Standardisation of the co-simulation of mobile machines with participation of different business partners

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Abstract

Modern products are characterized by an interdisciplinary development in fields like mechanics, hydraulics and controls. This development process can be optimized by using the coupled simulation. In this contribution facts will be shown why today the coupled simulation with more than two involved software tools is not used in the R&D process in mobile machine industry. Beside these facts methods of resolution will be described how a coupled simulation could work avoiding these problems. They are based on the idea of a simulation platform for a standardized coupled simulation.

Point of departure

The development of new products today is supported by the use of simulation tools. Actually in the research and development processes (R&D process) it has been shown, that the simulation tools can reduce research time and costs dramatically. So it is an intention of companies to support most of their research work with simulation methods.

The trend of simulation today is heading for the virtual prototypes, i.e. companies try to create complete simulation models of their products. Due to the example of a tractor the state of simulation shall be shown for companies in the range of mobile machines.

A tractor consists of a huge amount of components and small assemblies. The components are mostly supplied. The competence for the components sticks to the component manufacturer. The main competence of the vehicle manufacturer sticks to the integration of the components to the vehicle and their control. Beside structure and load tests of the vehicle with finite element methods studies of drive dynamics are done. The implemental tool is here the multi body simulation (MBS) software. For the simulation process the vehicle manufacturer has to build a virtual prototype with the supplied components or with the system reaction of the supplied components. However there is often a lack of parameters for the sub models or there is a lack of expertise in this particular range. The manufacturer also has to deal with a huge proliferation of variants and a low output. This must be economic with the simulation.

Because of the high complexity of vehicles and the different technical fields, like mechanics, hydraulics and controls to be dealt with, it is very difficult to create one simulation model of a whole vehicle in only one simulation tool.

State of the art

Over the years different methods of modeling a technical system have been developed. Today each technical field has his suitable established software tool to simulate. To deal with fact that modern products are characterized by an integration of different technical fields, a lot of specialized software tools have been enhanced to multi-domain-tools. Libraries of different technical fields have been added to the software tool. Thus the user is able to simulate complex systems with one tool.

On the other side interfaces have been developed to couple different software tools and by this way to couple different technical fields. This kind of simulation is called co-simulation or coupled simulation. It is based on the transfer of energy and power with the help of state variables. These variables describe the states of a system (e.g. position, pressure). They are time-variant and derived from the mathematical description of each sub system.

So with the help of the coupled simulation a user can create a simulation model of a system including different technical fields. In opposition to a multi-domain-tool simulation this kind of simulation uses specialized software tools for each technical field. Basically, the choice of the software of a certain technical field is free, only the communication variables have to match each other.

By using specialized software tools very detailed sub models can be created and therefore a very detailed model of the whole system. However with a more detailed model the calculation work and therewith the simulation time will be increased. Even a coupled simulation with very low detailed models needs more time to simulate in comparison to a simulation within one tool. And the user of a coupled simulation needs a special knowledge of this way of simulation. This knowledge is mostly lacking in mobile machine companies and they often do not have the knowledge of the supplied components. That is why the coupled simulation, especially the coupled simulation with more than two software tools, is not used in companies today.

However the coupled simulation offers the theoretical possibility next to a high detail level of the sub models that members of different bureaus, sections or even companies can work together on one simulation model because the whole system consists of several sub models that helps to dispose work. By doing this a special look should be taken to topics of know-how-protection and parameter and data administration.

To analyze these items a research project called GUSMA started on august 2008. The main topics of this project are the analysis if a coupled simulation with integration of different business partners could work and if this simulation method could be propagated and at least used in the range of mobile machines.

Project conception for the research project GUSMA

GUSMA is a German shortcut for the research project and means (translated to English): "Coupled Simulation of Mobile Machines between different business partners for the virtualization of the product design process". The project is sponsored by the Federal Ministry of Education and Research (Germany) and hosted by the Centre of Research Karlsruhe. Partners are the Professorship of Mobile Machines and the companies: AGCO GmbH, Hydac System GmbH, INTEC GmbH, LMS Germany GmbH and Fluidon – Gesellschaft für Fluidtechnik mbH. The main object of the project is the standardization of the coupled simulation procedure to simplify the simulation process, so that more users can work with this simulation technique in the range of mobile machines. A closer look will be taken to the know-how-protection of the sub models to realize a simulation with participation of different business partners.

The key-note of this project is a simulation platform where the coupled simulation should be done in a standardized way. The system to be simulated will be separated into parts of different technical fields. With the help of specialized and established software tools each sub model will be created and then exported in a platform compatible form. By exporting to platform and the associated conversion the know-how of the sub models must be protected. Ideally the numerical solver can be exported, too, so the sub model may run stand-alone.

The platform needs a graphical user interface (GUI). With the help of the GUI the user will be able to create the simulation model of the whole system by connecting each sub model. For this connection the user need to know the inputs and outputs of the sub models. A visualization of these values is necessary. In addition an administration of the sub model parameters as well as an identification of the initial values should be possible. An opportunity of data handling completes the requirement list of the platform.

Below the current state of the project is shown with a closer look to the simulation platform and the connecting variables.

Realization of the project objects / Status quo

In the project GUSMA the development of the standard for the coupled simulation will be acquired on the example of a hydropneumatic front axle suspension of a tractor. This suspension consists of mechanical, hydraulic and control elements. **Figure 1** shows the principle of the front axle suspension. A swing arm (2) is linked to a frame (1). The front axle (3) is located in the center of the swing arm and is able to oscillate. Both can swing to the frame. Two hydraulic cylinders (4) and three hydraulic accumulators (5) complete the front suspension. If the tire is moved up- or downwards, the plungers of the hydraulic cylinders displace oil to the accumulators. The nitrogen reservoir of the accumulator acts like a spring and the hoses and orifices act like a damper. A level control is added to the suspension. The setting of the level control is done by different pre-pressures of the chambers of the hydraulic cylinders. The suspension is able to deal with different load conditions.

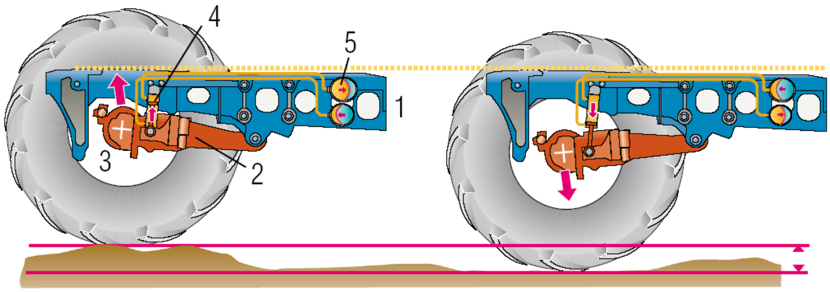

Fig. 1: Sketch of a front axle suspension [1]

The mechanical sub model of the front suspension is built by the vehicle manufacturer with the MBS-tool SIMPACK. It consists of the frame, the swing arm, the front axle and the cylinders. He also creates a sub model of the level control with Matlab/Simulink. The hydraulic manufacturer creates a hydraulic sub model with the software tools AMESim and DSHplus. It consists of the cylinders, the accumulators and the hydraulic power supply.

The simulation of the whole system will be done as a coupled simulation by the professorship of mobile machines. In this project the professorship imitates the vehicle manufacturer. The software tool for the platform is Matlab/Simulink for a start. In Matlab/Simulink there is a graphical user interface with visualization tools and possibilities of data handling. In addition Matlab/Simulink is widespread especially in control technique simulation.

For the simulation of the whole system the sub models will be connected to each other by the intercommunion of the state variables. **Figure 2** shows an example of such a whole system. This example consists of one mechanical, two hydraulic und two control sub systems. The inputs and outputs are shown for each sub model.

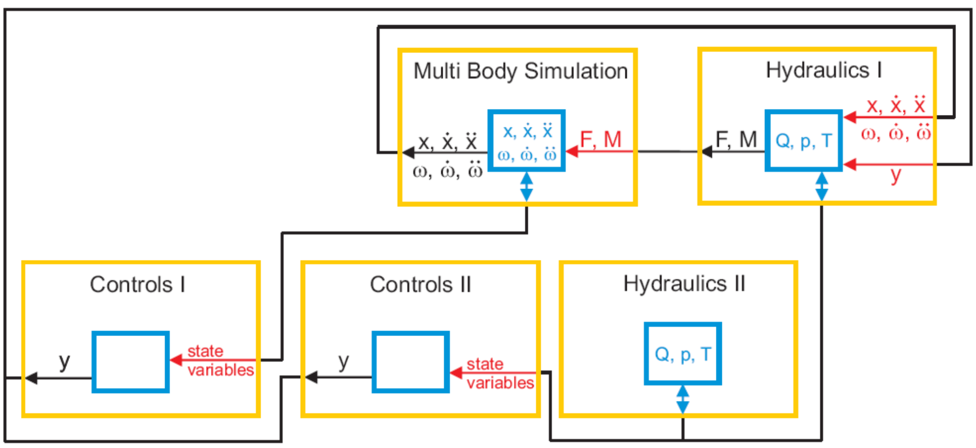

Fig. 2: Structure for the coupled simulation

The basic principles to this structure are the energy and power transfer between the sub models. On the platform a connection of sub models of different or of the same technical fields is possible. The communication variables can be differed into internal variables (inside a technical field, blue arrow) and external variables (between different technical fields, black arrows).

One main aspect for the creation of a sub model is the parameterization of the model. Parameters are time-invariant values and used for example for the description of geometrical issues. There are three kinds of parameters in project GUSMA. Protected parameters can only be seen and changed by the model creator. With their help the know-how-protection should be realized. Alterable parameters can be changed by every user (e.g. size of a damping orifice). This allows optimization calculations for the user. At least there are the common parameters. These parameters appear in different sub models. They have to be set by the user once and then will be used in the whole simulation model.

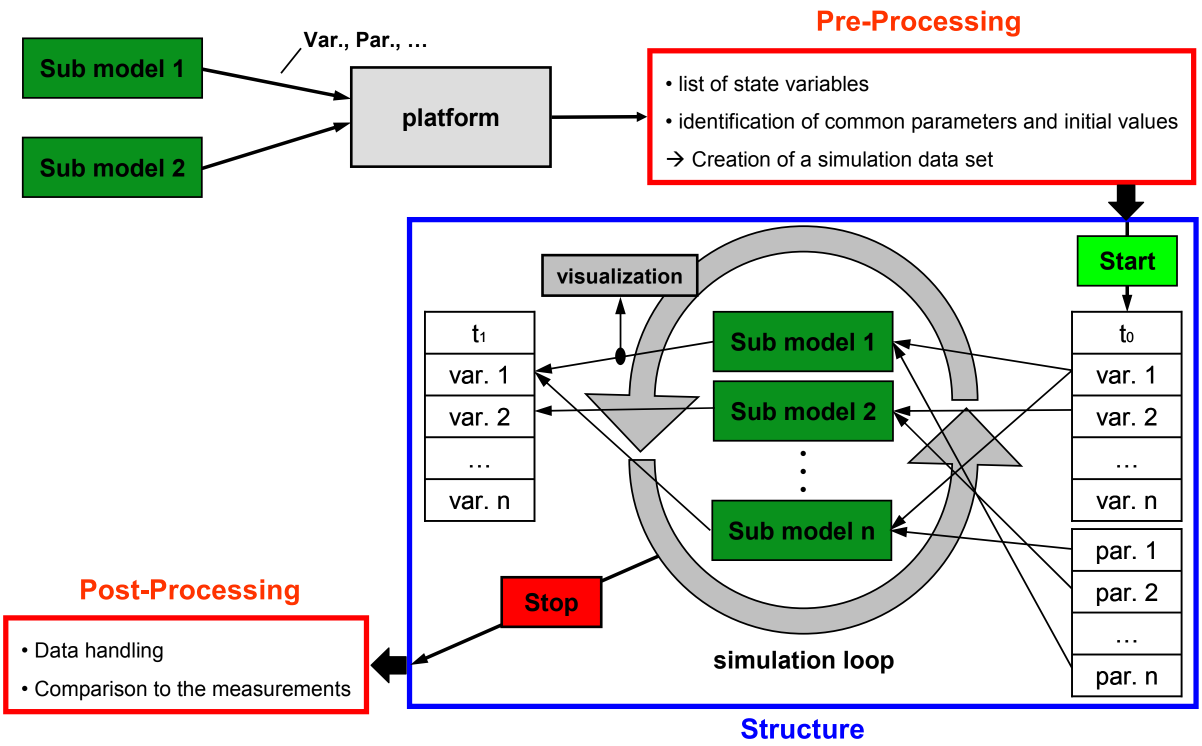

Fig. 3: Procedure of a standardized coupled simulation

Based on this the subsequent described procedure results for the standardized coupled simulation and is shown in **Figure 3**. Each sub model has to be brought onto the platform and connect to each other so that the whole system can be occured. Then a pre-process will start. In this pre-process every input and output variable will be visualized and the initial values will be calculated on demand. Common parameters will be identified and linked together with the alterable parameters. The simulation data sets created in the pre-process will be transmitted to the sub models in the following initializing process. After that the simulation model is ready to run. During the simulation run the simulation data will continuously be stored. A visualization of these data will also be possible. At the end of the simulation run the simulation data will be saved in one or more data files. These files can be used for the post-process.

Profits of the standardization

The vehicle manufacturer will be able to create a virtual prototype of his vehicle. He occupies the know-how of the supply companies and gets a detailed model of the whole vehicle with validated sub models.

The component suppliers can boost their market position because they are able to deliver hardware and software without worrying about the leak of their know-how. They will also be able to test their sub model with the whole vehicle in the simulation, so they can align their sub model to the customer requests.

The software producers enhance their products and align their software to the customer requests. So they can deliver the demanded interfaces earlier than their market opponents. They also have the possibility to configure the interfaces.

Outview

Since the project started a concept for a standardized coupled simulation on basis of a platform has been worked out and the today's results have been shown. The creation of the sub models is completed. Next the creation of the whole simulation model by connecting the sub models has to be done. The simulation results will be compared to the measurements and a validation of the sub models have to be done.

The communication between the connected sub models need to be checked. So there will be some research studies on the communication interval. On basis of this operation advises for the coupled simulation will be derived. The software producers adapt their interfaces to stick to the new standard. In addition graphical user interfaces will be programmed to allow the pre-process.

Literature

[1] -.-: Fendt – eine Marke der AGCO-Corporation. Internet: http://www.fendt.com/index.php?id=09434c27b1711863a43efcdaf5c6b383d7e13a320b1149b172&l=1, Stand 20.06.2007.