Transmission Development – Applying the MBD Method with SimulationX

Isao Tabushi
Honda R&D Europe, Offenbach am Main, Germany

Abstract

This paper shows the use case of SimulationX as part of the MBD method applied to the development of an automotive transmission. It explains three stages of the development within the MBD method and one example of an efficient modelling approach in SimulationX. At the first stage, requirement allocation and property analysis are done through simulation in order to check plausibility of the top requirement and a combination of requirements for each component. For the second stage, functional requirements and safety requirements can be simulated in SimulationX with the same model. For the third stage, model-based calibrations can find the best solution of trade-off relationship requirements. Such aspects should be considered at an early stage in the development. Furthermore, re-using elements will make modeling more efficient. The MBD method supports these early considerations.

Introduction

In recent times, our products have become subject to growing requirements from our customers and environmental regulations. Meeting these requirements can be very time-consuming as they are often connected with each other. If we solve one of the requirements, it may have an undesired effect on another requirement. So, we need to organize these requirements in order to derive the next requirements for each functional layer. On each functional layer, it is necessary to think about what is needed to solve the requirement from the upper layer. At the same time, these needs become the requirements allocated to the next lower functional layer. So, we need to check if the lower layer's requirements can be met and whether the upper requirements are solved or not. If not, we need to go back to the upper layer to find a solution or reduce the requirement level. Doing this for the prototype product is extremely difficult, because lower functional layers are already fixed by the upper functional layer. Therefore, we need to use a method of model-based development (MBD).

MBD Method with SimulationX

Requirement Allocation and Property Analysis

As an example, Figure [1] shows the model of an automotive transmission for the requirement "Accelerate from 60 km/h to 100 km/h in 6 s". The hardware model is created in SimulationX, and the software model is generated in Matlab Simlink & Stateflow integrated into SimulationX as a model-in-the-loop simulation (MiL). In our case, we defined the vehicle's resistance, maximum engine torque characteristic, gear ratios (as HW model), and transmission controller logics (as SW model). For each component, the requirements from above are divided and allocated. After that, we can simulate the combination of these parameters in a property analysis. If there is only one requirement for the vehicle, it is conform in itself. But there is a multitude of requirements that are allocated to several components at the same time. Therefore, we need to check whether these requirements are met or not. If not, we need to reconsider the corresponding requirement which had been divided and allocated. At worst, we need to discard one of the top requirements which has a trade-off relationship. That allows plausibility checks of allocated requirements for each component already at the design stage.

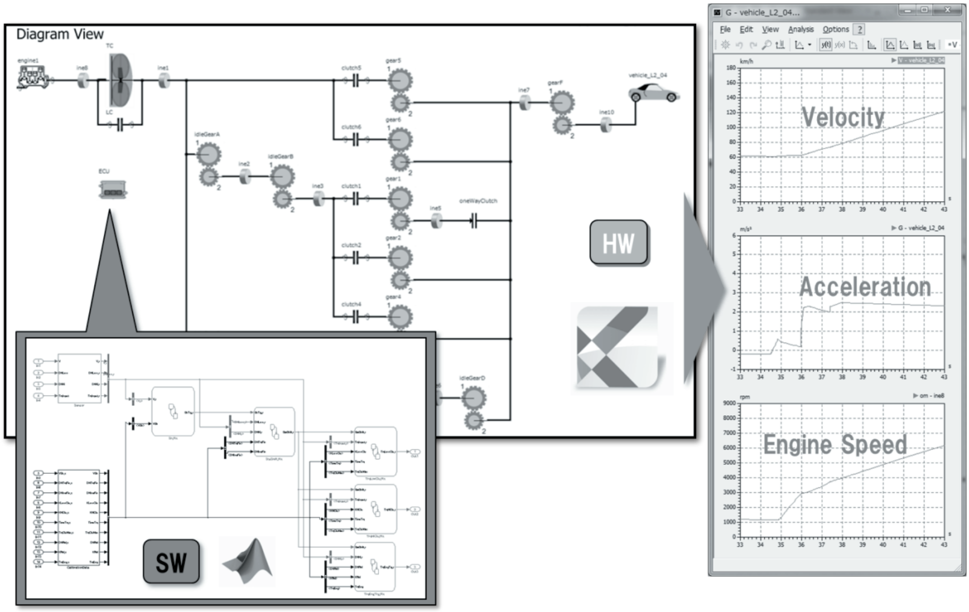

Figure 1

Functional Requirement and Safety Requirement

Figure [2] shows the model of a hydro-circuit for an automatic transmission. This hydro-circuit has to meet many requirements from transmission components, for instance, to control six clutches through a low number of electric control solenoid valves, with additional requirements for minimal friction, the necessity to control three clutches at the same time, and so on. These functional requirements can be simulated by using SimulationX.

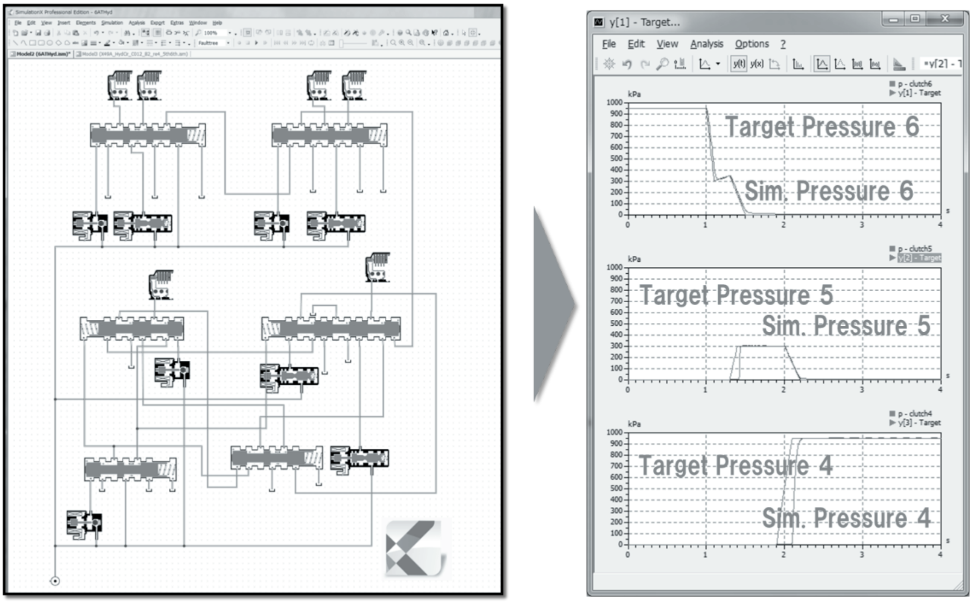

Figure 2

There are also safety requirements like to not engage two clutches at the same time as this may cause tires to lock or lead to abrupt deceleration. By using the Safety Designer, it is easy to determine situations which must be avoided. For each element of this model, it is necessary to specify failure modes and propagations of failures affecting other elements. Figure [3] shows the result of FTA & FMEA. Once we have the results from FTA & FMEA, we can assess how to avoid those situations.

SimulationX allows us to use the very same model to check functional requirements and safety requirements. In our case, we ran the Safety Designer to check the effect on safety requirements when functional requirements were changed. Changes deriving from safety requirements are dealt with in the same way.

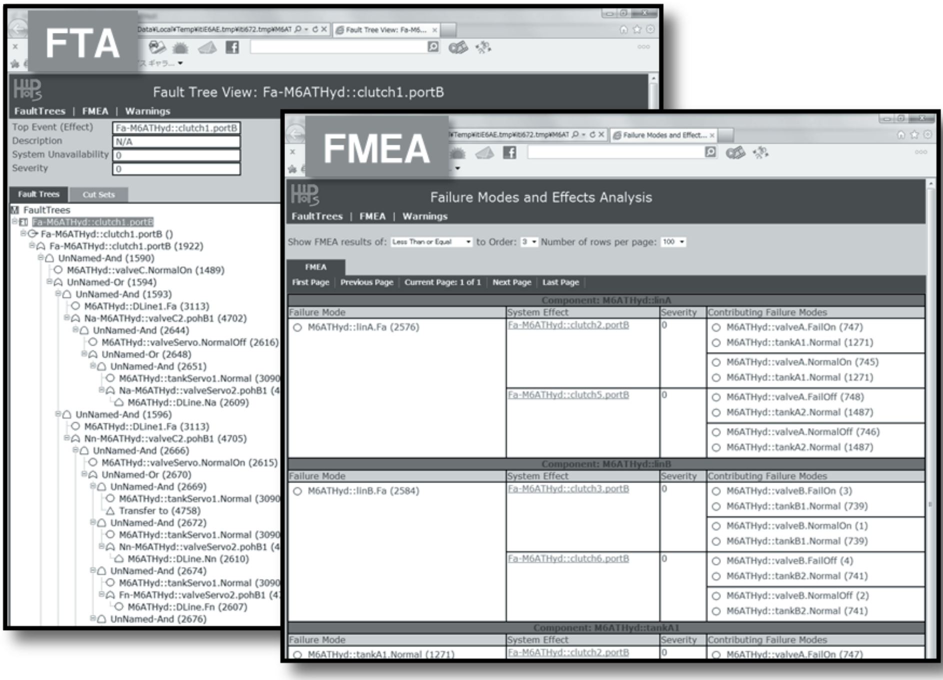

Figure 3

Model-Based Calibration

Figure [4] shows the workflow of optimization tools in modeFRONTIER including the SimulationX model. The SimulationX model is the same as in Figure [1]. This workflow illustrates optimization steps for shift comfort and clutch heat damages. We evaluated shift comfort from the vehicle's acceleration, and clutch heat damages from energy losses and power losses at the clutch.

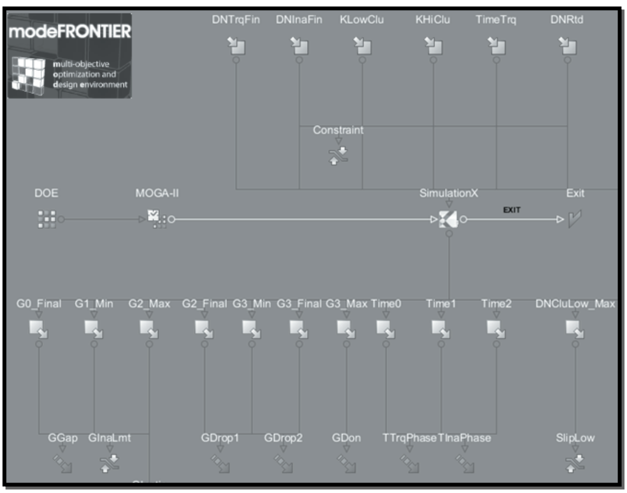

Figure 4

Running the SimulationX model through the modeFRONTIER workflow for several iterations, we could optimize the involved parameters. These parameters and the results are shown in a parallel coordinate plot (Figure [5]). All of these results are Pareto solutions. By doing so, we could get best results for shift comfort and clutch heat damages for any set of parameters. What is more, the engineer could evaluate from the relationship of each parameter which point should be the target requirement even though it had a trade-off relationship.

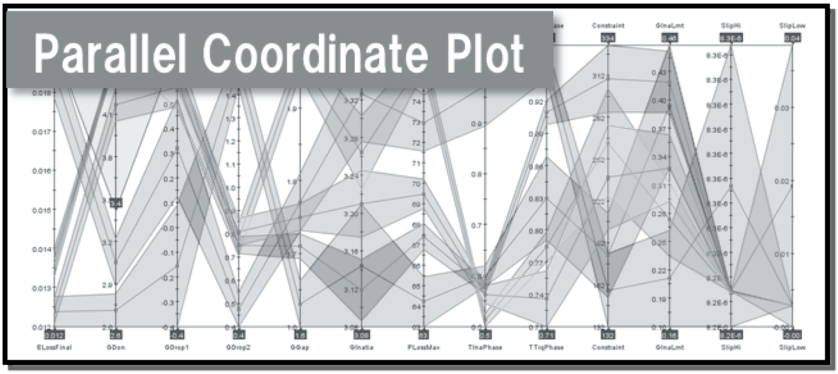

Figure 5

Custom Built Library

For our products, we may use some components in the next product version, with a few modified parameters and the same requirements, but just change the target values. In order to be more efficient during the development, we made our own custom built library. For example, electrical control solenoid valves in Figure [2] have functional requirements to control oil pressure through a given current value. At a later stage of the development, further requirements are added such as the delay between actual pressure and target pressure to be less than a few seconds. And further down the line, the model level is changed in order to reflect changes of the form requirements in the level of detail, such as valve diameter, spring rate, and so on. Within SimulationX, it is easy to create new elements and to manage such elements. That allows us to easily re-use elements through drag-and-drop with each functional & safety requirement properly defined.

Summary

The MBD method applied with SimulationX enables front loading and eliminates a time-consuming trial-and-error approach at a late stage of the development process. It supports us in the assessment "What requirements are to be allocated where?", "How to realize requirements?", and "Which requirement is more important". These points need to be discussed at the design stage. By the help of simulation tools, it is easy to discuss and achieve a suitable design. These methods become inevitable in order to keep up with more complex requirements and the growing complexity of system development.