Correlation Based Parametric Design Method of Lifting Device in Nylon Coated Conveyor Line

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Abstract. In order to solve the problem of low efficiency in design variation of the lifting device in nylon coated conveyor line and meet the user's individual and diversified demands, the key technologies and implementation methods of the automatic generation of lifting device were studied. Firstly, the dimension correlation between each part of the lifting device was analyzed and the dimension correlation diagram was established. Secondly, the parts parametric modeling method was given based on the dimension relationship. Then, the structural correlation was analyzed, based on which the assembly modeling was established. Finally, the design process of the lifting device was taken as an example to verify the effectiveness of the method.

1. Introduction
Nylon coated conveying line is an important equipment in extending the operational life and reduce friction losses of the spline shaft by coating nylon on its surface uniformly. The lifting device is one of the indispensable parts of Nylon coated conveying lines. Its deformation is mainly based on lifting weight, lifting height, lifting speed, working level, etc. Its design process is complex. How to realize the automatic design of lifting device is a problem that needs to be solved at present.

Parametric design is the core technology of intelligent CAD system and one of the most widely used hotspot designs. With the development of modern mechanical design, the research cycle of products can be shorten through parametric design [1]. By using certain parametric design method to create parts and assembly templates, modification and optimization can be realized by changing the main parameters [2].

Association design is a parametric design technique based on association geometry, which uses geometric relationships and parameters to spread variation. Because the size and structure related design in the product variant design can improve the design efficiency of the product and ensure the design quality of the product, the correlation-based parametric product design technology has been widely used in product variant design. As Jia proposed a novel modular design method based on the fuzzy correlation analysis [3]. Yang et al. put forward a method of building parametrization component library based on automatic assembly technology, which achieved the explicit expression of assembly relations and accelerated product design [4].

2. Size correlation analysis of lifting device
The dimensional information not only determines the size and the position of the part, the coordinates of the set size, but also determines the constraint relationship between the geometric features [5]. It is
the basis of constructing the whole assembly. In mechanical products, constraint relationship between parts plays an important role in the fulfillment of product function. Therefore, the associated design of the part should be based on constraint-driven association [6]. When the upstream design is changed, the change of design information was transmitted to the downstream and the transmission direction was maintained in time.

The lifting device of the nylon coated conveyor line is a component composed of many parts. As an assembly, assembly relationship exists among parts, that is, the dimensional parameters and the structure of the part have assembly-related characteristics. It is necessary to perform dimensional analysis on the dimensional parameters of the lifting device to determine the correlation between the dimensional elements and the basic design parameters.

2.1. The basic dimension parameters of lifting device
Parameters relationship reflects a valid portfolio relationship among the parts of the product, including constraints, characteristics and dimensions of the product. The basic size parameter is the first-order parameter of the parametric driven association, which can be established among different parameters in the same part or among different parts in the assembly. Therefore, it is very important to determine the basic size parameters of the lifting device.

The ball screw is the main part of the lifting device and the change of its design parameters has a great influence on the lifting device. Other parts are designed and selected on the basis of the ball screw. Therefore, the basic parameters of ball screw are the basic parameters of lifting device. In the design process, the ball screw is designed according to the working conditions of the lifting device, such as lifting weight, lifting height, lifting speed, working level. As shown in Fig.1, main design parameters of ball screw are: L0, L3, PB, Da, etc. In the design, the structural size of main parts was determined by Da, so Da can be used as the basic parameter.

2.2. Correlation analysis of dimension parameters
The key and foundation of assembly parametric design is to establish correlation of dimension variables between parts. In order to simplify the process, we stipulate that: Internal parameters are not related to the part or sub-assembly; External parameters refer to parameters published in the assembly environment; Correlation parameter refers to the parameters related to assembly between the parts that construct the assembly [2].

The association relation of dimension parameter is directional, including vertical relation and horizontal relation.
Vertical relation: It is a one-way relationship that changes in the upstream design will cause changes in the downstream structure. But the change of downstream has no influence on the upstream structure.
Horizontal relation: It is a two-way relationship that the change of any part will cause changes of the structural dimensions of relating parts.

Figure 1. Dimension structure diagram of lifting device (1. ball screw 2. screw support seat I 3. screw mounting seat 4. ball nut 5. screw support seat II).
In parametric association design, the order and direction of the parameters have a crucial influence, which in turn determines the overall size of the lifting device. Therefore, it is necessary to analyze the correlation of each part in lifting device.

As shown in Fig. 2a, changes in the ball screw (Da) will cause L3 to change, which in turn causes change in other dimensional parameters (L1, L2, L4, etc.). Between parts, the size of the ball screw parameters (L1, d1, Da, L5, d5) changes result in changes of other parts size parameters (d1 l2, Da’, L5, d5, etc.) as shown in Fig.2b. This is a vertical relation. The dimensional parameters of the ball screw (L2, d2, L4, d4) vary with the size of the screw support seat (I, II parameters (L2, d2, L4, d4), as shown in Fig.2c. This is a horizontal relation.

Figure 2. Vertical and horizontal correlation between parameters.

2.3. Parts modeling of lifting device based on dimension correlation

The size correlation of the lifting device determines the parameter transfer relation and provides a rule for parametric modeling. For lifting device components, there are standard parts and non-standard parts, both of them should be designed according to the correlation relationship between each part of lifting device. The determination of basic dimension parameters will directly or indirectly drive the design of other parameters.

2.3.1. Establishment of dimension correlation model. Based on basic dimension parameters and correlation between parts in lifting device, the interdependence among the components can be summed up. Thus, a parameter-driven association model can be established, as shown in Fig.3.

2.3.2. Parametric modeling of non-standard parts. Non-standard parts in mechanical products are designed by functional requirements. Its design modeling methods include: dimension parametric modeling, structural parametric modeling [6]. In this paper, the parametric modeling method of parts based on standard template is proposed.
(1) The establishment of the critical parts standard template: According to the functional requirements of the product, a standard model template for each part of the lifting device with universal applicable characteristics is established, and some key parameters are used to describe the relationship between the shape and the size of the model to form a module family. The main model of part module consists of its geometric model and the corresponding characteristic table. The geometric model and its parameters describe the unified characteristics and parameterized dimensions of the module family, and the characteristic table describes the specific dimensions and unique characteristics of each module in the module family.

(2) Based on the dimensional parameterization modeling of the part standard template, only the size of the standard template is changed according to the structural design requirements. In the design process, based on the standard template of the part, the dimensional relationship is used to drive the change of other dimensional parameters, and the part model is updated to complete the design of the part.

3. Structural correlation analysis of lifting device

Functional structure is the core of a product and the analysis of structural correlation relationship lays a foundation for the establishment of skeleton model and assembly model. The skeleton model is used to describe spatial requirements, important installation position and motion of the product. It is the three-dimensional space planning of product assembly, which determines the interface of design object structure. The skeletal model contains transmission mode and direction information for the upstream and downstream transmission of the design unit.

3.1. Basic structural correlation types

In the assembly model, the structural correlation determines the structural characteristics of the whole assembly model. The following four kinds of structure association constraint is the basis of assembly spatial planning.

Performance correlation constraint: It is interrelated constraint among several parts to achieve a certain performance. For example, the performance of ball screw is determined by the constraint of the rotary association between ball screw and ball spring.

Physical correlation constraint: It is physical relation of energy conversion and signal transfer between structures. For example, the torque on the ball screw is transferred to ball screw mounting seat through the ball nut which is transmission constraint of energy signal between them.

Shape constraint: It is a shape position relation between parts, including the link, fit and fixation between structures.

Other correlation constraint: It refers to other constraint relationships that are involved in the product life cycle [7].

The analysis of structural association constraints lays the foundation for product design, provides theoretical support for product design, and can effectively improve design efficiency and save production costs.

Figure 4. Associated configuration constraint of lifting device structure.
3.2. Structural correlation characteristics of lifting device

The assembly modeling was established according to the structural correlation of lifting device. Because the structure of the lifting device is relatively simple, its performance association constraint, physical association constraint and other association constraints are not considered. In this paper, the lifting device is described by the shape and position constraint in the structural correlation constraint. As shown in Fig.4, the structural shape and position correlation constraints mainly include: surface constraint (Mc1), coaxial constraint (Mc2) and thread fastening (Fc1). It is the key to define the assembly feature and assembly sequence between the parts in assembly [4]. The main and subordinate relations between parts are represented by directed line segments and the parts pointed by the arrow are Sub-part. For example, the shape and position correlation constraint of ball screw and ball nut in the Fig.4 is Mc1 and Mc2 and ball screw is subject to ball nut. In addition to the establishment of the structural correlation model, the assembly correlation relationship is also determined. This relationship does not change with the dimensional element of the part, thus ensuring that the relative position between the parts does not change.

3.3. Product assembly modeling based on structural correlation

The basic elements of the assembly model are determined by the analysis of structural correlation and the geometric elements of the skeleton model: datum plane, datum axis, datum point, etc. The assembly relation of the lifting device is determined by structural relation, on which assembly parameters, parameter constraints and assembly target constraints are determined. The assembly relationship will drive each part to establish the constraint association relationship of the corresponding features, so that the lifting device can automatically complete the assembly. Fig.5 shows the assembly modeling process of ball screw and screw support seat based on shape and position association constraint. The assembly is realized according to the shape-related constraints associated with the screw support seat and the ball screw, such as the coaxial constraint and the surface constraint. Firstly, the pose of screw support seat should be adjusted and then the radial freedom degree between them should be restricted by the coaxial constraint. According to the surface constraint, the corresponding surface of them are bonded together and the axial freedom between them is limited. These constraint types, as well as the adjustment and positioning of spatial position, are driven by assembly association.

4. Example

In order to realize the parametric design method of lifting device based on correlation, an associated parametric design system in Solidworks environment is developed. The following examples used to illustrate this process.

Initial design parameters of lifting device are: (1) lifting weight is 480 kg; (2) lifting height is 550 mm; (3) lifting speed is 150mm/s; (4) work level is level 5.

The design parameters are first input, and the part model can be generated through background design calculation and automated modeling.
Then in the assembly module environment, the system will automatically generate the lifting device assembly model according to the shape and position constraint relationship between the parts in Fig.4, as shown in Fig.6.

Change propagation design: The lifting height of the device changed from 550 mm to 600 mm. According to the dimension and structural correlation, the corresponding size and structure of ball screw, lifting installation plate and lifting transition plate can be changed automatically, as shown in Fig.7.

![Figure 6. Assembly view of lifting device.](image)

![Figure 7. Height change of lifting device.](image)

5. Conclusion
In this paper, a parametric design method based on correlation is proposed for the designing of lifting device in nylon coated conveyor line. The method focus on extracting the dimension parameters associated with the product. By defining the structure relation and dimension constraint relation between parts, the parametric design based on association-driven is formed. Based on which change propagation design can be realized automatically. This method lays a foundation for product design, provides theoretical support for product design, can improve design efficiency and save production costs.

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