Control Development for Marine Diesel Engines

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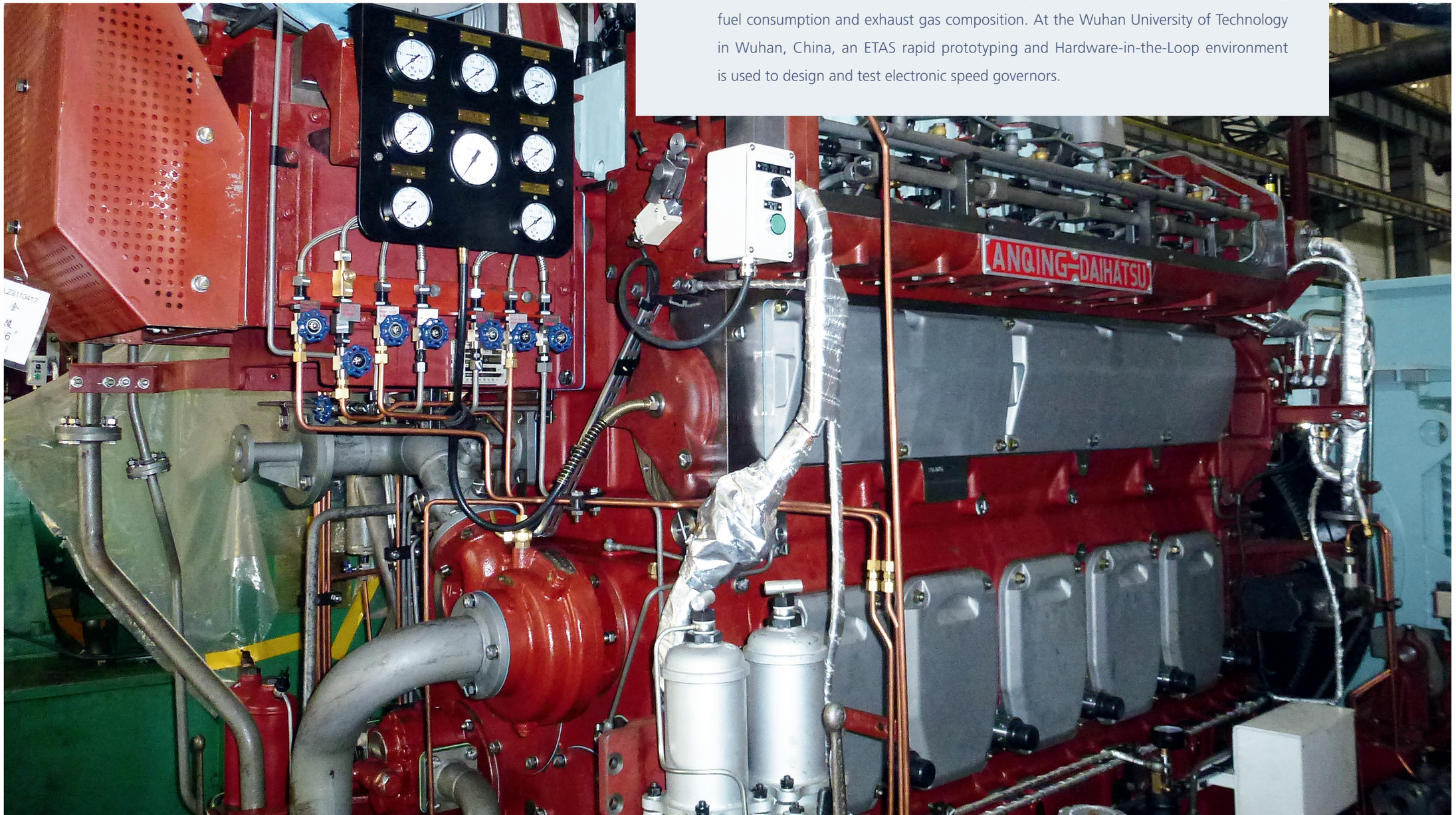
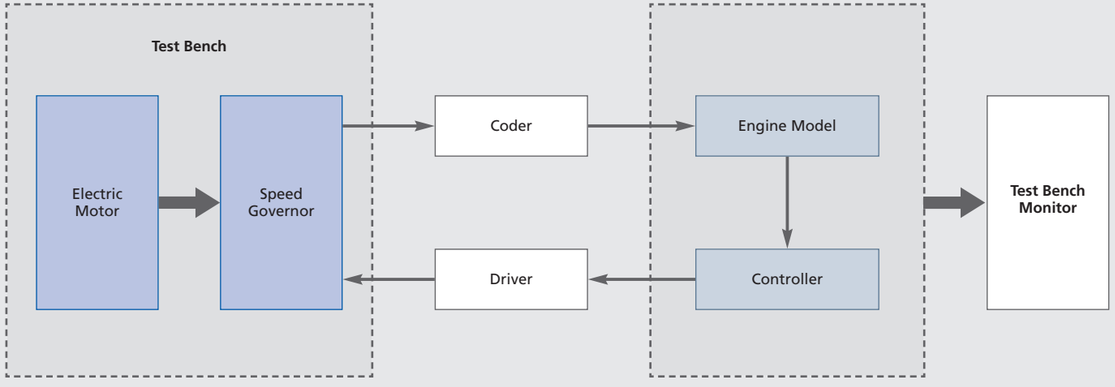
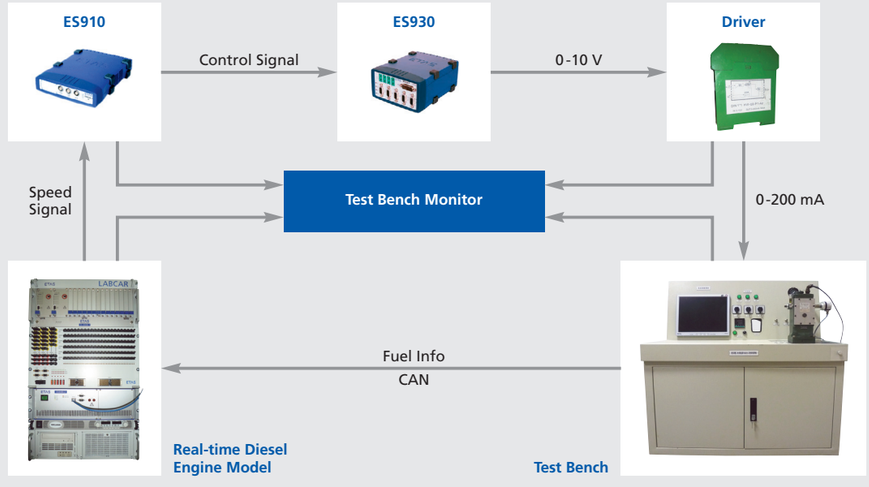
ETAS tools enable Wuhan University of Technology to develop electronic speed governors for marine diesel engines

The efficiency of an engine control system represents a key issue in systems development for both automotive and marine applications. In marine diesel systems, speed governors are important components that enable the tuning of the injection performance, affecting fuel consumption and exhaust gas composition. At the Wuhan University of Technology in Wuhan, China, an ETAS rapid prototyping and Hardware-in-the-Loop environment is used to design and test electronic speed governors.





HiL architecture used
at Wuhan University of Technology



Hardware platform
deployed for HiL testing

In newer medium-speed marine diesel engines, electronic speed governors are becoming increasingly popular thanks to their quick response, flexible configuration options, and data communication capabilities. At the laboratory, jointly operated by Wuhan University of Technology and ETAS, teachers and students designed electronic speed governor systems, incorporating ETAS ASCET, ES910, and ES930 for prototyping and as target hardware as well as ETAS LABCAR for Hardware-in-the-Loop (HiL) simulation. The objective was to have the entire platform available for researching electronic speed governor control strategy and testing actuator components.

ETAS software engineering and testing solutions provided an integrated development environment for control efficiency, enabling Wuhan University of Technology to advance their research activities. Because the flexibility of the ETAS tool chain facilitated an easy adaptation from automotive to marine applications, it supported Wuhan University of Technology during the entire development cycle.

Developing the control strategy

ETAS ASCET, ES910, and ES930 help to increase efficiency and, at the same time, reduce the challenges of developing the control strategy for the speed governor. ES910 is the rapid prototyping hardware module that runs the control software on the basis of different control strategies created in ASCET. The system provides several control functions:

Startup control: When the engine speed reaches the minimum startup limit, in terms of the open-loop control logic and setting curve, the controller will quickly move the oil rack forward to increase engine speed. Once the speed reaches the startup limit, the close-loop control logic will retract the oil rack to make the engine run at idle, which completes the startup control.

Rated/idle control: A switch can be used to select the working state of the engine between rated and idle. When the switch is on, the speed will accelerate to the time-based setting curve. When the switch is off, the speed will drop down to idle in terms of the time-based setting curve.

Load control: This is accomplished by first tuning the PID (proportional-integral-derivative controller) parameters to stabilize the no-load engine speed, then record the current differential coefficient and integral coefficient. The load is then changed to 25 percent, and tuning is restricted to the proportion that ensures stable engine speed. The same approach is then used to tune the load to 50, 75, 90, and 100 percent, where the 5-point proportion coefficients are noted and subsequently placed on the drawing of a proportion tuning curve. As the engine load increases or decreases, the proportion coefficient will change in accordance with the curve. In a Hardware-in-the-Loop (HiL) system, all PID parameters need to be calibrated.

Protection control: To protect the engine from overload and prevent smoking, the injection quantity limit function is implemented. When the engine is overloaded at a given speed, the controller will limit the oil rack movement to decrease the speed. If the load still increases, the oil rack will move back according to the limitation curve until the engine stops.

HiL testing

The ETAS LABCAR testing system permits the testing of both the speed governor characteristic and control algorithm on the test bench. The HiL platform includes the test bench, a self-developed real-time diesel engine model running on the ETAS LABCAR-RTPC, as well as the speed governor control module and the monitor system.

The HiL test bench uses a hydraulic actuator and a frequency conversion motor. An encoder is used to get the position signal of the actuator shaft and convert it to the injection quantity. The real-time diesel engine model provides the sensor signals such as speed, temperature, and pressures. The ETAS LABCAR-OPERATOR Experiment Environment is used as the monitoring system for measurement and calibration. The real-time diesel engine model meets the testing accuracy requirements and provides necessary boundary conditions for the test bench. The ETAS LABCAR HiL testing system is used for testing both speed governor characteristic and controller functions.

The following tests have been realized:

Actuator characteristic testing: The controller outputs a step signal. The monitor system checks the actuator displacement. There is a delay from the step signal to the actuator response. The larger the step signal increases, the longer the delay time.

Startup testing: The engine is started and allowed to idle, and the startup curve is recorded. The results are then checked in the ETAS Experiment Environment. The overshoot rate, settling time, and other parameters all meet specifications.

Sudden load change testing: After tuning the PID parameters, the speed response follows the sudden load change (0-100 percent, 100-0 percent) within an acceptable interval.

Summary

Using the ETAS rapid prototyping and HiL system, the laboratory team of Wuhan University of Technology was successful in setting up a complete development environment and test bench for electronic speed governors for medium-speed marine diesel engines.