Energy balance based Verification for Model Based Development

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This paper focuses on a new model verification method for Model-based development (MBD) using cross-sectional tools. GAIO technology Co. Ltd. (GAIO) have pushed Model-Centered Development (MCD) which targets tool developments and services for MATLAB based MBD and UML based MDD (Model Driven Development) so far. Especially, MCD ver.1.0 concentrates on the controller models whose code is mainly described by MATLAB/Simulink. The next generation, MCD ver.2 targets not only the controller models but also the plant models. For example, MCD ver.2 targets co-simulation based on the plant model composed of various simulation models such as MATLAB/Simulink, Mathematica, Maple/MapleSim, IMG-CarMaker and so on. This results in the expansion of test area not only unit tests of Function Mockup Unit (FMU) but also integration tests of Functional Mockup Interface (FMI). So, GAIO needs to enter a new stage of model verification and have to introduce new test insights.

The accuracy of MBD depends on the accuracy of the model. Typically, the accuracy of the model is categorized by two. The first is the correctness of the program code which realizes model. The second is the correctness of the law of physics which is realized by model. The former has been checked by a typical program verification method including unit tests and integration tests. The latter focuses on that ideal simulation models realize some physical laws. "The energy balanced verification" method proposed by Miyamoto et al. 2014 checks the energy balance of the model according to the fact that the energy conservation laws hold for no error models. That is, if the no error model has no internal loss energy, the total energy difference between the inputs and outputs will match the stored energy. Otherwise, the conservation law does not hold. Even if the hybridization and electrification of automobiles make system structure complexity, the energy conservation laws do not change. This paper introduces the energy balance based verification as a new model test concept for MCD ver.2.

This paper introduces a prototype system that streamlines the workflow of the energy balance verification method. The method checks on the input-output relation of each module consisting the model to calculate energy quantity. In other words, the model expression considering the energy relation leads to efficient energy balance check of the model. Then, this paper proposes a hierarchical diagram and an energy flow diagram of the model. The former categorizes modules of the model according to energy conservation laws. The latter expresses the energy flow relationship between modules. The prototype system supports the energy balance verification based on the two diagram. To verify the validity of the proposed system, we consider the mild hybrid electric vehicle (MHEV) composed of MATLAB/Simulink, MapleSim, and IMG-CarMaker as shown in Fig. 1.

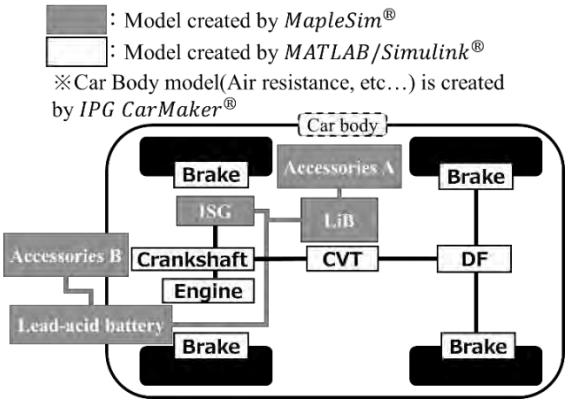

Figure 1. MHEV model.

The verification procedure is as follows:

I. Construct the hierarchical diagram of the model.
II. Energy calculation via the simulation.
III. Construct the EF diagram.
IV. Construct the energy balance checking equation and the loss energy checking equation.
V. Carry out the unit and integration tests.

We developed the prototype system carries out from Step III to V: Tool α and Tool β in Fig. 2.

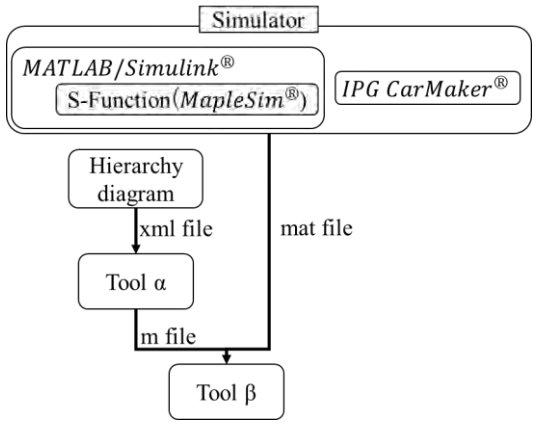

Figure 2. Data flow between tools.