Investigation of Drive Systems
Using ADAMS and MATLAB/SIMULINK

by

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INTRODUCTION

An electrical locomotive or even a multiple unit may be seen as a complex system containing electrical, mechanical as well as control subsystems. Followed by that a team of specialists has to work together engineering a new vehicle.

The point where electric meets mechanic is the air gap of the motor. There electrical energy has to be converted to mechanical energy. The environment of this point is often called as the drive chain. It includes at least:

- motor converter
- motor converter control
- asynchronous motor
- mechanical drive system, especially gear
- bogie
- rail-wheel-contact.

In some cases it is necessary to extend the definition by adding the line (catenary), transformer, line converter, line converter control on the electrical side and for example the track on the mechanical side.

It should be clear that no further improvement of one part mentioned above may be reached without regarding the other subsystems.

SIMULATION TOOLS

In order to reduce the engineering and commissioning expenses (time and money) different simulation tools have been used for a lot of years. Because simulation tools covering the mechanical side of the problem are well known there we would like to show the development on the electrical and control side on the example of Adtranz in Switzerland.

Simulation had always a big importance in the engineering process. Because the factory in Zurich-Oerlikon is the supplier of the electrical and control part the investigation and simulation of that part was the main point in the past. Very often a Hardware-in-the-Loop-Simulation (HIL) has been executed. That means that the original control system will be used and the power system is simulated by the computer.
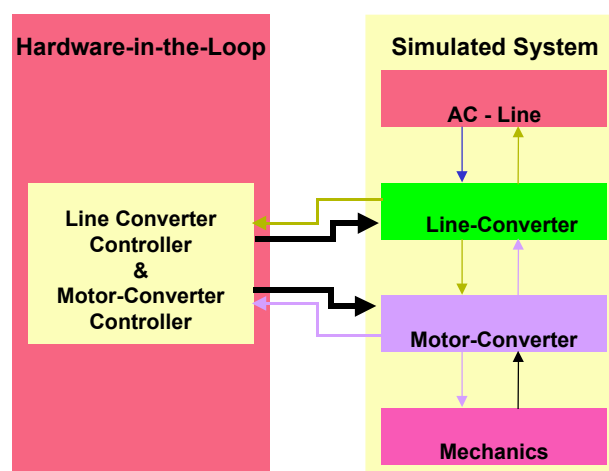

Figure 1: Hardware-in-the-Loop Simulation, Overview

This method clearly requires a high capability of the computer and also an interface between the computer and the control system. The used computer systems are listed below.

Period	Time	Kind of Simulation	Calculator, Language
BBC - times	until end of '80th	Analogue	Applied Dynamics AD 4
ABB - times	end of '80th - mid of '90th	Hybrid	EAI Simstar STARTRAN (similar ACSL) FORTRAN 66, FORTRAN 77
Adtranz - times	since mid of '90th	Digital	dSpace MATLAB/SIMULINK C
Daimler-Chrysler-Railsystems -times		Add-inns	ADAMS DYMOLA

Table 1: Hardware-in-the-Loop Simulation, History

In addition a lot of investigations is done outside the HIL-range but still using the tools and languages mentioned above.

Because the engineers in Switzerland are also responsible for the final assembly of the locomotives the simulation covered a small part of mechanics, at least a simplified mechanical drive system and the rail-wheel-contact. For example the rotational parts of a fully suspended drive (also referred to as hollow shaft drive) was described as a state-space-model with five rotational degrees of freedom (10th order ODE) .

As mentioned above the interaction between the different subsystems became more and more important. So different ways of improving our simulation capability have been investigated [1]. A number of simulation tools have been proven. Most of them pretended to solve all problems but no such "megatool" was found yet and is also not expected to come up in the future. Certainly each tool has its own advantages and most of them are able to solve problems outside of there main purposes. This is shown in figure 2. One other important point is that the engineers are most familiar with there "own" tools. If it is expected to use real synergy effects it will not be possible to advice them to use another tool.

So finally the solution is to search for the possibility to work together by using different tools. Having in mind that MATLAB/SIMULINK was in use some additional investigations have shown that using it together with ADAMS would fit the best our needs. One of the most important points is that ADAMS/Rail will be used also by our colleagues dealing with vehicle dynamics.
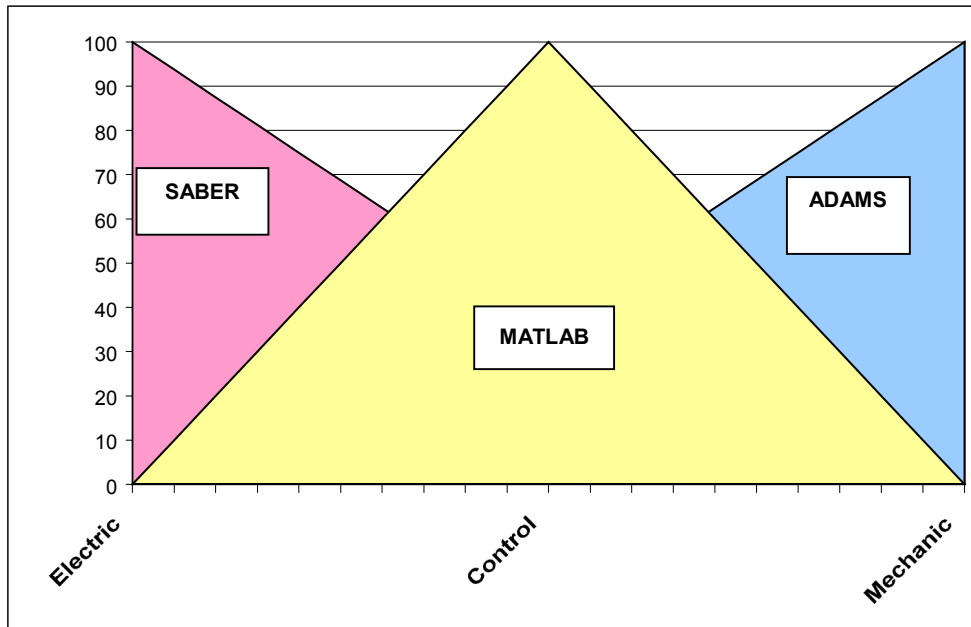
Figure 2: Examples of simulation tools and their favourite application

USING MATLAB/SIMULINK AND ADAMS TOGETHER

After the decision mentioned before the process of introducing and testing this way was started. It has not been finished yet and neither all features are tested nor in regular use. In principle the following ways of acting the tools together will be seen :

- Interchange of data
- Interchange of linear models
- Interchange of non-linear models
- Co-Simulation

The most advanced possibility of co-simulation was shown there last year [2]. Some examples for the other ways will be given now.

Interchange of data

This way will be preferred if the interaction between mechanical and electrical or control part are not very strong. Both directions can be used:

- MATLAB/SIMULINK output as ADAMS input
- ADAMS output as MATLAB/SIMULINK input.

An example for the first way is calculating the air gap torque in case of a short circuit with SIMULINK or more realistic obtaining these values from the HIL-Simulation. In order to get the loads and stresses in the mechanics they will referenced to the concerning torque.
In the opposite direction results of an ADAMS-Simulation may be used as an input for a SIMULINK description of a controller in order to check the correct work of the control algorithm. Beyond that the whole power of MATLAB's "Signal processing toolbox" may be used to generate spectra, correlation functions and so on.

Interchange of linear models

Actually this is the most common way of using the advantages of both systems together. Although both directions of interchange models as described before are possible the main point is obtaining linear descriptions of the mechanics. It is very easy to obtain the four state-space-matrices after running an ADAMS simulation an can be done just by simple "clicking" the button in the analysis toolstack. By that also some description files are generated.
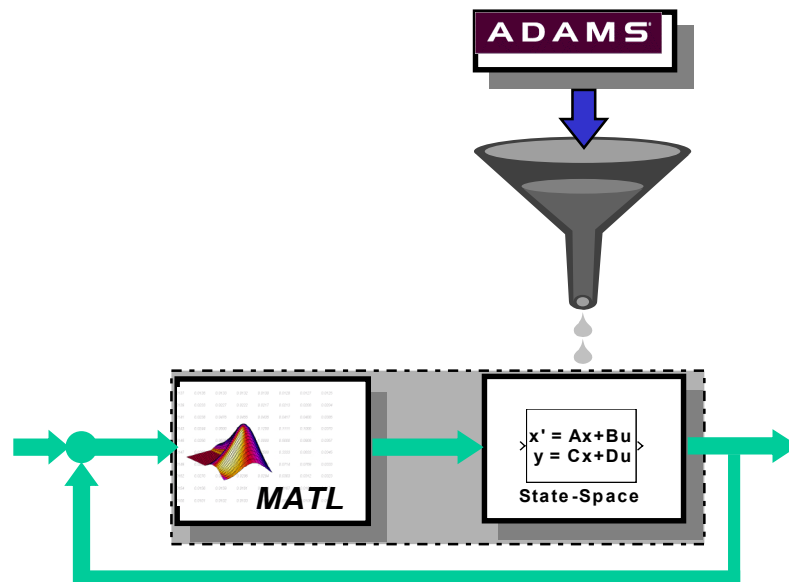

Figure 3: Interchange of linear models, ADAMS $\Rightarrow$ SIMULINK

But you have to think a little bit more about the steps before which are:

- Constraining the model
- Defining input and output variables
- Referencing the input variables by forces or torque (motions are impossible but not senseless)
- Containing the inputs and outputs within an appropriate structure

If you have to do this process regularly you will be worried that all four state-space-matrices have been in a separate file and you have to read in each single file. For the future we would expect that ADAMS uses the same structure like MATLAB describing a state-space model. Furthermore it is an disadvantage that ADAMS will not output the actual state vector which is necessary to set the SIMULINK-model into the correct initial conditions.

The opposite direction works nearly similar. If we want to obtain the state-space-description of a controller modelled with SIMULINK we may use MATLAB's "linmod" command and than saving the matrices to a file. On the other side ADAMS-Control provides the possibility to define a controller also by state-space-matrices.

Interchange of non-linear models

The Interchange of non-linear models is more difficult and actually works only in the direction MATLAB/SIMULINK $\Rightarrow$ ADAMS. In This direction we may use MATLAB's Real-Time-Workshop to produce the C-code of a non-linear electrical or control substructure. This code can be used within a subroutine in ADAMS.

A good example to demonstrate this possibility is the torque in the air gap of the asynchronous motor. It depends on the voltage and the angular velocity of the rotor. It has to be calculated as the product of the flux and current which are both states in the electrical model. For a two-axle bogie the feeding voltage is equal for both motors but the angular velocities are different. The result is a dynamical difference in torque.

BUILDING MODELS FAST

One step in improving the results of simulation is using more detailed models of the drive and bogie. The preferred way is to use the same models as used to investigate the vehicle dynamics. Due to different states reached in introducing ADAMS between different sites of the Adtranz company there are some difficulties yet. Fortunately the bogies and drives have are more ore less standardized. So the idea of a "kit" came up which allows to build models quick and easy. This idea was realised and now our library includes:

- Two- and three-axle bogie
- Two different types of primary suspension
- Three different types of the mechanical drive system
    - Nose suspended drive
    - Partly suspended drive
    - Fully suspended drive

In the following figures two examples were given. In the first one the primary suspension is shown. Also the dialog box is presented which allows to create or to even modify the geometry as well as the stiffness.
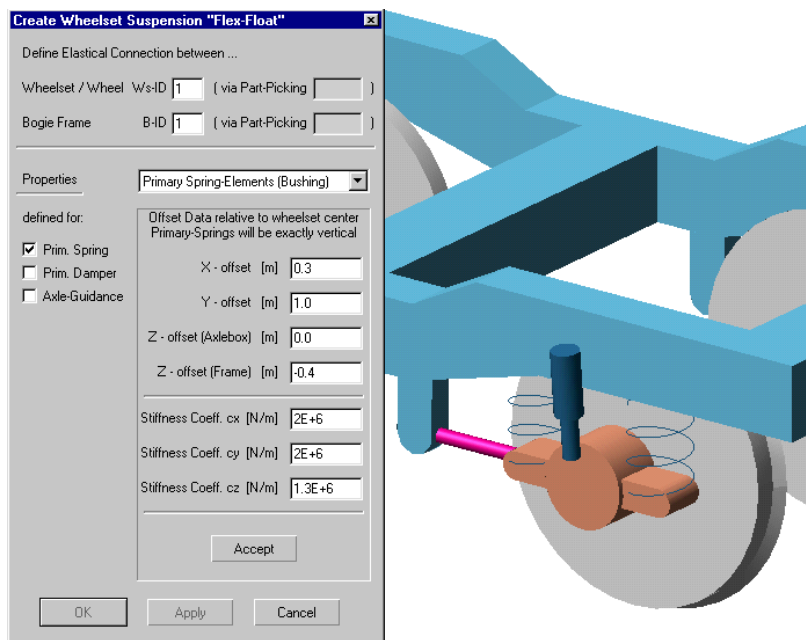

Figure 5: Primary suspension with dialog box

The second example shows a fully suspended drive with an intermediate gearwheel. To create this structure eight different dialog boxes are necessary. One of tem is also shown in the figure
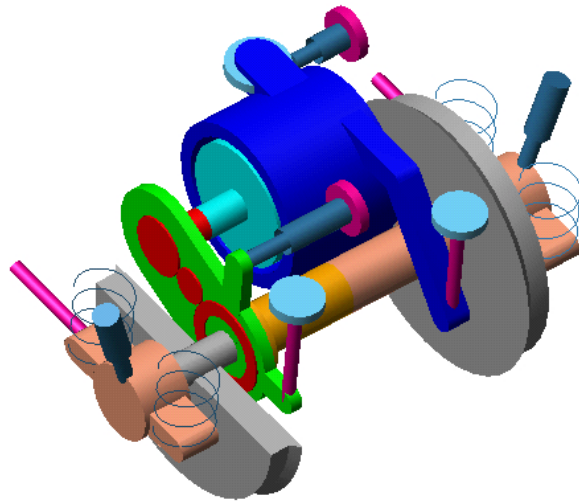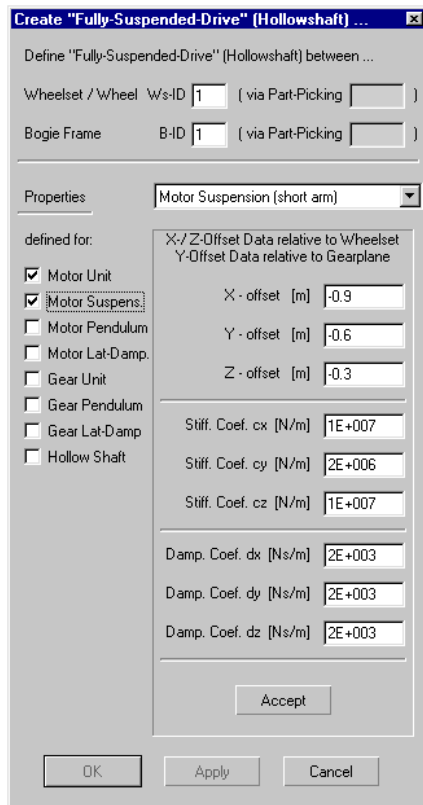

Figure 6: Hollow shaft drive with dialog box

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