Research on Mirror Prototype

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Abstract. In product research and development process using virtual prototype technology, there exist defect that virtual experiment can not reflect real physical prototype data information, mirror prototype is defined, framework of mirror prototype: model-simulation analysis- prediction and evaluation (qualitative and quantitative)- verification (qualitative and quantitative) is proposed, and data interaction of mirror prototype technology is presented in this study.

Introduction

Product research is a creative activity and its target is expecting to achieve some function, performance and reliability. Around the target, the product research experience two revolutionary leap. The first leap is from intuition research to graph paper research. The second leap is graph paper research to digitized research\cite{1-2}. Although the second leap happened, most product researches are still graph paper research or semi-graph-paper research and semi-digitized research. A few big substantial companies try their best to promote digitized research, and they know that digitized research could greatly improve the efficiency of product research and will bring about great economic benefit and market competitiveness\cite{3}.

Digitized research is just a concept. What is the technology to support the digitized research concept? For most industrial products especially mechanical product, virtual prototyping technology is a perfect platform to support the concept. People could make use of the virtual prototyping technology to achieve the products of the innovative design, testing and the evaluation, shorten developing cycle, improve products quality, reduce developing cost, and enhance the customer-oriented and market-oriented ability\cite{4-7}. What is the virtual prototyping? Li Bohu academician give the most complete definition for virtual prototyping technology.

The definition for virtual prototyping technology by Li Bohu academician is as follows\cite{8}: Virtual prototyping technology is a new product research method, which is a digitized design method based on the computer simulation model of products. The digital model is virtual prototype, which can combine the development model of different engineering areas. The virtual prototype can simulate the real products from appearance, function and behavior (performance) and replace the physical prototype finally. The virtual prototyping technology support engineering methodology involved multibody system kinematics and dynamics modeling theory and its technology achievement. The virtual prototyping technology is a comprehensive application technology based on advanced modelling technology, multi-field emulation technique, information management technology, interactive user interface.
technology and virtual reality technology. He thinks that the virtual prototype technology develops on the basis of CAX/DFX technology. The virtual prototype technology further integrate the information technology, advanced manufacturing technology and the advanced emulation technology and apply these technologies to full life cycle of the complex system, and comprehensively manage these technologies. The virtual prototype technology support the top-down developing mode.

The definition for virtual prototyping technology by Li Bohu academician essentially reflects in three aspects. The first one is virtual prototyping model, which means setting up digitized model of products. The second one is the essential simulation for products physical performance based on computer simulation, including the function and behavior and so on. The third one is the effective evaluation for the prototyping model according to the analysis result in order to improve the prototyping model in some aspects, which could make it approximate the physical performance of the physical prototype. In a word, model, simulated analysis and forecast evaluation (qualitative and quantitative) are three important processes of the virtual prototype.

The Definition of Mirroring Prototype

Why do we propose the mirroring prototype technology since we have the virtual prototype technology to support the digitized research concept? According to the definition of the virtual prototype technology, the target of the virtual prototype technology is to simulate the real products from appearance, function and behavior (performance) and replace the physical prototype finally. However, the virtual prototype could not achieve the target to replace physical prototype finally lacking of the validation feedback of the bottom-up interaction data from physical prototype. The definition of virtual prototype does not clearly mention the physical prototype validation [9]. And so we propose the concept of mirroring prototype. Fundamentally speaking, the target to develop the mirroring is to solve the problem whether the computer virtual model, simulation analysis and test are right or not, whether it truly reflects the test content of the physical prototype or not. We should verify the test by science and form the design model base and simulated test data base in order to improve and ensure the validity of the model design, simulated analysis and virtual test. The test of physical prototype should be from less to more and then to less. We should continuously deposit the test knowledge of the physical prototype into the design model base and simulated test base in order to realize the function, performance and reliability of products just according to the model design, simulated analysis and virtual test of computers without physical prototype.

Let’s explain the mirroring prototype in a visual way. For example, we design and select schemes through the simulated prototype way and select C as the best design scheme from schemes A, B, C. However, making a physical prototype on the basis of scheme C to test and verify before mass production, the virtual prototype, like looking into the mirror after making up, will receive the verification data from the physical prototype and improve to get scheme C1. Over and over again, we will approach optimal scheme Cn. At the same time, continuously inputting the test data to the virtual prototype data base is like looking into the mirror, which the brain will store important informations getting from looking into the mirror. Finally, people could have a perfect make-up depending on the stored information in the mirror without the mirror. Physical prototype, which is just like a mirror, and virtual prototype form the mirroring prototype.
The relationship between production research, virtual prototype, physical prototype and mirroring prototype are as shown in Figure 1. The imaginary line frame is the mirroring prototype. The physical prototype in the right imaginary line frame may be a complete one or a just a semi-finished physical prototype, which partial function and performance should be verified by the physical prototype.

The essence of the mirroring prototype should be reflected in four areas. The first one is simulating the prototype model, which means to establish the digitized model. The second one is simulating the essence of the products physical performance based on the computer simulation, including its function and behavior (performance) and so on. The third one is the effective evaluation for the prototyping model according to the analysis result in order to improve the prototyping model in some aspects, which could make it approximate the physical performance of the physical prototype. The last one is verifying the whole process of the digitized development by the physical prototype and semi-finished physical prototype. In a word, model, simulated analysis, forecast evaluation (qualitative and quantitative) and verification (qualitative and quantitative) are four important processes of the mirroring prototype. The four complete processes could guarantee the exact verification for the function, performance and reliability of products.

The System Frame of the Mirroring Prototype

According to the definition of the mirroring prototype, we propose the system frame of the mirroring prototype on the basis of the virtual prototype. The system frame is mainly that the physical prototype test bench joins the simulated prototype system. The mirroring prototype technology involves plenty of tools, including CAX/DFX tool, simulation tool, management tool, virtual reality tool, evaluation tool and verification technology. In order to form the integrated and collaborative development environment, we should integrate all kinds of tools to form the integration of functions, informations and processes among tools[10-13]. The technology system is as shown in figure2. Besides model, simulated analysis and forecast evaluation (qualitative and quantitative), verification, which fill up the deficiency of the virtual prototype to perfect support the products development(the green bold line in the middle shows the data channel of data flow of mirroring prototype), is another important process.
Data Interaction of the Mirroring Prototype

The mirroring prototype includes vast and multi-layered knowledge and information, so it will involve plenty of data, models, tools, processes and staffs in the development process of mirroring prototype. We need efficient organization and management to ensure that the correct data are transmitted to the correct staff in the correct way at the correct time[11].

The management technology of the mirroring prototype includes the management of data and models and the management of programs and processes, which means the integration of informations and processes, shown in figure 3.
Figure 3. The Relationship among PDM, SDM and TDM.

PDM(Product Data Management) manages the design data and processes of products, which corresponds to the data management of the model frame in the mirroring prototype frame. SDM(Simulation Data Management) manages the simulation data and processes, which corresponds to the simulated analysis frame and forecast evaluation frame in the mirroring prototype frame. The evaluation frame is the simulation process for the physical prototypes. The simulation here is a more generalized concept than it in the simulated analysis frame. TDM(Test Data Management) manages the verification data of the physical prototype tests, which corresponds to the data management of the verification frame in the mirroring prototype frame. If the model, the simulated analysis, forecast evaluation and verification attribution of the mirroring prototype are compared to a carriage, the entirety formed by PDM, SDM and TDM can be taken as the yoke of the carriage. The three aspects mutually coordinate and communicate to harmonize the operation of the mirroring prototype to effectively support the products development.

Conclusions

Virtual prototype technology is an emerging modern design method and way and it plays an important role in improving the efficiency of products development, reducing the development cost and improving products quality. The virtual prototype technology has been applied in automobile products development and other fields. On the basis of virtual prototype, the mirroring prototype effectively evaluate the simulated analysis result of the
virtual prototype in order to improve the virtual prototype model, which could make it approximate the physical performance of the physical prototype. Finally it is verifying the whole process of the digitized development by the physical prototype and semi-finished physical prototype.

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