

# Generating Driving Signals of a Virtual Test Rig for Replication of Physical Target Signals using RecurDyn/TSG Toolkit

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We made a VPG (Virtual Proving Ground) in order to do a vehicle test using RecurDyn as Fig1. Left side of the Fig1. shows a physical test. And right side of the Fig1 shows a virtual test rig. On the environment of VPG, the physical test is defined that a virtual vehicle moves a virtual road consists of some triangle shaped surface. Then we can get acceleration signals of vehicle. We select the 2 directional accelerations to the target signals. We will find the driving signals for inputs of the virtual test rig to replicate the target signals of the physical test using RecurDyn/TSG (Time Signal Generator) toolkit. We will introduce the process of finding the driving signals. Another name of this process is called the TWR (Time Waveform Replication).

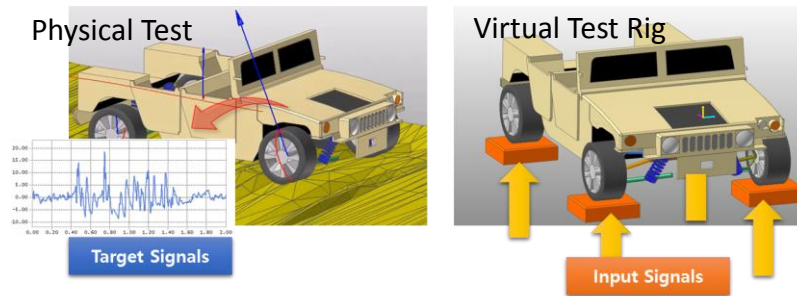


Fig. 1: An example of VPG for a vehicle test

In the test rig, the actuators which are inputs of the system are defined 4 point displacements on the vehicle tires. The sensors which are outputs of the system are defined 2 directional accelerations like as the physical test. Before the finding the replication driving signals, the system identification is needed. It means a finding process the FRF (Frequency Response Function) of the test rig system.

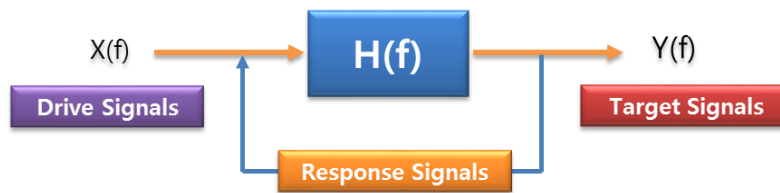


Fig. 2: Configuration of the virtual test rig system

Where,  $X(f)$ ,  $Y(f)$ , and  $H(f)$  are the driving signals, the sensor (or target) signals, and the FRF, respectively. The FRF  $H(f)$  can be calculated using following equation.

$$\mathbf{H}(f) = \frac{\mathbf{Y}(f)}{\mathbf{X}(f)} \tag{1}$$

All the signals are defined in frequency domain. Therefore, the time domain signals must be converted to the frequency domain signals using the FFT (Fast Fourier Transform). In the system identification process, the

simulation is needed. First simulation in the system identification process, the first actuator signal is defined only a swept frequency signal with changing from 1 Hz to 50 Hz with time changing and the other actuators are defined all zero. Because, we must check an independent influence of first actuator. Therefore, the number of simulation is the same to the number of actuators in the system identification process.

Theoretically, if we can get the inverse of the FRF  $H(f)$ , then we can calculate the driving signals in order to replicate of the target signals using following equation.

$$\mathbf{X}(f) = \mathbf{H}^{-1}(f)\mathbf{T}(f) \tag{2}$$

Where,  $\mathbf{T}(f)$  is the target signals.

The number of actuators (=system inputs) and the number of sensors (=system outputs) are usually not the same. The number of actuators are selected equals or more than the number of sensors. Therefore, the FRF  $H(f)$  is usually rectangular complex matrix. For calculation the inverse FRF, we use a pseudo inverse based on a SVD (Singular Value Decomposition).

The result  $\mathbf{X}(f)$  of Eq. 2 is called a first driving signals. The simulation result has a still errors using the first driving signals. The errors are defined subtracted values from sensor signals by target signals in time domain. In order to reduce the errors, we need to do iteration simulation. Figure 3 (a) shows the iteration simulation process. The next driving signals is defined as following equation.

$$\mathbf{X}_{i+1}(f) = \mathbf{X}_i(f) + \alpha\mathbf{H}^{-1}(f)\mathbf{E}_i(f) \tag{3}$$

Where,  $i$ ,  $\alpha$ , and  $\mathbf{E}$  are the iteration number, a learning factor (0.5 is used), and the errors in frequency domain, respectively.

And the Fig. 3 (b) shows a RMS errors in 10 times on each iteration simulation.

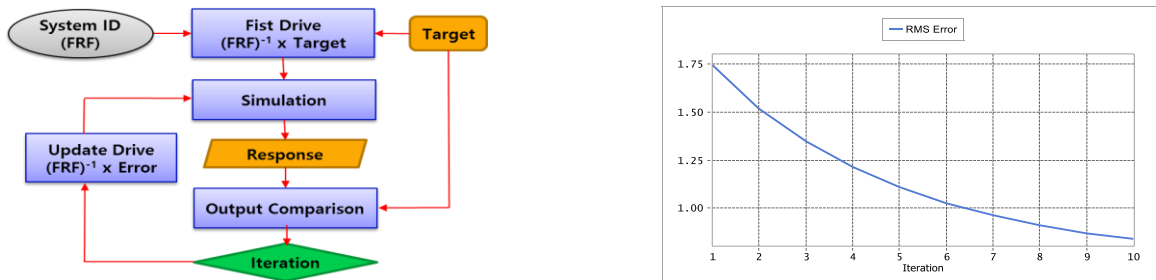


Fig. 3: (a) Iteration simulation process (b) Simulation result – RMS errors on each iteration

Figure 4 shows comparisons with both target signals and sensor signals on 10 times simulation result. There's still existence of errors. But, the signal tendency is similar and the RMS error are acceptably small.

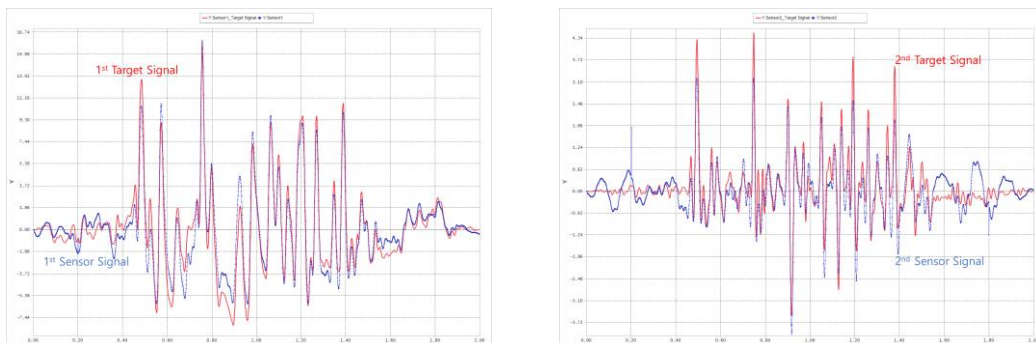


Fig. 4: Target and sensor Signals of 10 times simulation

## References

[1] RecurDyn TM Online Help Library : <http://www.functionbay.co.kr/documentation/onlinehelp/default.htm#!Documents/tsg.htm> , 2017