Variable Parameter and Real-time Co-simulation Method and Its Application in the Analysis of Train Dynamic Air Consumption Law

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Abstract. System simulation technology is currently the mainstream technology for system design optimization. Parametric design can greatly improve the speed of model generation and modification by establishing various constraint relations. In this paper, the parameter design method is improved and combined with the system simulation technology, and the variable parameter and real-time co-simulation method is proposed. In order to verify the feasibility of the method in system dynamic performance analysis, this paper builds a real-time co-simulation platform based on AMESim, and applies it to the analysis process of train dynamic air consumption law. The results prove that the method is beneficial to reduce the workload of designers, and can be applied to the design optimization, analysis and tracking of complex systems.

1. Introduction
The design of modern products requires that new products be launched in the shortest possible time and at the lowest cost. Therefore, the system must be designed according to the requirements of dynamic performance indicators, and the design of components must be optimized from the perspective of the system. At present, system simulation technology has become the mainstream technology of system virtual optimization design [1].

Parametric design controls the geometric shape of the design by constraining parameters, so when redesigning the same type of product, only the size parameters need to be changed, instead of repeated design [2]. At present, parametric design methods are mainly applied to the physical structure design of parts, and most of them are CAD (Computer-Aided Design) software, such as AutoCAD, SolidWorks, UG, etc. For example, existing researchers have carried out parametric design studies on vertical hydraulic pumping stations [3]. In order to improve design efficiency, a variety of secondary development methods based on SolidWorks, SolidWorks software parametric design principles and key technologies have also been applied to the parametric design of hydraulic components [4]. According to previous research, the parametric design method is obviously not suitable for the analysis of system dynamic performance.

In order to apply the parametric design method to the study of the dynamic performance of the system, this paper proposes a joint simulation method of variable parameters and real-time. Based on the AMESim simulation platform, a real-time co-simulation platform based on variable parameters was built, and it was applied to the analysis process of the train dynamic air consumption law.
2. Research on Variable Parameters and Real-time Co-simulation Method

2.1. Parametric Design Method
In the process of system design, designers tend to pay more attention to the performance of system components compared to the size and structure of each component. Therefore, the numerical model of the system is often used for the system, and the use of computer simulation makes a large number of design defects be dealt with before the physical formation [5].

However, for complex systems, even if numerical modeling methods have been adopted, the number of model parameters is still huge. Based on the parametric design method, parameter selection can be performed through the following two steps to reduce the dimensionality of the variable parameter set.

- Extraction of key parameters of components: The key parameters that affect the functional characteristics are extracted based on the physical model, and the other parameters have little effect or can be determined according to the key parameters. In order to use as few elements as possible to build as detailed as possible a complex model that reflects the function of parts.

- Determination of the variable parameter set of the system: Based on experience and experimental design, the key parameters that are less sensitive to the target performance of the system are screened out as implicit parameters, and those that are more sensitive to target performance are used as explicit parameters. Explicit parameters can be classified and sorted out the variable parameter set that constitutes the model, and implicit parameters can be assigned based on experience as immutable parameters.

The variable parameter model greatly procedurally perfects the way of changing the design model, improves the automatic generation and modification speed of the model and the flexibility of the design, thereby greatly improving the design efficiency of the product, reducing the development cycle, and reducing the design Cost [5].

2.2. Research on Real-time Co-simulation Method
Although the variable parameter model of a particular system has been processed by parameter space dimensionality reduction, there are still many model parameters involved. When studying the influence of variable parameters on the target performance within the simulation software, it is usually used to directly modify the corresponding parameters on the model, and then proceed to obtain the simulation results. For a more complex system, the single simulation time of the model is longer, the model parameters need to be modified frequently, and the data processing implementation steps are also more complicated [6].

The real-time simulation method proposed in this article is different from the traditional real-time simulation method in which the controller and the physical object participate together. This article refers to the establishment of a co-simulation platform and the real-time online modification of variable parameters based on the platform to avoid Edit the model in the simulation software environment. At the same time, expansion modules can also be added according to needs, such as quick and real-time generation of control instructions corresponding to different target outputs, so as to establish a real-time simulation platform based on a variable parameter model.

This article uses AMESim software as the system modeling platform. Its biggest feature is that users pay attention to the design of physical systems in modeling, instead of spending a lot of energy to study complex mathematical analysis. When modeling, you only need to select the corresponding model according to the engineering structure and working principle of the required model, and match the parameters, and then connect and assemble the model [7]. In addition, AMESim provides a complete set of scripts that can use a more abstract language to compile short programs, just like Python, MATLAB, Scilab or Visual Basic and other applications, which can automatically realize the interaction between modules [8].
Figure 1. Design of real-time simulation platform based on variable parameter model.

Figure 1 shows design of real-time simulation platform based on variable parameter model. When it is necessary to study the impact of a variable parameter on the target performance of the system, only a single element of the parameter needs to be modified. When the model system is large and complicated, if you want to modify a specific parameter inside the model, you not only need to spend time searching, but also pay attention to avoid modifying other parameters by mistake. The whole process is very inconvenient. The co-simulation platform displays the system structure hierarchically according to the actual physical structure in the form of a graphical interface, and the modified parameter interface only exposes the elements in the variable parameter set, so it can greatly reduce the cost of parameter search and parameter misoperation. At the same time, when you need to view the current value of a parameter, you only need to look for it on the basis of understanding the physical tomographic structure of the system, instead of looking in the complicated simulation model [8].

3. Analysis and Application of Train Dynamic Air Consumption
The train's air supply/use system is a key component to ensure the safety of train operation. Under continuous operating conditions, the dynamic train wind directly affects the air supply system. Studying the laws of train dynamic wind use requires modifying a large number of parameters, setting up complicated operating conditions, and then obtaining multiple schemes for comparison and selection. Obviously, the analysis of the train dynamic wind law is just in line with the applicable scope of the variable parameter and real-time co-simulation method.

Figure 2. Air supply/consumption system layout.
3.1. Variable Parameter Extraction
The train’s air supply/consumption system runs through the entire train. It includes multiple components such as air sources, pipelines, control valves, cylinders, and air-consumption equipment. The system structure and control logic are very complex, and the entire pneumatic system is directly established. The simulation model is more difficult.

By adopting the improved parametric design method, the train’s air supply/utilization system can be first decomposed into several subsystems or components, firstly establish a simulation model of the subsystems or components and extract the key parameters of each part, and then divide the various subsystems or components are connected according to a certain internal connection, and as is shown in Table 1, a variable parameter set corresponding to the system is established based on experience and experimental design results.

### Table 1. Variable parameter set (part).

| Parameter                  | Unit  |
|----------------------------|-------|
| Volume flow                | L/min |
| Drying efficiency          | %     |
| Starting pressure          | kPa   |
| End pressure               | kPa   |
| Main air cylinder volume   | L     |
| Main air initial pressure  | kPa   |
| Brake air cylinder volume  | L     |

3.2. Real-time Co-simulation Platform Establishment
Use the Python interface module provided by AMESim to build a real-time simulation platform for the analysis of train dynamic air law. Its main functions are as follows:

- Vehicle parameter setting module
- Line parameter setting module
- Operation mode selection module
- Result view analysis module

The interface of the real-time co-simulation platform is designed with the hierarchical structure of the train gas path system. The user can quickly locate the target parameter and view the remaining parameters in real time while modifying a single parameter. In addition, the simulation platform can also automatically generate input instructions suitable for the background model by inputting actual line parameters. After inputting parameters and signals, the simulation platform can control the running and ending of the model, and at the same time, the simulation results can be called and viewed on the interface.
3.3. Result Analysis
This case simulates the dynamic law of the train's air supply/consumption system during the process of 10 braking (the braking decelerations are not all the same) on the train. Select a typical parameter change curve that can reflect the law of train dynamic wind use, and the results are as follows:
Figure 5. Dynamic wind performance curve.

It can be seen that the real-time simulation platform proposed in this paper can quickly modify parameters, efficiently define multiple working conditions, and conveniently view the results for the research of train gas circuit system, which meets the needs of the analysis and research of the dynamic air law of trains, and also greatly improve the efficiency of simulation analysis.

4. Conclusion

Based on the parametric design method, this paper proposes a variable parameter and real-time co-simulation method for complex system research. At the same time, relying on the AMESim simulation platform, this paper designs a specific real-time joint simulation platform architecture based on variable parameters. Finally, the real-time co-simulation platform is used to study and analyze the dynamic wind usage rules of trains, and it is verified that the platform has the advantages of real-time simulation of multiple working conditions, convenient acquisition of simulation results, and rapid program comparison and selection in system design.

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