Parameterized Modeling and Material Intensity Simulation of Excavator Stick

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Abstract. In order to shorten the design cycle of excavators and to meet the needs of users constantly updating key parameters in their designs, a reusable parametric design model of excavator sticks has been developed. Based on the WAVE function of Siemens NX, a parameterized model of large excavator stick is constructed, and a codeless reusable system is constructed by using NX / PTS powerful interactive operation function. At last, the reliability of the model is verified by the strength simulation. The entire system interface is intuitive and easy to operate, which greatly shortens the design cycle of the excavator stick and improves the design efficiency of the stick.

1. Introduction
Excavator is a kind of construction machine used for excavating soil. It is mainly used for excavation of trench in road construction, dredging of river in hydraulic engineering and ore excavation in mining engineering [1]. According to statistics, about 60% of the earthwork volume of the construction of the project is achieved by excavators. According to the development of construction machinery in recent years, the excavator has become one of the most important construction machinery in the construction. Excavator main components are sticks, buckets, boom, rotary platform, power transmission and walking agencies [2]. The stick is an important component that connects the boom to the bucket, and its structure is complicated, which often takes a lot of manpower and money in design. In order to complete the complex structure of product design in a relatively short period of time and meet the rapidly changing market demand, it is necessary to realize the rapid design of the parametric model of excavator main components.

NX is an interactive CAD/CAE/CAM system. WAVE(What-if Alternative Value Engineering) is a powerful module in NX and the top-down modelling approach is WAVE's guiding principle that makes it possible to design a top-down association between product components. PTS (Product Template Studio) is a functional module in NX that implements code-free human-computer interaction design, which makes it possible to design object-oriented visualization parameters. Based on the traditional design experience of excavator, this paper constructs a parametric reusable design model of excavator stick by using WAVE and PTS module functions, and uses ANSYS and ADAMS software to simulate the strength of the stick to verify the reliability of the model [3]. This model greatly shortens the design cycle of the excavator stick and improves the re-design efficiency of the stick.

2. Parametric Model of Stick

2.1. Siemens NX
Siemens NX is an all-in-one product engineering solution that drives product innovation through process changes. WAVE is a NX technology that enables the modelling of relationships among product components. It effectively controls the assembly design and part design of complex products to ensure the interconnection of the entire assembly and components. PTS is a reusable module of NX that significantly improves the re-use of design knowledge by creating product templates, and can also create intuitive and interactive interface for model parameter called, in order to achieve the related control parameters.

2.2. The functional composition of the stick parametric model
Stick is an important part of the excavator, mainly by the root bracket, front bracket, the middle bracket and the connecting plate, as shown in Figure 1. The parametric model of the stick must be designed to be easy to use and will not cause confusion in the control of the parameters and to achieve the following functions:

(1) Open the template browser through "Edit Reusable Components" in the NX Assembly Navigator. The key dimension parameters in the related components can be modified, and the model can be updated with the parameter changes.

(2) When the parameters of the stick top model are modified, the bottom sub-part models will also be updated; when the parameters of the stick bottom model are modified, the same level model associated with it will change, and the top model of the stick will also be updated.

3. Construction of Parametric Model Based on WAVE
Parametric modelling is the core of CAD technology. At present, most CAD software has the function of parametric modelling, and WAVE is the top-down parametric assembly modelling function of NX. The key to parametric modelling is using parameters, formulas, links, features, etc. to drive and change the model. It is the premise of using PTS to make product templates and the key to realizing knowledge reuse.

3.1. Determination of overall control parameters for stick
The overall control parameters mainly refer to the parameters that affect the function and structure of the product. When using NX / WAVE function to parameterize the excavator stick, we first need to analyse the structural design demand of the stick by relying on the accumulated experience of the traditional design of excavator stick. Then according to the characteristics of the structure of the stick, the root of the stick is set as the origin of coordinates, and then the overall control parameters are obtained as follows: L1 (horizontal coordinate of the front bracket hole), L2 (horizontal coordinate of the middle bracket hole), H (vertical coordinate of the middle bracket hole). As shown in Figure 2.
3.2. *Determining the associated structure of stick*

The composition of the excavator stick is more complicated. In order to show the clear associative design structure of the stick and facilitate the operation and management of the designer, we define the control structure between the stick components and the parts, according to the symmetrical structure of the stick and the interrelationship between sketches and benchmarks of each component, as shown in Figure 3.

![Figure 2](image)

**Figure 2.** Overall control parameters of stick.

3.3. *Construction of stick parametric model based on WAVE*

The parametric modeling of the excavator stick adopts the top-down design method. The stick model is constructed by two layers in sequence according to the associated structure diagram:

3.3.1. *Top components.* Firstly, we use NX modeling module to create a 3D empty model of excavator stick and name it “stick” as the top component of the entire assembly model. Then use the expressions, datum, and sketches to create three overall control parameters for the stick in the empty model. As shown in Figure 4.

![Figure 4](image)

**Figure 4.** Creation of overall control parameters.

3.3.2. *Bottom components.* Firstly, we use NX/WAVE "New Level" function to create each subcomponent of the stick as the bottom components of the assembly model and named them "root bracket", "front bracket", "middle bracket", "horizontal plate", "bottom plate", "top plate", "side plate", and then use the WAVE Geometry Linker to copy the geometry features of the top components to the newly created bottom components. We use this as a base plus a new sketch to create the bottom geometry. Taking the root bracket as an example, the parametric model is created as shown in Figure 5.
Need to pay attention to: Sketching process must be in line with the specifications to ensure that all constraints and cannot have virtual constraints or over constraints. Full constraints may have a variety of design schemes; the design experience needs to be based on a more reasonable selection of all constraints in order to meet the design requirements. The bottom sub-components may also need to be related to each other through the WAVE, in order to achieve the purpose of updating simultaneously.

3.4. The creation of stick 2d drawings

In the actual design process of the excavator stick, after the 3d model of the part is created, 2d drawings conforming to the corresponding standards and specifications are also to be designed and produced. We also need to mark the size and tolerance, display style and attribute filling operation, and finally to save as the 2d drawings of the stick.

4. Construction of Interactive Dialogs Based on PTS

PTS module is NX user-oriented, code-free parameter dialog design tools, the establishment of the expression, sketch data, etc. simply by dragging can be passed to the PTS, and generate user interface with display, data input and other functions. The user interface can be directly embedded into the NX assembly model file, and the user can modify the model parameters through a simple interface operation.

PTS dialog box design is divided into the following steps: Start PTS and import the parametric model of stick, and double-click the model thumbnail into the user interface. In the work area, add items such as type block, group, separator and bitmap etc. In the model operation interface, we drag and drop the relevant dimensions and expressions established in the parametric modelling into the corresponding groups, and add the created 2D drawing to the PTS to establish the connection between the model and the 2D drawing. The design dialog box for overall control parameters and root bracket dimensions are shown in Figure 6.
5. Operation of Stick Parametric Model
Start NX, open the "stick" .prt file, select the top-level component in the Assembly Navigator in the modeling environment and right-click on "Edit Reusable Components" to bring up the template browser and enter the parametric modeling dialog box. We can double-click to open the top and bottom components in the template browser, modify the appropriate dimension to achieve the model and 2d drawings associated updates. Taking L1 about overall control parameters of stick as an example, before and after the modification model comparison shown in Figure 7.

![Comparison chart of L1 changes before and after](image)

**Figure 7.** Comparison chart of L1 changes before and after.

6. Simulation of Stick Material Intensity
We use the finite element software ANSYS and multi-body dynamics software ADAMS together to achieve the strength simulation of the stick. First import the stick model into ANSYS, create an modal neutral file (.mnf) of stick by operation, then import this modal neutral file into ADAMS and assemble it with the bucket and boom, then apply the constraints and loads in the ADAMS to perform the dynamics simulation, and finally get the stress map of the stick, as shown in Figure 8. We can see that the maximum stress of the stick is 205MPa, which is within the range of the stress limit of steel 300Mpa, which meets the design requirements.

![Stick stress diagram](image)

**Figure 8.** Stick stress diagram
7. Summary
In this paper, the parametric construction of the excavator stick model is realized by using the WAVE technology, parameter association and feature chaining. An interactive dialogue box of the stick is created by using PTS module. It realizes the function that modifying the size of the top model to drive the modification of the associated subcomponent model and modifying the size of the bottom model to drive the modification of the interrelated bottom model. Finally, the reliability of the model is verified by the structural strength simulation. The interactive dialog interface of the parametric model is simple, easy to operate, can greatly improve the re-design efficiency.

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9. References
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