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Research on Virtual Assembly and Performance Simulation of Electric Bicycle

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***Abstract*—The design is very important for electric bicycle production. To design a new electric bicycle, the designer needs master knowledge in many fields which include industrial design, 3D modeling, ergonomics, computer aided design, etc. But many electric bicycle manufacturers are small or medium-size and the designers cannot meet the practical demands. So, electric bicycle virtual assembly and performance simulation method is proposed in this paper. Firstly, a 3D-part database is established. Secondly, virtual assembly of the electric bicycle is done based on the database, and the performance of the new design is analyzed. By this way, it can detect assembly errors and design defects. It provides a convenient and practical method for electric bicycle designing, and by which it can improve the efficiency and accuracy of design work and reduce the design cost.**

Keywords- virtual assembly; performance simulation; finite element method

I. INTRODUCTION

Electric bicycles have many advantages as following: energy conservation, cheapness, light and safety. They are popular and welcomed by the people. The demand for electric bicycles has been increasing year by year. However, the bicycle industry has imbalance between high production capacity and lack of research and development capability. Design is very important for the electric bicycle production. To design a new electric bicycle, the designer needs master the knowledge in many fields which include industrial design, 3D modeling, ergonomics, computer aided design, etc. But many electric bicycle manufacturers are small or medium-size and the designers cannot meet the practical demands, and the design capability is a weakness in electric bicycle production and development.

To solve the above problems, electric bicycle virtual assembly and performance simulation method is proposed in this paper. Based on the fully investigation and analysis of the electric bicycle characteristics, this paper designed and constructed a 3D database which has geometry features and assembly features. This database can store a large number of 3D parts of electric bicycle. The virtual design of electric bicycle is performed based on this database. Referring to the knowledge of ergonomics and industrial design, the performance analysis and simulation analysis of the assembled bicycle model are carried out according to the bicycle national standard.

By simulating the bicycle assembles and quantitative analysis, it can find out the incorrect and unsuitable part in current design, which is the basis for designers to design modifications. This method can ensure the design of electric bicycle is reasonable and feasible. This process provides a convenient and practical method for electric bicycle design, make designers can modify and optimize the design parameters, and it can improve the design efficiency and accuracy, reduce the design cost. By this way, the bicycle design is scientifically, and effectively solves the design problem of the bicycle industry.

II. CONSTRUCTION OF 3D PART DATABASE

3D part database is the basis of the design of electric bicycle, and the design process and assembly process are completed based on the part database. So, the construction of 3D part database is the most important task of this research.

The idea of part database design is to build 3D part model from top to bottom. Designers only design parts and parts which they are specialize in, and use existing parts (or standard parts) to assemble products. We modeling the design process as a three-layer framework. The hierarchical model is shown in Fig. 1.

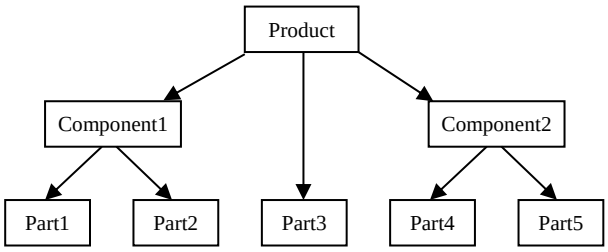

Figure 1. Model of product

The 3D part database is open, extensible and shared. The part model in the database is standard or general, and its description is divided into geometry features and assembly features. Geometry features describes the part information such as shape, size, structure, etc. Assembly feature is the information can be used in virtual assembly, which includes the semantic assembly features, assembly feature coordinate, mating feature and assembly tolerance content.

In order to ensure consistency of feature description between geometric features and assembly features, the 3D part database uses "part dictionary" to standardize and unify

feature description nouns. The dictionary follows the international standard of part database PLIB (ISO13584). It is an international standard of part data expression and exchange which is used in computer science. It is a guiding framework which focuses on the system structure, part encoding, and part classification and retrieval, etc.

According to the above discussion, the design structure of the 3D part database is shown in Fig. 2.

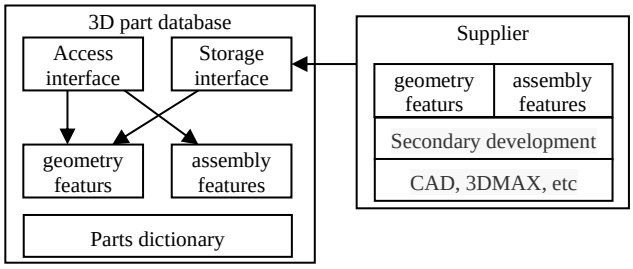

Figure 2. Structure of the part database

III. VIRTUAL ASSEMBLY

In this part, the designer selects the suitable parts and parts to design an electric bicycle based on the 3D part database. In this process, the virtual assembly technology is used to analyze whether the parts can be assembled together reasonably, and the assembly results are displayed by 3D graphic generation and rendering technology. There are three commonly used assembly strategies: bottom-up, top-down, and hybrid. The paper adopts the bottom-up assembly strategy. Firstly, the basic parts of the electric bicycle are assembled, and then the whole bicycle is completed assembly by these parts.

When assembling parts into component, it is necessary to analyze the assembly features of the parts. Assembly feature mainly includes two aspects: the first is the geometric characteristics which includes the elements as following: point, plane, spherical, cylindrical, conical surface and tensile type; the second is the mating features of parts, with common types are: surface matching, noncontact surface matching, alignment, insert, orientation, tangent, etc. It analysis whether the parts are in proper assembly sequence at the beginning. Then, it analysis coordination geometry features and assembly features. Let *MR* indicates the matching relation between parts, *MT* represents the matching type between parts, and *ME* represents the matching feature of parts. The coordination relation can be expressed as: *MR*={*MT*, *ME*}. When the mating sets of the parts can uniquely determine the positions of the parts, the assembly relation between the parts is obtained, and the two parts are connected in accordance with the assembly type. The assembly process is shown in Table I.

TABLE I. COMPONENT ASSEMBLY PROCESS

Let P_1, …, P_n are assembled parts, and P_{n+1} is the part to be assembled

① select P_{n+1} and move to the assembled parts;

② traverse the assembly information set of P_{n+1}, and find the part which has the matching relationship with P_{n+1};

③ analyze the matching type between $P_{n+1}$and these parts;

④ if (matching type == surface matching)
{ assemble P_{n+1}; }
if (matching type ==concentric)
{
if (size of axle and hole ==dimension tolerance)
{
determine the type of fit between shaft and hole;
According to the characteristics of the mating type, select the assembly method;
if (corresponding assembly method is available)
virtual assemble;
else give message about product design error;
}
else
{ give message about error design of axle and hole; }
}
else
{ virtual assemble; }

⑤ put P_{n+1} into the assembly list, record assembly method;

⑥ select the next part, till all the parts are assembled.

The virtual assembly method of bicycle is similar to component, which is also embodied by assembly features. It reduces unnecessary component matching analysis and improves assembly efficiency. In this paper, the assembly sequence of the whole bicycle is adopted as following:

① Assemble the frame part;
② Assemble the saddle on the frame;
③ Assemble front fork on the frame;
④ Assemble the handle on the frame;
⑤ Assemble front wheel on the frame;
⑥ Assemble the brake;
⑦ Assemble rear wheel on the frame;
⑧ Assemble the pedals on the frame.

IV. PERFORMANCE SIMULATION

The performance of the designed bicycle needs to be evaluated and analyzed. In this paper, the performance evaluation includes two aspects: the first is to calculate the static performance parameters, such as weight, cost, maximum speed, and maximum mileage, etc. These parameters descript the intuitive external performance of the bicycle. The second evaluation is safety performance. This paper uses computer simulation technology to test the safety of the bicycle design, which includes the main braking distance simulation test, force simulation test of braking system, impact simulation test, etc. These tests can evaluate the safety performance of the bicycle. The calculation of static performance parameters is relatively simple, while the

evaluation of safety performance parameters is more complex and difficult. The analysis method is given as follows.

(1) Calculation of static performance parameters.

Firstly, give the corresponding calculation formulas of the static performance parameters according to the actual situation. After the whole bicycle design is completed, the actual parameters of the parts are computed and extracted, and use these parameters to calculation. The static performance parameters can be obtained. The formulation of the static performance parameters will be improved continuously according to the actual situation and the experience, which can ensure their accuracy.

(2) Analysis of safety performance parameters.

At present, some parameters (such as the size and shape) are often given base on the designers' experience in bicycle design. While the safety performances (such as the structure strength, fatigue properties) are verified by the actual experiment after the product is manufactured. In order to ensure the safety performance of the electric bicycle in actual use, the quality supervision departments give a series of experiments provided to ensure the strength and durability of the bicycle. Those experiments are according to the national standard of People's Republic of China (GB 3565-2005/ISO 4210:1996). The design process should always be implemented to improve quality and safety.

Based on the national standard "bicycle safety requirements" and the "test of National Bicycle Quality Supervision and inspection center", this paper provides simulation tests include the following items: (1)brake system performance testing (including brake test, force test of braking system, braking performance test); (2) vertical tube performance test (including handlebar torque, bending test); (3) performance test of frame/fork (including weight drop test, impact test of frame/front fork, front fork fatigue test); (4) static load test of wheels; (5) pedals performance test (including pedal static load test, dynamic pedal durability test, fatigue test of crank assembly); (6) saddle performance test (including saddle pipe test, saddle static load test, strength test, fatigue test); (7) road test.

The content of the above tests are divided into the following three categories according to the difficulty of computer simulation. Most types of tests for electric bicycle tests are of this type,

The first type applies a single, specified pressure to do load test, which can detect the deformation of the bicycle (or a part), and whether it breaks. Most types of tests for electric bicycle tests are of this type, such as torque tests, static load tests, and strength tests.

The second type applies the specified pressure on a part repeatedly to test the deformation. Such tests are mainly fatigue tests.

The third type applies the specified pressure on the bicycle which has been speeded up and tests the running condition. These tests mainly refer to the brake test and road test.

This paper use the finite element analysis function of UG NX to simulate and analyze the above three types of tests. The first and second tests apply finite element technique to simulation and analysis static structure. The third test applies finite element technique to simulation and analysis the structural vibration. The basic mechanical parameters are similar to the above static problems, and the inertia force, damping force and time factor are added. The finite element analysis can analyze the accurate tested parts parameters (including mechanics, displacement, deformation and stress) under the influence of complex external force.

The finite element analysis technique can obtain the exact mechanical information of the internal deformation of a complex body with complex geometry. The steps of the finite element analysis are described below.

① Imposes loads and constraints on the model.

②Calculate the stiffness equation of each unit.

③Assemble the stiffness equations of each unit.

④Deal with boundary conditions and solve them.

⑤Seeking counterforce.

⑥ Calculate other mechanical quantity for each unit (such as, stress and strain).

⑦Analysis and calculation.

For example, in the "frame weight drop test" simulation, the frame and the front fork are generally welded and assembled by the hollow thin-wall round steel tube, and the quadrilateral shell element can be used to mesh the steel tube of the front fork. For the connection part between the steel tubes, the welding unit is used for the unit connection transition. The finite element model of the frame is shown in Fig. 3. According to the test requirements, a hammer weighted 22.5kg fall from a height of 180mm, which aim at the wheel at the reverse direction of the front fork.

According to gravity, impulse and law of conservation of momentum, the force that the hammer falls on the frame is N (Fig. 4), which is the load applied on the model. Then the stress and strain of different frame can be obtained by finite element analysis. According to the maximum shearing force of the material, whether the frame is broken can be detected. If the material has yielded or sheared, it is because the maximum shear stress within the material is up to its ultimate limitation.

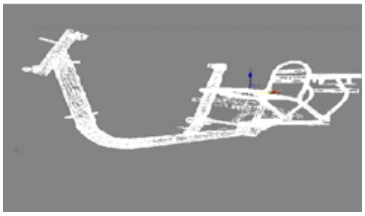

Figure 3. Finite element model of frame

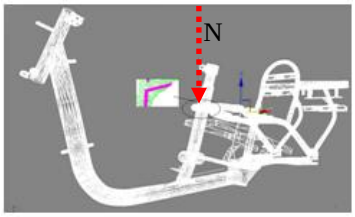

Figure 4. Load model of frame

The safety performance of the electric bicycle is simulated and analyzed by the finite element analysis

technology. The designer can judge and analyze the force, strength, stiffness and other aspects of the whole product design. Furthermore, the unreasonable design parameters can be modified and improved, and the optimized design will be obtained.

V. CONCLUSION

At present, bicycle manufacturers are generally small and medium-sized enterprises and few factories are equipped with the qualification that making the integrated product design. In view of above problems, this paper investigate the computer aided design, virtual assembly and performance simulation of electric bicycle based on the 3D parts database. In accordance with international standards, we establish a parametric standard database of 3D digital parts. On this basis, it describes the process of virtual assembly of electric bicycle. At last, the performance of virtual assembly result is analyzed and simulated from two aspects: static performance and security performance. The performance simulation result provides designers with more in-depth and rational analysis of the performance of the product that being designed. Designers can modify the unreasonable designing and get a more optimum result. This research can help to increase the rationality of purchasing parts and components in the whole bicycle production enterprise, improve the design level, and promote industrial upgrading.

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