

GPGPU-Based High Performance Parallel Computation Method for Valve Body Failure Mode

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ABSTRACT

The method that enables a Simulink model to execute parallel computation by using GPGPU technology is introduced.

The GPGPU, General-purpose computing on graphics processing units, is a technology to accelerate program by using graphic card instead of CPU computation.

This method was developed to reduce the time to detect failure mode of automatic transmission's valve body.

The valve body is the major part of automatic transmission. It is extremely important to confirm the functional safety of automatic transmission in the case that any parts of valve body failed. We have developed Simulink-based valve body failure mode simulator, and made a considerable contribution for this work.

However, the number of failure mode is increasing recently. Therefore, we made the simulator to compute at a high-speed using GPGPU technology.

We have sharply reduced the computation time and strengthened the computing ability to support the detection for an increasing amount of failure modes. In addition, we have automated almost a whole detection process and have made the simulator easier to use and scalable from now.

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INTRODUCTION

Role of Valve Body

The valve body plays an important role for both shift quality and functional safety of automatic transmission.

Figure 1 shows the structure and functional flowchart of valve body. It is composed of fluid channels through which ATF flows and a number of valves to regulate oil pressure or to switch the fluid channels. ATF stands for Automatic Transmission Fluid, and is the oil used for automatic transmission. The controls of automatic transmission are done via ATF. For example, in shift sequence, electric signals from transmission control unit are input into solenoid valves. The solenoid valves regulate ATF oil pressure. Regulated ATF is supplied to a desired clutch/brake through fluid channels via some switch valves. The switch valves also switch drain channels to drain fluid unnecessary ATF.

Supplied ATF engages clutch/brake and drained ATF releases clutch/brake. The clutches/brakes are installed to planetary gear sets. By engaging and releasing the clutch/brake, the gear shift is achieved.

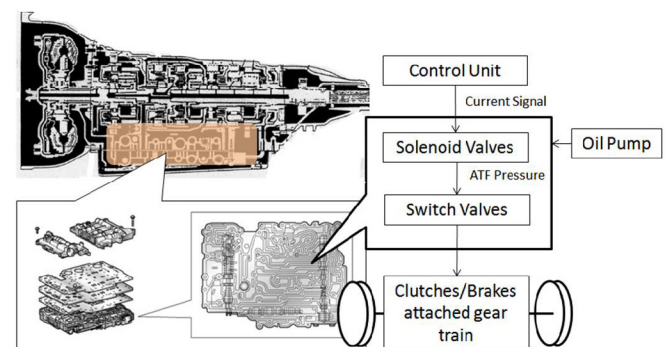


Figure 1. Structure and functional flowchart of valve body

Importance of Failure Mode Detection

A valve body is an important part which directly affects gear shift quality. It also influences the safety of the vehicle. The design which can maintain the safety driving, even when any part of valve body failed, is demanded.

For example, when the valve stuck failure occurred, (This failure means that the valve in the valve body gets stuck and becomes uncontrollable.) the ATF was supplied to the clutch/brake that is not expected to and engagement that is out of the design occurs. Or, when the electric wire that connects between the controller and the solenoid valve is disconnected, the solenoid valve is forced to be returned to the initial status.

Failures may occur at any timing when driving. Failure situation can cause a sudden change of gear ratio. In the worst case, planetary gear sets can be locked up that may cause the sudden deceleration of the vehicle. To avoid these troubles, the prior safety confirmation of valve body in all possible failure modes is essential in the development of automatic transmission.

MOTIVATION

It is important to confirm functional safety of valve body when any valve failed. However, there are various situations on driving and there are various valves in valve body. Usually, the number of failure modes is large and therefore, a large power of work needs to be achieved.

We developed the Simulink-based valve body failure mode simulator for this work in the past and have contributed to evaluate the functional safety of automatic transmission. It took approximately one week to finish this work.

Figure 2 shows one example of detail of used time. Computation time was most part of used time.

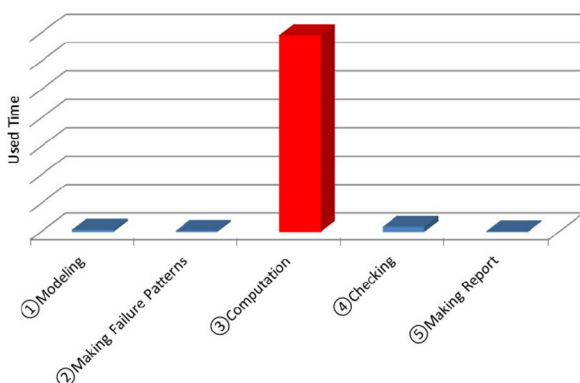


Figure 2. Time that takes for each procedure

In addition, the valve body is often used under more advanced software control recently. It makes the evaluation work more complex and it is often required to be performed under more various conditions. As a result, the number of failure modes has increased largely.

In order to support the increasing amount of failure modes, we worked on the speedup of the simulator. We tried parallel computation approach. Because each failure mode is independent, the computation algorithm which corresponds to target valve body is common for all failure modes. Therefore, we thought that this simulation style would be easy to shift from serial to parallel computation.

In this paper, we used GPGPU technology. The paper explains about the developed simulator. Then, it explains major point of our speedup activity.

ABOUT VALVE BODY FAILURE MODE SIMULATOR

In this section, we explain the details of the valve body failure mode simulator.

Why do we use Simulink?

In the valve body development process, a professional valve body engineer designs valve body structure and usually expresses it as a hydraulic circuit diagram.

For non-Simulink program language such as C language, a programmer has to understand a hydraulic circuit diagram. Then, he translates the diagram to programming language he uses. Because the programmer needs to have an advanced skill, an expert is needed to operate the simulator.

To be able to operate the simulator without an expert staff, we decided to use Simulink for hydraulic circuit program. Using Simulink, the programming becomes easier. It can be done by simple mouse operations, such as placing Simulink valve blocks on Simulink model editor. Then, it is also easy to connect based on the hydraulic circuit diagram. An example of the modeling is shown in Figure 3.

The design process of valve body sometimes takes several design changes. Therefore, the flexibility for design changes for specification change is very important for the simulator. In the case of Simulink-based programming, design changes are easily performed by replacing or adding valve block, and changing connection or changing parameters. These changes are also visible. Therefore, the Simulink-based programming style does not depend on programmer's personal skill and an error is hard to occur.

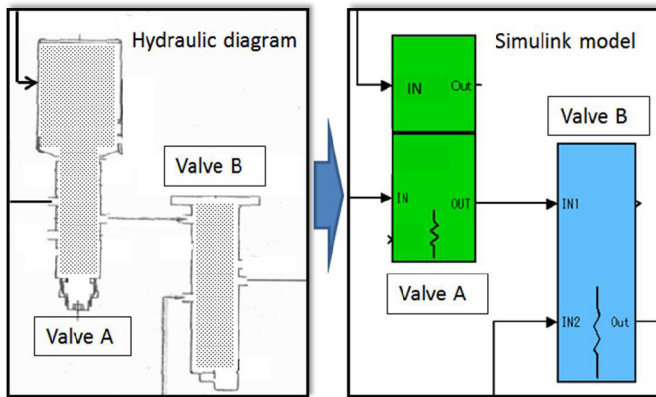


Figure 3. A sample image of modeling. The programming can be done by simple drawing work based on the diagram.

Flowchart of whole of work (Before speedup)

Figure 4 shows the flowchart of the entire failure mode investigation work before it is speeded-up. The computation is done by each failure mode consecutively.

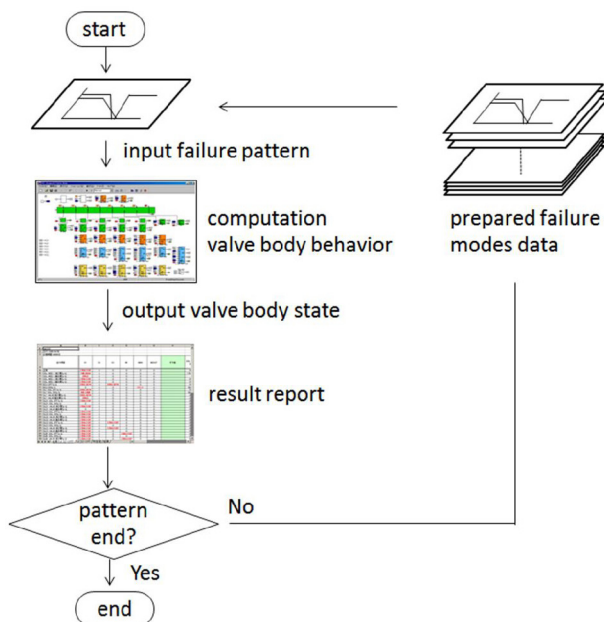


Figure 4. Flowchart of the entire failure mode investigation work (Before speedup)

Overview of Valve Body Model

In this section, details of valve body Simulink model are mentioned.

Figure 5 shows top layer of valve body model. This model has three blocks, shown on Table 1. It is important to maintain this model structure for automation which is described below.

Table 1. Explanation about valve body blocks.

1.Signal generation block	This block generates solenoid control signals to force a valve body on target condition and also generates failure trigger signal.
2.Target valve body block	This block is a target valve body hydraulic circuit. The internal state and output are calculated by this block.
3.Output block	This block is a set of output ports and is also an interface to other software.

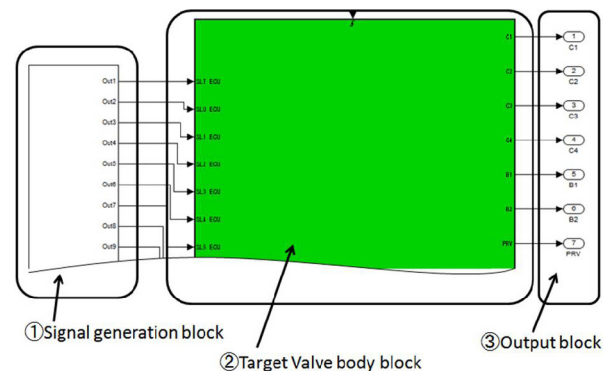


Figure 5. Overview of a valve body model

Modeling of Signal Generation Block

Signal generation block generates two types of signals. One is the solenoid valve control signal which corresponds to electric signal from transmission control computer. The other is the failure trigger signal.

A valve body hydraulic circuit is driven by solenoid valves. In other words, solenoid valve control signal is input to valve body. Therefore, the internal status of any valve body can be simulated by solenoid control signals, such as any gear step ratio or any shift sequence.

Failure trigger signal changes valve to an abnormal condition. A valve model includes sub models corresponding to some failure behavior and these are selected by trigger signal. Therefore, the desired failure conditions in any valve at any timing can be simulated by failure trigger signal.

Figure 6 shows an example of signal generation block. In this example, a generated signal has a maximum of three phases.