



Highly flexible HIL simulators can fulfil the demands of testing a variety of agricultural vehicles

Testing On Demand

Electronics and software have become core contributors to innovations for today's agricultural vehicles. With the growing scope and amount of testing, developers nowadays face great challenges when developing software. Japanese agricultural machinery manufacturer YANMAR tackled these challenges with a comprehensive HIL simulation based on SCALEXIO and other dSPACE products.



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Food demand is increasing due to a growing population. However, arable land is limited, and farming populations are in decline. Nowadays, improving land and labor productivity has become a pressing challenge for farmers. The Japanese manufacturer YANMAR contributes to solving the farmer's challenges with their company products, such as tractors, harvesters, and planters. The agricultural vehicles with high efficiency and functionality help farmers shorten labor time, minimize harvesting loss, and increase yield.

High-Performance and Easy-to-Use Harvesters

Rice harvesters have combined functions for reaping, threshing, and grain separation. They are also optimized for rice farming to perform high-speed and low-loss harvesting. Despite the functional complexity, YANMAR rice harvesters are easy to use and can be operated without stress thanks to a multitude of features for drivers (figure 1). The steer-by-wire system is one of the features that gives the driver the intuitive feeling of a passenger car. Depending on how far the driver rotates the steering wheel, the vehicle performs smooth movements, ranging from a gentle turn to a spin turn by adjusting the direction of movement and the speed for each of the two crawler tracks. It allows the vehicle to run perfectly along the field lane. Another example is the automatic chassis. It works to keep the vehicle body horizontal and deliver maximum performance during reap-

ing and grain separation, even if the vehicle chassis tilts on a soft paddy field. Automatic adjustment of grain separation is a feature of the newest model. A chaff sieve is a device that separates rice grains from straw chaff. Harvest loss changes depending on the sieve aperture and the reaping speed (vehicle speed) during the operation. A sensor detects the amount of loss at the end of the chaff sieve and in return the system automatically adjusts both parameters to minimize the harvest loss. A monitor helps the driver observe how the harvest loss decreases after the adjustment.

Challenges for Software Developers

Electronics and software have become the core contributors to developing the agricultural vehicles with these impressive features, and now the software developers at YANMAR play important roles in introducing innovations. Comprehensive testing and validation therefore involve a growing scope and amount of work, while the developers had to overcome multiple challenges at once: First, they had to eliminate gross errors even before a vehicle was used for field tests, because, for some types of vehicles, the real test drive can be performed only for a limited period of time. For example, if any defects were found during the test drive of a harvester, the rework for the software revision would raise the risk of losing the opportunity of retesting during the harvest season.

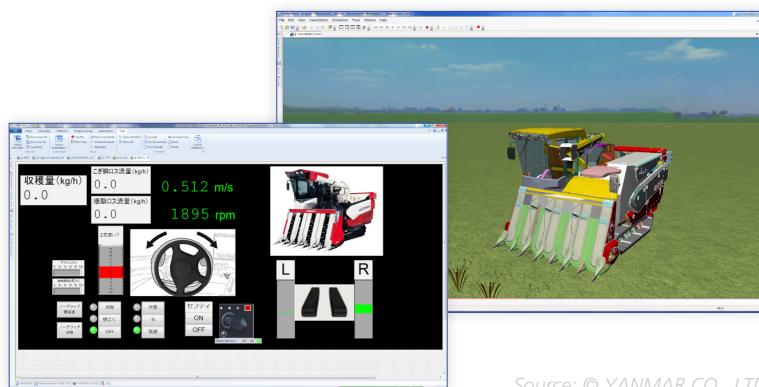
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Figure 1: A YANMAR rice harvester has many features to benefit farmers, such as a Steer-by-Wire System for low-stress and smooth maneuver (top) and Automatic Chassis to keep the body horizontal (center). Automatic Adjustment of Grain Separation is the feature of the company's newest model: the rice grains threshed by a drum are separated through a chaff sieve adjusted to minimize harvesting loss (bottom).

Figure 2: YANMAR uses ControlDesk (lower left) to create an intuitive user interface for HIL simulation. MotionDesk (upper right) provides a realistic visualization of the vehicle motion that results from the user input.



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Second, they had to test a vehicle in complex working conditions, such as different conditions of paddy fields or various types of rice plants. It would be time-consuming and expensive to recreate these conditions for real test drives with the real machines.

Quick Setup of a HIL Simulator

To meet these requirements, YANMAR opted for a hardware-in-the-loop (HIL) system with dSPACE SCALEXIO. The HIL simulator enables them to test all the functions of electronic control units (ECUs) without a real machine and to cover a wide range of vehicle operations in realistic working conditions. YANMAR introduced the HIL systems in two steps: In the first step, the company commissioned a simulation environment for a tractor in 2015. In this setup, a central processor rack was complemented by three I/O racks for the engine and vehicle controls as well as the display instruments. Functionalities for the evaluation of the harvester followed in 2016, and two I/O racks were also added. By simply adding I/O boards to the I/O racks, the system finally covers the physical aspects for all ECUs, bus systems, and electric loads of the vehicles.

Sophisticated Software Tools

On the virtual model level, while YANMAR relies in part on their own libraries of vehicles and environment models, the company uses diesel engine and exhaust libraries of the dSPACE Automotive Simulation Models (ASM) to simulate the diesel engines and the exhaust gas aftertreatment. The libraries are perfectly adjusted to the YANMAR models. The models can be distributed across multiple processor cores for the simulation to optimize computation time. To monitor and control the HIL simulation, YANMAR uses ControlDesk and MotionDesk from dSPACE. While ControlDesk gives the test engineers customized instru-

ments and an intuitive user interface, MotionDesk lets them realistically visualize all movements of the simulated agricultural vehicle in a three-dimensional environment (figure 2). To reduce work efforts even further, the HIL tests can also be automated to a great extent. This is done with dSPACE AutomationDesk. YANMAR set up a test automation framework with the assistance of dSPACE. It allows them to implement new test cases quickly, where they have to do nothing more than updating the test parameters, such as the given input and expected output signals.

Highly Flexible Multi-Vehicle and Multi-Domain Systems

In the meantime, YANMAR has made the modular SCALEXIO HIL system even more flexible. Instead of using I/O racks that are tailored to certain functional aspects, such as an engine or vehicle components, YANMAR uses standardized ‘Master I/O Racks’, each of which has the exact same set of hardware interfaces. Various combinations of the Master I/O Racks can cover the entire range of YANMAR agricultural vehicles. Vehicles to be tested are different from moment to moment depending on plans for new product launches. If a sufficient number of Master I/O Racks is available, the developers can use them to set up precisely the HIL system required for the task at hand (figure 3).

Benefits and Outlook

The flexible and extensible dSPACE SCALEXIO system contributed to the



A set of standardized Processor/Power racks and Master I/O racks

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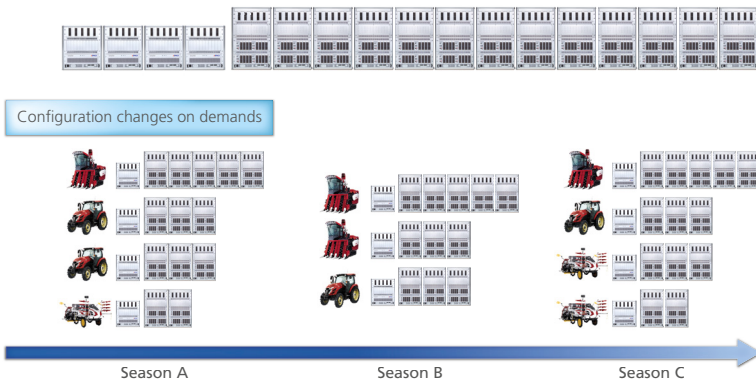


Figure 3: While YANMAR initially used task-specific I/O racks for HIL simulation, they now exclusively use identical Master I/O Racks. Each set of functions of an agricultural vehicle requires a certain number of the Master I/O Racks.

quick setup of the HIL simulator for YANMAR. A mere six months passed from ordering to the first commissioning in late 2015. The HIL simulation and the test automation revealed hidden software defects without the real machines and reduced the workload of testing. It allows the developers to focus more on the analysis of errors. With the successful introduction for the tractor and the harvester as a start, they set up the HIL system for a variety of agricultural

vehicles. The more flexible Master I/O Racks enable YANMAR developers to set up HIL systems by themselves. The racks are also used to test more innovative functions, such as tractors that can drive autonomously. After all, thanks to efficient simulation solutions this is just one more area in which agricultural vehicles are on par with modern road vehicles. ■

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“The flexible, highly scalable SCALEXIO system and the sophisticated software tools from dSPACE quickly gave us the great benefits of HIL simulation.”

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