Research Progress Reviews of Digital Design for Automotive Products

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Abstract. For adapting the change in requirements of the products, the modern digital design has becoming one of the most important methods which could improve the sensitivity to the market, and meet the requirements for the functions, quality and development cycle of products. In this paper, it is firstly presented the definition and features of the digital design method. After that, some key technologies of realizing the digital technology is introduced. Moreover, a case of digital design for automotive mechanism is given from the systematic points.

Introduction

The digital design of automotive products is the important content related to the enterprise information. In recent years, with the growing demands for the diversiform automotive products, the complexity of products is increased, and the competition among the automotive companies is fierce, so that traditional design methods are hard to meet the survival and development of the automotive companies. For obtaining a position of strength, it is imperative and effective to realize the digital design for automotive products.

This paper is organized as follows: Section "Definition and Features of Digital Design" introduces the definition and feasters of digital design, Section "Key Technologies of Modern Digital Design for Automotive Products" describes the key technologies of modern digital design for automotive products, and a case study of digital design for automotive mechanism is presented in Section "A Case Study of Digital Design for Automotive Mechanism", this paper is concluded in Section "Conclusion".

Definition and Features of Digital Design

A. Definition

The definition of digitalization has been divided into broad and narrow areas. Broadly speaking, the digital design is of using mathematical theories or mathematical methods to define, express reform or simulate the entities or abstractions. In narrow sense, the digital design is of applying the computer processing technology to transfer acoustic, optic, electronic or magnetic signals into digital signals, or transfer the audio-visual information such as sound, characters, videos, etc. into digital encoded information for transmission and processing. Comparing to the traditional non-digital technology, the digitalized information has some advantages such as rapid transmission rate, improved anti-aliasing, good anti-interference, etc.

Essentially, the products design is the progress which collects, transmits and processes the information. This progress is composed of two important actions: the design action and the simulation action. Therefore, the products design could be viewed as the interactive result of the design action and the simulation action. The design action pushes the information flow forward, and the simulation action verifies the design result.

B. Features

The digital design method has three main features such as the virtualization, the uniform definition model and the concurrent design realizable.

1) Virtualization

The virtualization is the main feature of the digital design. It has three aspects:

- the virtualization of the design platforms

- the virtualization of the design tools and materials
- the virtualization of the design objects

2) uniform definition model

The digital design technology establishes the single digitalized product definition model from products design to manufacture, which is the basis for the product life management (PLM). There emerged a lot of multi-modal product models aiming at information integration, such as integrated product model, product perfect information model, holographic product model, etc. These models have different emphases. For example, the integrated product model emphasizes the integration of the product information, while the product perfect information model emphasizes the interaction between the product model and the development environment.

Generally speaking, the product definition model is more or less abstractly a functional concept framework, and the concrete implementation method is still under research.

3) concurrent design realizable

A task could be concurrently designed and assembled by multiple design teams in different areas. It is ultimately formed an achievable, manufacturable, cost and functions controllable digitalized model. Due to the completeness of the product model information aiming at the product life cycle, the digitalized design has contributed to accomplish Design For X (DFX) such as Design For Assembly, Design For Manufacturing and Design For Service ability. Moreover, DFX is important for improving the quality and speed of designing products.

Key Technologies of Modern Digital Design for Automotive Products

The traditional design methods have manifold of drawbacks: the manual computation is error-prone, high cost, and without comprehensive optimized design results; the product design process multiple links includes "market survey- conceptual design-technical design-process design-manufacture-assembly-debug", so it is time-consuming; the design scheme is of low comprehensible and communicable; the manufactured products based on traditional design methods is difficult to update and the production line is also hard to renew, etc.

However, the digital design is the method using modern, high technologies to reform the traditional products design methods, aiming at establishing a modern design system with concurrent, intelligent, virtual, green and agile abilities based on computers, organizing multi-discipline development teams, fully applying multiple computer-aided tools, and considering the whole process of the product development and manufacture. Therefore, the modern digitalized design can reduce the construction cycle and cost, improve the quality of products and meet the needs of consumers. The key technology of the modern digital design for automotive products is as follows:

A. Life Cycle Design

Life cycle design is a design method which considers the raw materials for manufacturing the products, up to the life termination of the products. It could be divided into the following 6 phases: demand analysis, product design, product manufacture, product marketing, product usage and product discarding. The modern advanced design requires that it is important to comprehensively consider the whole process of products design. Due to that the products are always surrounded by natural and social environment, we have to fully consider the environmental factors during the life cycle design process, i.e. realizing green design which is composed of materials selection and management, products detachable design and product recyclable design.

B. Concurrent Design

Comparing to the traditional sequential design, the concurrent design is more remarkable. The outstanding features of the concurrent design are resource sharing, real-time interactive and collaborative. The globalized computer network makes the real-time interactive concurrent design possible. The concept of this kind of design method is that the key links of product design such as design optimization, materials selection, structure analysis and modeling, manufacturing engineering selection, assembly operation optimization, sample product manufacture and marketing could be acted simultaneously, and all of the professional engineers can design the products with shared resources and the interactive cooperation. Any modified or updated product information

from any design engineer could be transferred to any other engineers in the whole developing process. Furthermore, the updated or modified new model sketch could be selected in terms of the parametric form, so that the repeatedly modification times across design and manufacture could be reduced. This design method could adapt the constantly changeable market with the flexible effective design and manufacture style.

C. Robustness Design

Robustness design is a kind of engineering design method which mainly considers the products quality and cost. In the process of designing products or process system, the stability of product quality could be definitely guaranteed through applying the basic theory and method for the manufacture or user phase.

Modern robustness design method can be divided into two types: one is the traditional robustness design method which is based on empirical or semi-empirical design, such as the response surface methodology, the double response surface methodology, and the general linear model method, etc.; the other is based on mechanical engineering model, such as the mechanical optimized robustness design methods including the tolerance polyhedron method, the sensitivity method and the stochastic modeling method, etc. The products which are designed with the robustness design method could maintain the stable quality during the interference of various factors, even for assembling high-quality and stable performance products with cheap components.

There are two purposes of the robustness design: one is to make the mean value of the product performance achieving targeting value, i.e.

$$\delta_y = \left|\bar{y} - y_0\right| \to \min$$

$$\text{or } \delta_y{}^2 = \left(\bar{y} - y_0\right)^2 \to \min$$

Where, δy is the sensitivity robustness which makes the functional performance variability as small as possible during the interference of different factors, i.e.

$$\sigma_y{}^2 = E\left(\bar{y} - y_0\right)^2 \to \min$$

Where, σy is the variance robustness.

With regard to the output of a product, no matter how perfect the mean value is, big values of the variance will increase the quantity of poor quality products. Simultaneously, no matter how small the variance is, inappropriate mean value will severely affect the functions of products.

The main methods for achieving the first purpose are as follows:

1) through redesigning the product scheme to change the relationship between the input and output of the scheme, it could make the mean value of functional features approach the targeting value;

2) through the parametric design to regulate the nominal value of the design variables it could make the output value approach the targeting value.

The main methods for achieving the second purpose are as follows:

1) 1) through reducing the offset of the nominal value to narrow the variance of the output feature but increase the product cost;

2) 2) through appropriately select the working point of the nonlinear curve by applying nonlinear property to narrow the variability of the product quality.

A Case Study of Digital Design for Automotive Mechanism

At present, automotive mechanism design methods are mainly aiming at the overall requirements, and directly building the 3D component models of mechanical structures using 3D modeling software. Then, the 3D model will be inserted to the structure analysis software and dynamics analysis software, or re-modeling the simplified mechanical structures using the structure analysis software and dynamics analysis software. Finally, the design and analysis files related to each component will be summarized to output the feasibility report of the design. These three sequentially implemented processes have some drawbacks such as that the relationship among them is poor, and the designers have to rebuild and re-analysis the structures when the systematic overall requirements are changed. For some mature schemes of mechanical structures, this design method

will generate a lot of repeated design operations after many times of modified designs, which reducing the design effectiveness and increasing the time-consumption of design cycle.

The digital design system for automotive mechanism mainly aims at the mechanical structures whose scheme and configuration are comparably mature. It rapidly realizes the design and analysis scheme of automotive mechanical products in terms of changes of input requirements with the automatic design system.

In the digital design system, there're two supporting database, i.e. design model database and analysis model database. The 3D parameterized models related to common mechanical components are stored in the design model database, while the analysis models related to multiple components are stored in the analysis model database.

The digital design system is composed of various modules: system input and output interface program module, design guidance module, CAD second development program, CAE analysis software interface program, design and analysis model database, design and analysis supporting software, etc. These modules could be integrated by using the plug-in structure and multiple different tools and technologies. The digital design process for automotive mechanism shows in Fig.1.

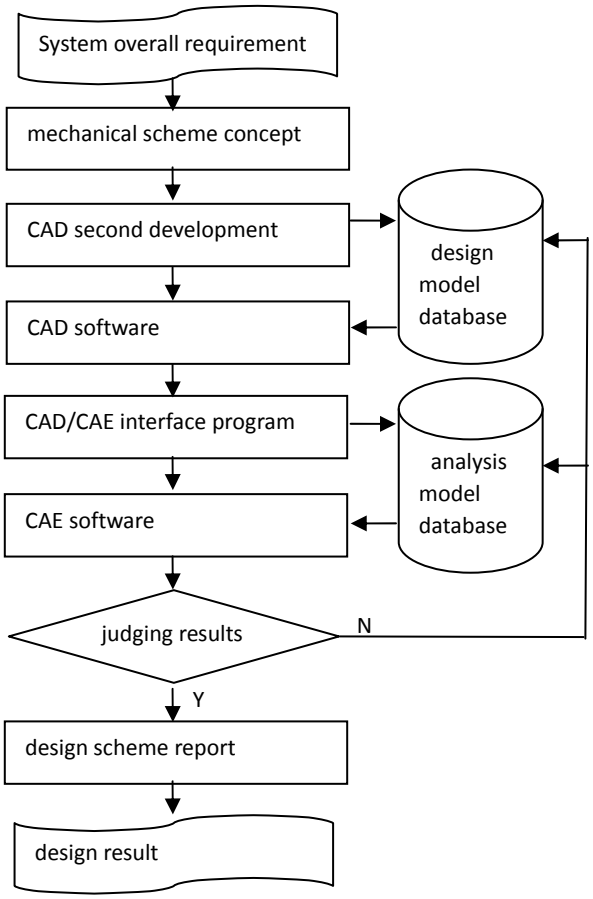

Figure 1 the digital design process for automotive mechanism

Conclusion

The digital design method considers the overall components of each product as an entity system. It builds the overall arrangement of the product according to the mutual position relationship and the targeting functions. With the design information such as constraint conditions, key design parameters, it is launched the whole design process of the product. The digital design method has some important meanings for reducing the design cycle and costs, while improving the quality of products.

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