined model app. 200 * real time
    - single ADAMS model app. 50 * real time
    - MATRIXx model app. 5 * real time
- **A fully integrated simulation in one software tool might be more efficient in terms of required CPU time but the proposed solution does not require additional CAE models because the ADAMS and MATIXx models already exist within Ford.**