The study of hardware in the loop on the development of Vehicle

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Abstract—In this paper, it is introduced the current status and development trend, combines the vehicle development process, and studies the application of hardware in the vehicle development, providing the direction for the future vehicle project development and information teaching reform.

1. Introduction
With the rapid development of computer technology, many types of simulation techniques and methods are also produced in the vehicle project development and information teaching. How to better apply these simulation technologies, how to improve the simulation accuracy, expand the scope of verification, and choose the most suitable vehicle plant research and development system of the simulation technology, is the urgent need for engineers to establish and improve the ability at present.

The application of hardware in the loop (HIL) technology in vehicle development is a typical of many emerging simulation technologies. Its application in vehicle project development is an important research topic for vehicle engineers.

The application of hardware in-ring technology in the vehicle development can save a lot of development costs, shorten the vehicle development cycle, and provide a favorable guarantee for new models to seize the market.

2. Hardware in the loop (HIL) technology introduction
Hardware in the loop (HIL) technology is a semi-physical test simulation technology in the loop, which is a simulation technology that transfers the road test to the powertrain laboratory, that is, the simulation technology of the calibration and development of the powertrain and ECU, VCU vehicle controller instead of the simulation model[1]. It can provide a more accurate theoretical reference for the whole vehicle development process, especially the matching and verification of the powertrain, and greatly reduce the road verification task and risk of the whole vehicle, so as to achieve the purpose of shortening the development cycle and reducing the development costs.

HIL technology is a total of six simulation platforms: powertrain hardware in the loop, VCU/ECU and other controllers development hardware in the loop, hybrid hardware in the loop, body stability system (ESP) hardware in the loop, body electronic hardware in the loop, power steering body electronic hardware in the loop. That is, the bench simulation test conducted after the vehicle without the engine or transmission components can be connected to the analog signal of the engine or transmission, and the actual operating condition test can be simulated on the rack. It can be divided into three stages of vehicle
performance verification for testing, early-medium-late, real-time, authenticity, accuracy are also increased[2].

Hardware in the loop (HIL) technology is a method of testing, analyzing and evaluating vehicle performance along with the development of electric control technology and needs to be derived, and it is a manifestation of hardware in loop simulation technology (i.e. semi-physical simulation technology)[1]. It can provide a cost-fast verification platform for vehicle performance research and development. The quasi-real (semi-physical) of vehicle performance through electric control and semi-physical simulation on the platform has the advantages of consistency, dynamic and real-time.

![Fig 1 Vehicle system integration and virtual simulation environment](image1)

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![Fig 2 Gasoline engine vehicle model under the HIL simulation test](image2)

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3. The status of hardware in loop simulation technology

Abroad, in July 2008, AVL and VOLVO in Lyon, France, first worked together to apply the hardware in ring technology represented by engine in ring simulation technology to a new truck development test, and AVL then launched its own hardware in ring product in the software model (INMOTION hardware system and the CARMAKE) in the Chinese market. At the same time, because dSPACE and ETAS, the mainstream suppliers of hardware in the ring platform, occupy an absolute market advantage in this field and have a large number of user groups, AVL also cooperated with the two companies to focus on the in-ring simulation testing and analysis services of domestic platforms.

AVL has conducted a lot of research on hardware in the ring simulation test. Its engineers tested the complex road fuel consumption in the ring platform and the actual road platform in Graz, southeastern Austria. The research results show that the error between the simulation test value is-2.4% (Fig. 3), with the results and the actual vehicle road test results[3].
At present, the hardware in the ring simulation technology has been widely used and promoted abroad. With various hardware in the ring (the loop, the engine and the powertrain in the loop), domestic joint ventures often place this part of the platform resources abroad (such as pan-Asia) to strengthen the control of core technology.

In China, the universities and independent brand car companies relying on the mainstream suppliers dSPACE and ETAS are gradually orderly established hardware in the ring platform, its focus is on the development and verification of control system, the traditional automobile hardware in ring simulation technology (belongs to the middle stage) research is few, most of the new energy vehicle platform research (belongs to the initial stage).

Based on the platform in the ring simulation technology, China automobile center (tian jin) automotive engineering in January 2011 first began the platform capacity construction and test method exploration, in recent years, some larger vehicle enterprises (SAIC, BAIC, GAC, etc.) in this respect capacity construction is also gradually accelerating, which SAIC has applied the hardware in the loop simulation technology to the performance development of a newly developed hybrid model.

In all, the hardware in-loop simulation technology will play an increasingly important role in the future vehicle performance development process. Build and in-depth research of the platform application methods and technology will provide more favorable help to enterprises in the future model development, the construction of the platform not only for the vehicle's professional capacity construction and provide help, model development cycle, performance verification will be more favorable, will make the process of vehicle development of modules more effective, convenient and economical.

This technology can be combined with vocational education in the project, and the simulation technology can effectively improve the students' practical and theoretical ability with less resources.

4. The development trend of the vehicle development process and hardware in the ring simulation technology

With the extensive application and penetration of electric control technology in the automotive field, the current vehicle performance development process has shifted from the traditional structural design to the performance design, gradually promoting the vehicle project into the positive development mode. In the early stage of product development, conduct relevant calculation analysis and test research on the main performance, and propose the corresponding design indicators and requirements to the design department of the whole vehicle in the design engineering stage, to guide the positive development of the whole vehicle, and ensure that the indicators of all stages of the development process meet the set objectives. Real-time tracking and feedback of the vehicle performance in this process is crucial, which directly determines the development cycle, cost and risk of the project, in this context, the hardware in the ring simulation technology emerged at the historic moment. In 2016, AVL analyzed and predicted various test technologies in the vehicle development process, which showed that the future application of hardware in ring technology will increase sharply, especially the application of powertrain in ring technology and new energy vehicle controllers, and the actual road test task will be reduced (Fig 4).
Fig 4 Current and future vehicle development and test tasks are compared

5. **Research purpose and significance of hardware in ring (HIL) technology**

In the whole model development process, the development of powertrain is the top priority. The development of general model powertrain selection is mainly to determine powertrain torque, power to select the engine, transmission, considering resource, technology, quality, cost, etc., form feasible 3-5 proposals, and then layout and use Cruise one-dimensional simulation software for performance simulation calculation, determine the primary speed ratio, and then real vehicle road test evaluation, to achieve the final speed ratio selection. When selecting other components, because such simulation software has large errors, the selection range cannot be narrowed through simulation calculation. For example, when the catalytic catalyst type selection is impossible, or the scheme selection requires continuous testing and calibration to determine the ratio, so the development period is long and the cost is high. In addition, in each professional proposed to put an energy saving technology or parts (intelligent oil pump, start-stop function, electronic grille, low roll resistance tire, etc.) applied to the vehicle, in the test of energy saving technology or parts, basically through the vehicle fuel consumption drum test, due to operating error and environment, sometimes unable to obtain accurate fuel saving rate. Insufficient decision support cannot be given in model configuration planning.

Hardware in the ring (HIL) technology platform, effectively improve the power integration ability, can transfer the road test to the powertrain laboratory, has the characteristics of high accuracy, good effectiveness, and convenient verification, is an indispensable way for vehicle performance analysis and verification in the future.

The technical platform can realize the engine condition conversion of any vehicle cycle, The key areas of engine matching optimization can be clearly defined, That is, to provide better guidance for the matching and optimization of the powertrain; Can the ride comfort, operating stability and shift quality of the vehicle, conducive to the improvement and precipitation of technical level and quality of shift strategy development of automatic transmission; An energy saving technology or energy saving component can be replaced with a simulated NEDC cycle test on the bench, Verify the fuel-saving rate; Assist in the corresponding relationship between engine and vehicle cycle conditions in different gears of the transmission, Including the engine fuel consumption condition diagram and the vehicle energy consumption flow research and so on.

6. **The application mode and specification of hardware in the ring (HIL) technology in the vehicle performance development process**

In the new vehicle performance development, the hardware in-loop simulation technology verifies the vehicle performance by semi-physical testing, somewhere between CAE simulation calculation and road testing (Figure 5). After CAE simulation analysis, the technical scheme to be verified and analyzed by hardware in the loop simulation platform. Therefore, hardware needs to input three aspects in the loop simulation platform: verification scheme, test specification (standard) and model parameters. Finally, the final scheme is determined by the evaluation results of the ring simulation platform, and then the road verification is conducted.
The process and specification of hardware in loop simulation technology are the key technology of hardware in loop simulation technology seamlessly linked to the vehicle development process. After clarifying the input and output interface information of the simulation platform, it is necessary to further plan the implementation process, steps and content of the verification of the simulation platform. In general, it is roughly divided into three parts: vehicle model establishment, model in ring simulation verification and hardware in ring simulation platform verification, that is, according to the project development objectives, according to the mature model or benchmark model as vehicle research and development verification of the model, through the ring technology platform, to refine the model subsystem parameters according to the project needs, finally complete the model establishment and verification of the experimental simulation platform.

The input and output information of the hardware in the loop simulation platform is integrated into its technical process and content to form a specification description, that is, to form operation instructions or processes to carry out the guidance of related projects.
7. The application of hardware in ring (HIL) technology in power integration development

According to the vehicle performance development process, the hardware ring simulation technology platform, combined with the development needs of a model, build a platform, carry out the corresponding power integration development work, provide analysis, evaluation for the final determination of the powertrain selection scheme and provide help for the power integration optimization.

The application of hardware in ring HIL technology in power integrated development is mainly divided into 5 stages. The main working content and cycle are shown in the following table:

Table I. The main content and cycle of hardware in the vehicle development of ring technology

| stage     | content                                      | describe                                                                 | Cycle      |
|-----------|----------------------------------------------|--------------------------------------------------------------------------|------------|
| stage I   | Vehicle model preparation                    | Vehicle model modeling, vehicle model calibration, test specification input | Six weeks  |
|           | Engine rack preparation                      | Engine platform scheme design, installation, HIL platform hardware and software connection | Two weeks  |
|           | Hardware is built on the ring platform       | Communication protocol matching, Engine rack with HIL commissioning, Engine performance confirmation, Status confirmation | Two weeks  |
| stage II  | Performance Validation window configuration  | Development of vehicle dynamics, emission and economy                     | a week     |
|           | Vehicle digital information window configuration | Key parameters acquisition for each vehicle system (engine/transmission/main reduction/tire/body, etc.), Monitoring and recording | a week     |
|           | Powertrain integrated matching window         | Allocation of fuel consumption distribution diagram of engine working condition (corresponding to gear dynamic process), Vehicle energy consumption flow spectrum map configuration | a week     |
| stage III | Model power verification                     | Test and verification of different powertrain and whole vehicle configuration schemes | a week     |
|           | Model economy verification                   | Test and verification of different powertrain and whole vehicle configuration schemes | a week     |
|           | Model emission performance verification       | Test and verification of different powertrain and whole vehicle configuration schemes | a week     |
| stage IV  | Model configuration scheme evaluation        | Configuration scenario analysis report                                    | Two weeks  |
|           | Scheme determination                         |                                                                          |            |
|           | Model powertrain integration and optimization | Integrated matching analysis report, Engine calibration optimization, Transmission shift strategy is optimized | four weeks |
| stage V   | The final scheme is verified in the loop simulation | In the ring simulation of power, economy and emission verification | a week     |
|           | Road validation of model model               | Power nature, economy and emission nature road verification               | Two weeks  |
|           | Hardware in the ring platform technical index verification | Verification report of technical indicators                              | a week     |

8. Conclusion

In today's deteriorating energy and environment, promoting the application of energy-saving technology has become the irreversible trend of automobile technology and the unshirkable social responsibility of enterprises. With the introduction and promotion of fuel consumption regulations, more and more energy-saving technologies will be used in vehicle performance development in the future. Through the semi-physical simulation mode, the basic performance through simulation calculation, better save the test cost and time in the development process, and further vehicle performance optimization, improve the optimization efficiency.
In addition, can establish through HIL technology platform vehicle performance digital platform, accumulate data, strengthen the vehicle performance integration and matching ability, and based on data analysis to improve powertrain tuning means and accuracy, improve product energy saving effect and quality, for product later improvement and upgrade to provide vehicle information reference, combined with models, optimize the vehicle performance. It provides the basis for evaluating the feasibility analysis of energy saving technology application (energy saving rate such as intelligent oil pump and PWM fan).

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