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# Study on Modular Design Based on the Theory of Life Cycle

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**ABSTRACT**
Based on the analysis of the traditional automobile design mode, the paper puts forward that the concept of changing from simple function design to product life cycle design. Moreover, the life cycle design theory based on modular design can better serve the subsequent links of automobile manufacturing in the design stage. Combined with the wide application of CAD / CAE technology in automobile design, the concept of automobile modular design based on life cycle theory is explored. Automatic Mechanical System Dynamics Analysis Software (ADAMS) can realize the functions of parametric modeling, design and analysis. In addition, parametric simulation analysis can analyze the influence of design parameters on vehicle performance. By taking the vehicle model created in ADAMS/Car and Vehicle handling analysis as an example, the combination of various module types and relevant parameters can quickly realize the module variant and model expansion. The modular design of automobile based on life cycle theory can analyze the most dangerous operation conditions, obtain the optimal prototype model and the best parameter setting, shorten the design cycle, reduce development cost and improve the product performance. This kind of automobile design mode, which integrates advanced theory, mature design means and excellent computer software will become the future development direction and trend of automobile design.

***Keywords:*** *life cycle, CAD/CAE, ADAMS, modular design.*

## 1. LIFE CYCLE OVERVIEW

Since the beginning of the 21st century, product innovation has become the focus of enterprise competition. The common goals pursued by new products are how to shorten the product development cycle, improve the quality, reduce the cost, better provide services to users and realize the recycling of resources. In order to achieve the multi-objective of product development, we cannot only rely on the improvement of a certain technology and a certain stage in the development process, meanwhile we must consider the entire product life cycle as a complete processs. [1]

The so-called product life cycle refers to all the time that a product has gone through from design, manufacturing, assembly, packaging, transportation, and use to scrap. So for a product, its life cycle including market demand analysis, concept design, preliminary design, detailed design, process design, production planning, production, transportation and sales until after use, maintenance, product scrap disposal (including dissolution or remove, reuse, recycle, development, incineration and landfill) and so on. Therefore, the above stages can be divided into five stages: product development design, product manufacturing, product sales, product use, and product recovery. Among them, the development and design stage is crucial, which determines the market competitiveness of the product largely. However, the present design idea is different from the traditional design mode of separation of design and manufacturing. Modern product design must be oriented towards the full life cycle of the product. With the increasingly fierce competition in the automobile market, the development situation of China's automobile industry will be more severe. The pressing task is to improve the automobile design method, introduce advanced design concept and design method, and fully adopt advanced design means. [2]

At the same time, the modular design of the car is interrelated with the rest links of the life cycle, and affects the subsequent links. The modular design based on the life cycle theory can well solve many drawbacks and problems brought by the traditional design. Because the core of modular design idea is to divide the system into several modules according to the function. Each module integrates all units of the same function in a product, has different performance, and is interchangeable. Through the different combination of modules, we can obtain different types and specifications of products. By adopting this method, the product can be improved and maintained more easily, the complete machine need not be scrapped, and the personalized design can be fully realized. This can better adapt to the diversity of user needs, shorten the development cycle of the entire product and reduce development costs. [3]

## 2. APPLICATION OF MODULAR DESIGN IN VEHICLE DESIGN

### *2.1. Overview of Modular Design*

With the diversification of user demand, automobile manufacturers have to constantly develop and design new models and personalized products to meet the needs of the market and users. However, the traditional automobile design idea is based on the large-scale production of a single vehicle model and unable to meet the changing needs of the market. Therefore, the automobile design concept and the automobile design method have to be constantly updated and developed. In the modern design theory system, as an advanced design method, modular design can alleviate this problem. Modular design refers to the design according to the function divided into several large independent modules. Multiple parts or assemblies are integrated on each module. The connection between each module is fixed and will not be changed due to the changes of parts or assemblies. Moreover, the assembly is based on modules during assembly. A car designed with a modular design can be deformed, when different parts or assemblies are selected in the same module. Module combination can make vehicle parameters. According to this design idea, the development of car can meet the needs of consumers for personalization.

With the development of computer technology, CAD/CAPP/CAE and other computer aided design technologies have been widely used in automobile enterprises. The application of these technologies provides powerful technical support for shortening the development cycle. Among them, the automobile CAE software can significantly improve the scientific nature of product design, reduce blindness, and improve design efficiency. Its biggest advantage is that the strength, life and performance of the designed product can be predicted by establishing a computer analysis model at the initial stage of product design, namely the stage of drawing design. his ensures the product design index, effectively improves the reliability of the design product, and reduces the design cycle. [4]

### *2.2. ADAMS Overview*

Automatic Dynamic Analysis of Mechanical Systems (ADAMS) is a famous virtual prototype Analysis software developed by American MDI Company. It integrates module design with computer aided engineering (CAE) very well. After establishing the prototype model, the engineer can directly analyze the dynamic performance of the prototype, and improve the design scheme of the prototype, which replace the traditional prototype test with digital form. Virtual prototyping technology can greatly simplify the design and development process of mechanical products, greatly shorten the product development cycle, greatly reduce product development costs, significantly improve product quality, improve product system performance, and obtain optimized and innovative products. In addition to mechanical system dynamics and kinematics analysis, virtual prototype analysis software also includes the following technologies, as shown in Figure1.[5]

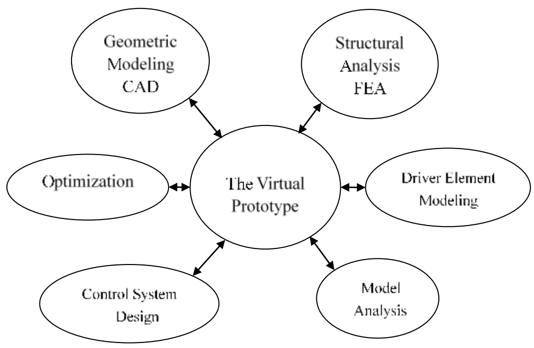


**Figure 1**Virtual prototype and related technologies

ADAMS contains several modules, such as ADAMS/Car. It can quickly build high-precision virtual prototype of the whole vehicle, including the body, suspension, transmission system, engine, steering mechanism, braking system and so on. The dynamic response of the vehicle under various test conditions (such as weather, road conditions and driver's experience) can be intuitively reflected through high-speed animation, and the characteristic parameters of control stability, braking, ride comfort and safety can be generated.[6]

### *2.3. Example Analysis*

Take the creation of a complete Car model in ADAMS/Car as an example. In this model, the vehicle chassis module, front suspension module, steering mechanism module, rear suspension module, tire module and road spectrum are firstly created respectively. The types of each module, related parts parameters can be freely selected and combined, so that different models can be created. For these modules, we can directly apply the shard module in the system, and get the model we need by modifying the relevant parameters. Or create new modules entirely by yourself using the Expert User Model in the User model. In the process of creation, some annotated files, such as tire files, road files, spring and damping files, etc. are used to set and explain the properties and structural parameters of each part. However, in the actual development and design process, it is usually to design a series of vehicle models. We can directly refer to the existing vehicle models, replace some modules or design individual modules, according to the user and market demand, which will greatly reduce the product development cycle and costs.[7][8]

#### *2.3.1. Create the model*

Using the existing suspension modules provided in the system, a double wishbone type independent front suspension is created. The relevant structural parameters can be modified, as shown in Figure 2.

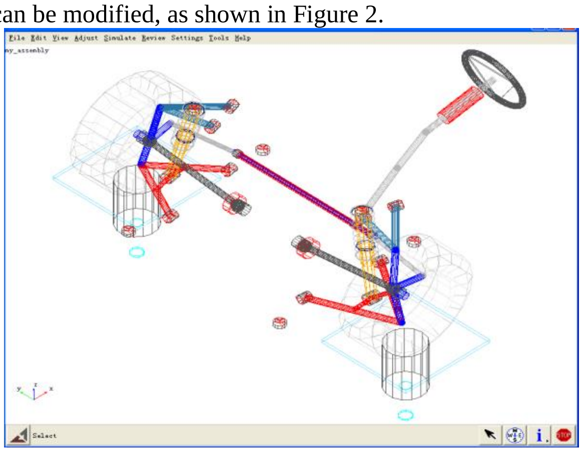

**Figure 2** The front suspension after modifying the structural parameters

In order to improve the accuracy of system simulation, a flexible body can be introduced into the system. In this case, we introduce a flexible body to the left and right lower fork arms in the front suspension, as shown in Figure 3. The deformation of these two control arms can be understood through the result diagram after simulation.

Figure 3 shows the creation of a steering system connected to the suspension system. FIG. 4 and FIG. 5 show the vehicle assembly created, and the rear suspension, rear wheels, body, brake and transmission components imported from the system. Figure 6 shows the final vehicle model.

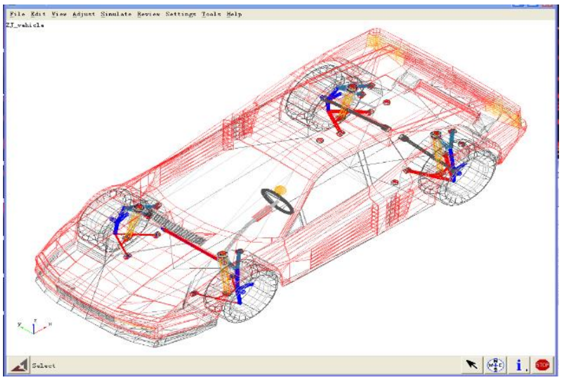

**Figure 3** Change of front suspension control arm after introducing a flexible body

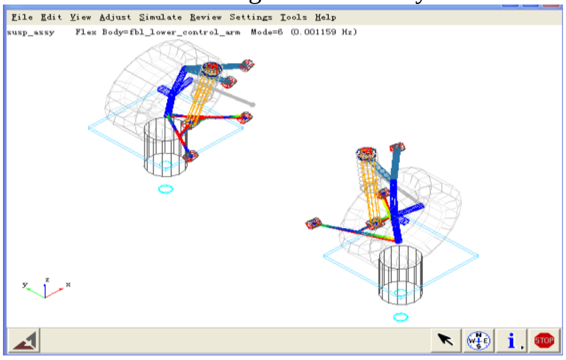

**Figure 4** Create steering system and connect suspension

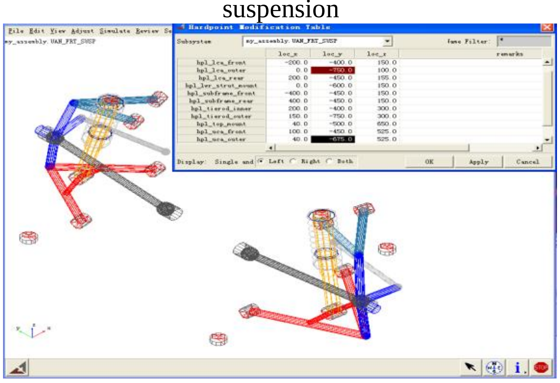

**Figure 5** Create models for rear wheels, rear suspension and rear body

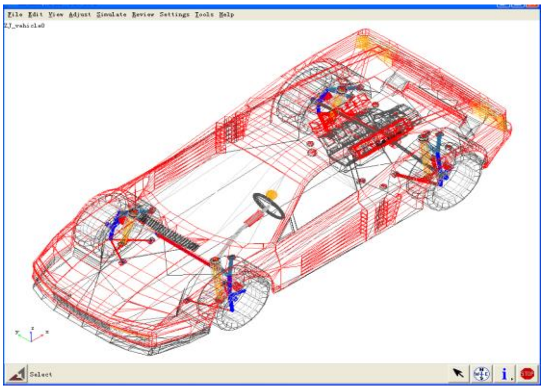

**Figure 6** The vehicle model

After the vehicle model is created, dynamic simulation analysis of the vehicle can be carried out, such as the motion simulation analysis of the vehicle's steady-state steering characteristics, steering, braking, angular step input transient response, etc. and the simulation analysis of the vehicle's ride comfort can also be carried out by changing the road surface spectrum. Through the analysis of the simulation results, we can judge the rationality of the design and complete the whole vehicle design task quickly and accurately. As the flexible body is introduced into the left and right control arms of the suspension in this example, we can find the difference between them by comparing the simulation results without the introduction of the flexible body and the introduction of the flexible body. The following two figures show the sidewise Angle of the left and right wheels and the transverse wobble speed of the chassis in the rigid body and flexible body, respectively.

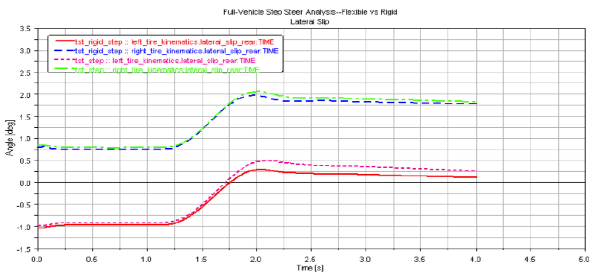


**Figure 7** The deflection angle of left and right wheels, before and after the flexible body is introduced

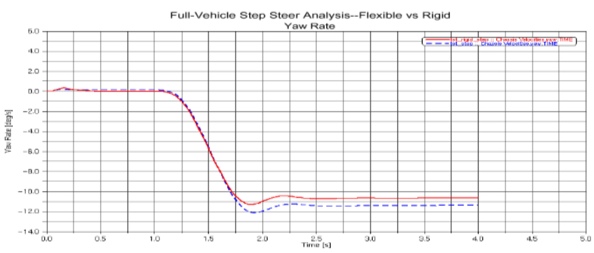


**Figure 8** The deflection angle of left and right wheels, before and after the flexible body is introduced

## 3. CONCLUSION

In the increasingly fierce competition in the automobile market, if China's automobile industry wants to compete with developed countries, it must start from the source of product production, namely the design stage, and change from simple functional design to product-oriented life cycle design as soon as possible. Modular design can fully reflect the relationship between each link of the life cycle theory in the design stage, so that the design stage can better serve each subsequent link.

We chose ADAMS (automatic analysis software of mechanical system dynamics) for modular design, because ADAMS can apply CAD/CAE technology to the modular design of automobile. Moreover, the parametric modeling, design and analysis functions provided by ADAMS fully embody the idea of modular design. Parametric modeling and design can be realized in the model construction stage. Through parametric analysis function, the influence of design parameter change on model function can be analyzed, so as we can obtain the most dangerous operating conditions and the optimal prototype model.

With the development of automobile industry and the maturity of automobile design technology. This kind of automobile design concept integrating advanced theory, method and excellent computer software will become the development direction and trend of automobile design in the future.

## ACKNOWLEDGMENT

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