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Research on innovation design of the DTH drill based on reverse engineering

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Abstract. This paper analyzes the theory of reverse engineering methods, combining with digital modeling technology and virtual prototype technology, a model of product innovation design is established and the evaluation index is introduced based on the theory of reverse engineering. The design defects of a certain imported down-the-hole drill(DTH drilling rig) is analyzed. According to the process of innovation design model, innovative design of the DTH drilling rig is done and the strength of the improved structure is verified. The improved 3D model of DTH drilling rig is built by Pro/E, and the kinematics simulation analysis about key components of the new products is carried out. There is no interference phenomenon in the simulation results analysis, which verifies the rationality of the model establishment.

1. Introduction

DTH drilling rig is mainly used in various projects such as mining, construction, water conservancy, power station, transportation and national defence construction. Compared with the common rock drill, it has the characteristics of deep drilling, large bore diameter, high drilling efficiency and wide adaptability. It is currently common large-scale rock drill equipment. DTH drilling rig technology appeared in foreign countries in 1932 and China's first DTH drilling rig appeared in 1964. The rapid development of the economy in recent years has enabled domestic companies to narrow the gap with foreign countries[1,2]. Related enterprises in our country need to quickly absorb the latest foreign advanced technology and innovate and improve their product on their basis. In this paper, a certain type of imported DTH drilling rig is taken as the research object and an innovative design method based on reverse engineering and digital modeling technology is proposed. The innovative model is established by combining with the product design process, and the model is applied to the design process of target product. Finite element analysis and structural strength checking are used to the improved structural parts. The improved product is simulated by virtual prototype technology and the analysis results verify the rationality of the established model.

2. Theory analysis of the Reverse Engineering

Reverse Engineering is originated in the 1960s. It is helpful for designers to analyse existing products and use modern design methods to reconstruct the original products so as to improve the product performance[3].The reverse engineering mainly focuses on re-creation. Any product improvement and innovation is based on the inheriting the advantages and improving the shortcomings of the original product structure.The reverse engineering is a redesign process of the product design[4,5].

The traditional design of mechanical products is based on the market research. It is modeled and manufactured according to the functional use of the product. Reverse Engineering seeks the design



process of the product from the existing products and digests and absorbs its design concept. On the basis, the process of re-creation can obtain new products with independent innovation and competitiveness to meet the needs of the market[6,7]. In reverse engineering, the data processing based on the decomposition of the physical product structure is the basis of all work. The decomposition of physical structure is the analysis process of topological relationship from whole to partial, and then from partial to detail. It is necessary to obtain the connection method of each component and its positional relationship, and repair the measured data through relationship of structural assembly and analysis of constraints. Reverse engineering can rapid simulate the modeling process with the standard model on the virtual design platform and realize the reproduction of the prototype structure and function. Designers need to innovate and redesign the model based on the potential market needs and functional defects of the existing products. Therefore the products can be updated quickly.

3 .Innovative model based on reverse engineering

The process of getting an innovative design model method is shown in Figure 1.

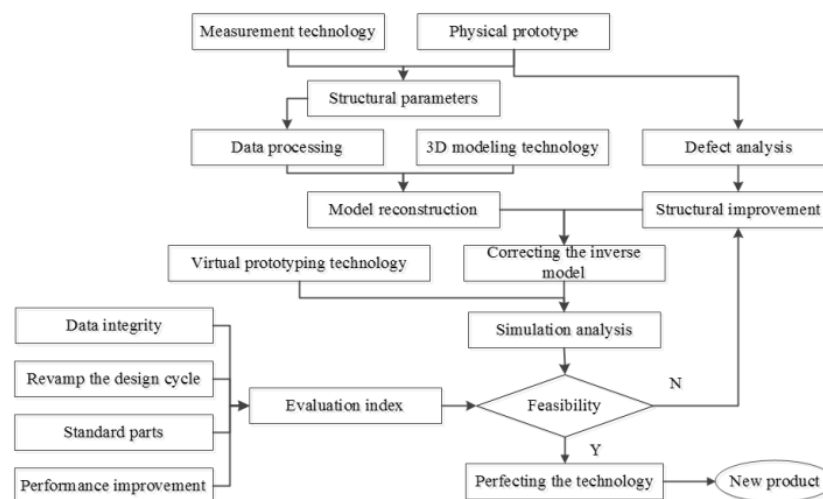


Figure 1. Innovative design method model flow

The development of modern science and technology makes the design of product mainly line in innovation. In the era of rapid economic development, innovation should reflect a kind of foresight[8]. Innovative designs of traditional product get the market demand of products through the market research in order to achieve innovative structural design and producing prototype. This method of innovation has obviously hysteresis and it is difficult to adapt to the rapid development of market demand. Innovative design model method is based on reverse engineering design theory, using modern measurement technology, digital modeling technology and virtual prototype technology, considering the defects in the use of the product, correcting structural models, absorbing the latest technology, improving the traditional product design process, introducing reverse engineering evaluation index, exploring a Innovative design method to speed up the process of updating and reducing the research and development costs.

The development of 3D modeling technology and virtual simulation technology also promotes the application of reverse engineering. It digitally processes parts or products without design papers and uses the 3D modelling software to rebuild the product models. Innovative design is made for the deficiencies of the existing products. The original product was modified and designed by reverse engineering, and verified by 3D modelling and simulation technology.

4.Case Analysis

4.1 Problems analysis of DTH drilling rig

The first step of using the innovative design model for reverse design is to analyze the defects of the

products and find out where the product structures need improvement. The DTH drilling rig is mainly composed of a power device, a traveling mechanism, a lifting mechanism and a working device. The lifting mechanism and the working device rely on the bottom slide on the working device and the gooseneck of the lifting mechanism to connect each other. When working normally, slide guide groove and beam on bottom slid can slid relatively through the telescopic cylinder, while the lower part is connected with the gooseneck. The relative rotation between the fuel tank and the gooseneck is realized through horizontal angle adjusting cylinder on the right end of the beam. Therefore, the angle is adjusted. The bottom slid and the gooseneck are shown in Figure 2.



Figure 2. Picture of partial structure on DTH drill rig

The bottom slid and the gooseneck of the imported DTH drilling rig relies on the pivot to connect each other. Due to the limited diameter of the pivot, the bottom slid and gooseneck are not stable enough to change the angle, and shaking obviously during the working process. Moreover, spatial orientation of the working device is limited by the gooseneck design. Therefore, it is necessary to improve the structure of bottom slid and gooseneck, which can greatly improve the stability of DTH drilling rig when it is drilling.

4.2 Innovative design of the DTH drilling rig structural

According to the innovative design model, the main dimension parameters of the bottom slid and the gooseneck on the prototype are obtained by using modern measurement technology, and the structure is improved according to the result of the problems analysis. Here, the connection method between the bottom slid and the gooseneck is changed from the shaft connection to the pipe connection, and then the relevant parameters are subjected to data verification processing. When the DTH drilling rig working normally, the force and displacement constraints of the bottom slid and the gooseneck are shown in Fig. 3.

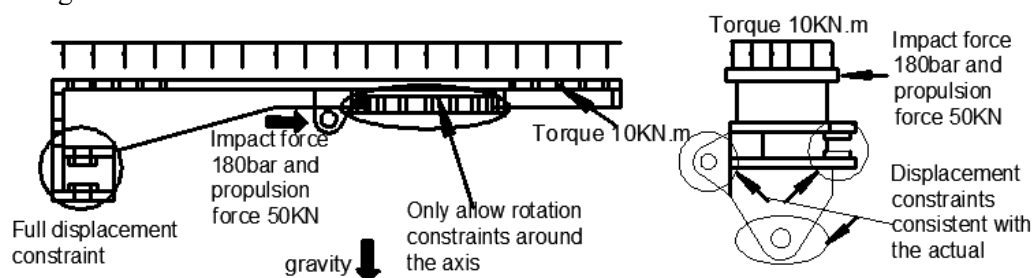


Figure 3. Picture of the force and the displacement constraints of the bottom slid and the gooseneck

After changing the format of the 3D pro/e model of the bottom slid and the gooseneck, the model is imported into ANSYS. Applying the displacement constraints and external loads shown in Figure 4 to the model for static analysis. The analysis results are shown in Figure 4.

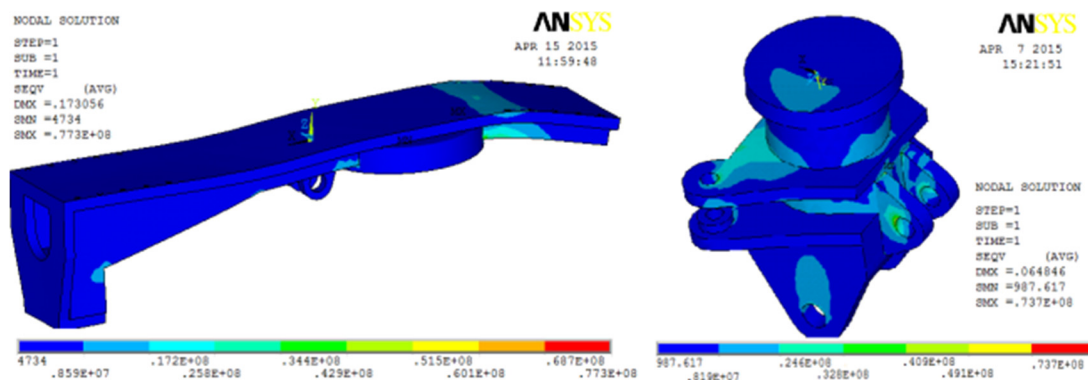


Figure 4. Stress analysis results of the bottom slid and the gooseneck

During the working process, the maximum stress of the bottom slid is 77.3MPa, and the maximum stress of the gooseneck is 73.7MPa. The material of the bottom slide is Q345A, and its allowable stress is 345MPa. The material of gooseneck is cast steel, and its compressive strength is 200MPa. The static analysis of the improved structures shows that the structural strength can meet the requirements.

4.3 Simulation analysis of the DTH drilling rig motion

After improving the structure, the other structures need to be measured. For hydraulic components and chains, sprockets, etc. in the working device, standard parts with the same structural dimensions can be selected for rapid model reconstruction. It is meaningful to study the spatial position change of the drill frame positioning device of the improved DTH drilling rig. It is possible to testify that if there are interference phenomenon in the structure of the DTH drilling rig and verify the rationality of structural improvement. Driving parameters such as cylinder added in virtual prototyping technology are shown in Table 1.

Table 1. Movement parameters of the hydraulic cylinder (unit mm)

Cylinder name	Full shrink length	Full expand length	Maximum Displacement	Standing length
rotate cylinder on main arm	760	1094	334	183
lift cylinder on main arm	700	1140	440	212
flip cylinder on drilling frame	745	1245	500	50
rotating cylinder on drilling frame	820	1220	400	398
compensation cylinder on drilling frame	1205	2085	880	880

Changing the telescopic length of the hydraulic cylinder can obtain the moving trail of the locating point on the drilling frame of the DTH drilling rig. Visual kinematics simulation analysis of the working device can be realized when the DTH drilling rig is working under three different combinations of working conditions. The working conditions of the cylinder are shown in Table 2.

Table 2. Cylinder status parameters in simulation model of DTH drilling rig

Working condition	Working condition of cylinder
Condition one	lift cylinder of the main arm extend to the longest, cylinder on the drilling cramp cylinder closed to receive the shortest, lift cylinder on the main arm、rotating cylinder on the drilling frame and compensation cylinder on the drilling frame combined together
Condition two	rotating cylinder on the drilling frame shrink to the shortest and locked, Chassis cylinder、Main arm lift cylinder and turning cylinder on the drill frame combined together
Condition three	rotary cylinder on the drilling frame shrink to the shortest and locked, chassis cylinder、rotary cylinder on main arm and compensation cylinder

on the drilling framework together

After setting the working status of the cylinders, the kinematic simulation of the virtual prototype is carried out according to the cylinder parameters in Table 2. The moving trail of the working device of DTH drilling rig under three conditions is shown in Figure 5.

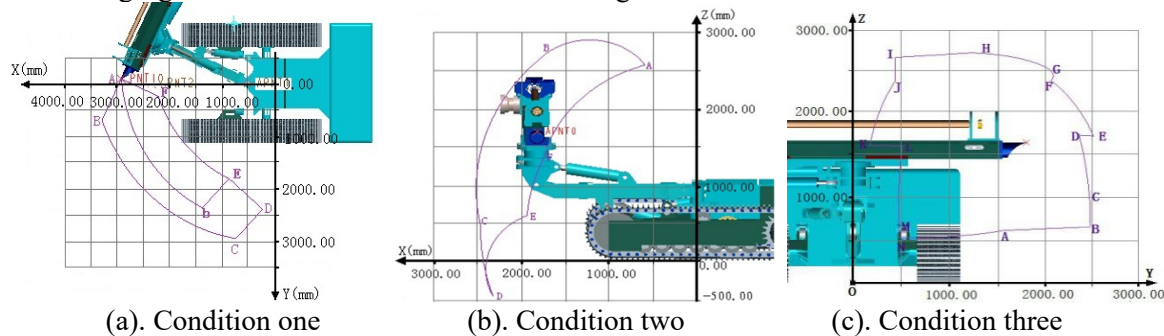


Figure 5. Motion simulation results of DTH drilling rig

From the simulation results of the virtual prototype, it can be seen that there is no motion interference in the improved DTH drilling rig structure, which verifies the rationality of the innovative design model. Through the innovative design model established in the paper, the data of the DTH drilling rig prototype is measured by modern measurement technology which can ensure the integrity of the data. The key dimensions of the common parts are measured, and the 3D model of the standard parts with the same structural function is selected for mathematical modeling, which improves the utilization rate of the standard parts.

5. Conclusion

The structural innovation of the product cannot be separated from the original functional requirements of the product and the perfection of the product function depends on the structural innovation. The relationship between the product structure and the function determines the final design form of the product. Based on the reverse engineering theory and Pro/E software platform, this paper proposes an innovative design model. The model introduces innovative evaluation indicators and virtual prototyping technology, and is successfully applied to the innovative structure of the DTH drilling rigs. The digital model of the new DTH drilling rig is obtained, and the structural function is improved. Finite element analysis and structural strength checking are applied to the improved structural parts. Then the virtual prototype of the DTH drilling rig is established, and kinematics simulation analysis is performed on it. The finite element analysis and virtual prototype simulation results verify the rationality of the innovative design model. The innovative design method based on reverse engineering realizes the innovative redesign of the new DTH drilling rig, shortens the development cycle of new product, and provides a new reference method for the functional improvement and structural innovation for related products.

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