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A Modeling Programming Used OOP for Lattice Boom

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Abstract: The combined jib of a crane is a complex system, its mechanical analysis modeling is difficult, and the efficiency is low. In this regard, it is researched that the object-oriented programming technique is applied to truss crane jib modeling. Proposing a generic modular truss jibs modeling based on parametric modeling for rapid modeling method and providing a new method for truss boom system simulation design is necessary. The development and design of truss boom system time can be greatly reduced by using the modeling method in the paper. The design efficiency can be improved significantly. This paper takes the VisualBasic as the programming platform making the truss boom of the all-terrain crane as an example to verify the effectiveness of the new modeling method.

Keywords: Complex Lattice Boom Structure, Mechanical Analysis Modeling, Parameterization, Modularization Programming, Object-Oriented Programming

1. Introduction

Because of the small self-weight, transport and splicing convenient, strong ability to resist the wind advantages, the lattice boom is widely used in crawler crane, tower crane, truck crane jib, floating cranes, some towering structure of boom system and tower structure with large wind power occasions. With the popularity of the development of computer simulation technology and analysis software, the finite element method has been widely used for crane boom's design and analysis [1]. Parametric modeling technology in the design of the crane boom has been widely used. From the access point of view, the domestic and foreign research on the truss boom modeling technology are also stay at the level of parametric modeling [2]. But the parametric modeling technology can only be parameterized for the specific structure type, the modeling efficiency is low, the flexibility is poor, and the dependence on the two development platform is very large [3].

The parametric modeling technology is a basis of this paper. A set of truss boom system of generalization and modular modeling method is established through the deep excavation of the structure characteristics of truss boom extracted their common characteristics [4]. The object oriented programming technology is adopted in this modeling method, the corresponding class module is established for different parts of the crane boom system and the independent modeling program of boom system is developed [5]. This method can't rely on other modeling software, the finite element analysis of the different software for secondary development has the characteristics of high generalization, modularization and flexibility. The study for the series design of truss boom system provides a rapid and reliable modeling method.

2. Class Module of Complex Lattice Boom

Truss boom system generally consists of boom sections, hydro-cylinder, pull rod and other components. By extracting the typical features of boom write the corresponding module in order to realize the modular modeling and automatic assembly of the boom system, reduce the modeling workload and improve modeling efficiency and accuracy greatly.

2.1. Structure Characteristics of the Truss Boom System

The typical structure of truss or lattice boom system as shown in Figure 1, its parts is generally connected through a hinge pinto, so the boom section, hydro-cylinder, pull rod and scaffold can be regarded as independent component modules. The component model is connected after establishing the corresponding class module respectively and generating corresponding component.

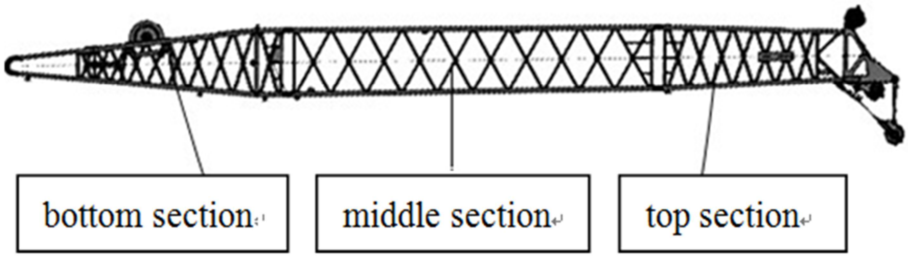

Fig. 1. *The typical structure of truss boom system.*

The boom section and the scaffold of the truss boom are welded together and strengthen with plate in the complex parts. According to the structure characteristic, the boom component can be regarded as a constructional entity which is consist of a bar or a scaffold between welding spot and welding spot. The characteristics of truss structure are shown in Figure 2.

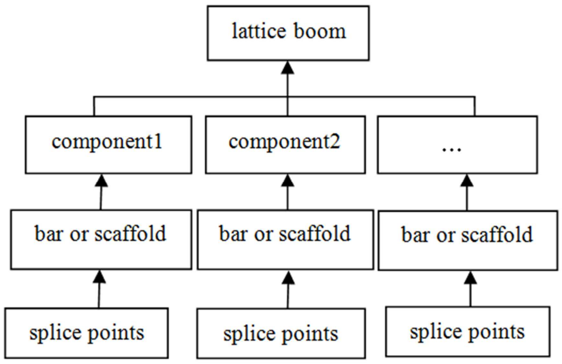

Fig. 2. *The characteristics of lattice or truss structure.*

2.2. Class Module Corresponding to Each Component

Through the summary of the different forms of truss boom, according to the characteristics of the boom structure extract the common feature parameters. Using the object-oriented programming technology, establishing boom component class module and automatically generating boom component model and splicing achieve the purpose of rapid modeling.

2.2.1. Class Module of Complex Truss Structure

In object-oriented programming, class is mainly composed of attributes and methods. Attributes contains public and private variables, public variables can be accessed outside the class, private variables can only be referenced within the class, the method can be done on the content of the class. The modeling method in this paper is based on the above features of object-oriented programming.

The common characteristics of different parts can be summarized by extracting the characteristic parameters of the truss boom components. The structural parameters of the components can be divided into three parts, the basic parameters, the derived parameters and the operation method.

Basic parameters: the boom structure parameters are often regarded as the basic structural parameters, in the construction of a class need to set the input, such the length, width and height of the section. These parameters are set in the class module as a common variable, which can be set by the external input.

Derived parameter: the other parameters in the boom structure can be derived from the basic parameters, such as the volume and mass of the boom though the length and width of the boom and the material parameters can be obtained by the formula. For the parameters that can be derived from the calculation of the basic parameters, the class module is set as a private variable, not by external input. Not only to reduce the number of manual input parameters, but also to avoid the error caused by the input.

Method of operation: when the object of the component class is set up, the position of the component usually needs to be adjusted. By adding a translation, rotation and other methods in the class module the assembly of the boom can be realized by simple translation, rotation and other commands. At the same time, we can also get the derived parameter by processing the parameters of the internal variables of the components.

In the program operation, the translation, rotation, and splicing of the components can be realized by using the geometric transformation of 3D graphics [6]:

(1). Translation transformation

The point $\boldsymbol{x}$ which was translated $\Delta = (\Delta x, \Delta y, \Delta z)$, and the final coordinates is x',

$$\boldsymbol{x}' = \boldsymbol{x} + \Delta\boldsymbol{x} \tag{1}$$

rotation transformation: when rotate the boom section model the point $\boldsymbol{x}$ relative to the origin of the coordinate and rotate α, β and γ degrees around the coordinate axis x, y and z respectively, the corresponding transformed coordinates are:

$$\boldsymbol{x}_n = \boldsymbol{T}\boldsymbol{x} \tag{2}$$

Where, $\boldsymbol{T} = \boldsymbol{T}_z\boldsymbol{T}_y\boldsymbol{T}_x$, and

$$\boldsymbol{T}_x = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$$

$$\boldsymbol{T}_y = \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix} \quad (3)$$

$$\boldsymbol{T}_z = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

(2). Assembly of the parts

The sections of the truss boom are usually articulated, in the process of the secondary development, the assembly of components is achieved by using the software's command statement.

2.2.2. The Programming of Class Module

According to the sequence bottom to top style, the boom model can be done through the 6 class modules in Figure 3.

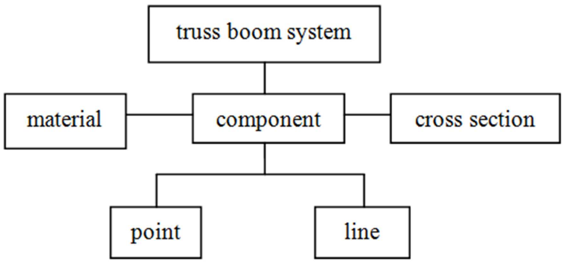

Fig. 3. Module classification and relationship in the modeling of truss boom.

(1). Point class: the point of the class structure which include the node coordinates and serial number.
(2). Line class: the connection between point and point, also known as the link. The physical quantity contains the size, section properties and material properties of the line corresponding to the bar.
(3). Component class: refers to the special components which include pull rod hydro-cylinder and boom section.
(4). Boom class: the original parameters include name, size and so on. Derived parameters include weight, volume, etc.; Methods include the addition components, translation, rotation, etc.
(5). Material class: including the density of the material, elastic modulus, Poisson's ratio, yield strength, etc.
(6). Section class: including section type, size parameters, etc.

This study implements the modular, universal, rapid modeling, and the modeling process of the boom as shown in figure 4.

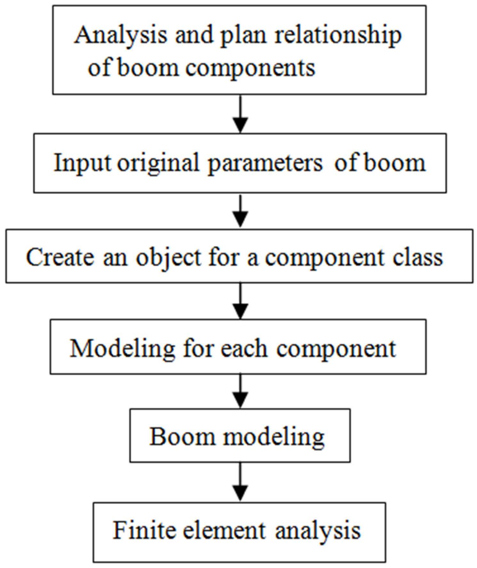

Fig. 4. Schematic diagram of the boom system development process.

3. Engineering Case

In the case of an all-terrain crane's fixed jib, by VisualBasic 2005 platform to establish the module of boom modeling and through secondary development of ANSYS to achieve the boom of the modeling and nonlinear analysis to verify the applicability and efficiency of this method [7].

3.1. Fast Modeling and Programming of the Boom System of the All-Terrain Crane

The truss boom of the all-terrain crane is mainly used as the auxiliary boom which is an extension and improvement of the function of the main boom and is an indispensable position in the operation condition. In this paper, a type of all-terrain crane as shown in Figure 5. The application of this method to establish the model of the boom and the operation steps are as follow:

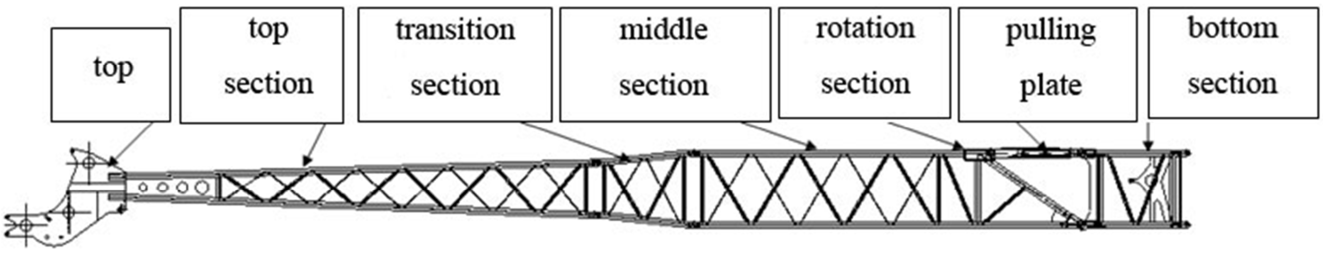

Fig. 5. The structure of truss boom of all-terrain crane.

The first step according to the connection of each part of the boom, the boom is decomposed into independent components as shown in Figure 5. The boom is divided into the top, jib top ganglion, transition section, jib middle ganglion, rotating knot, pulling plate, jib root ganglion and other part [8].

The second step extraction of the typical parameters of the components. Take the jib root ganglion as an example, as shown in figure 6. To distinguish the basic parameters and derived parameters in order to get the corresponding class module [9];

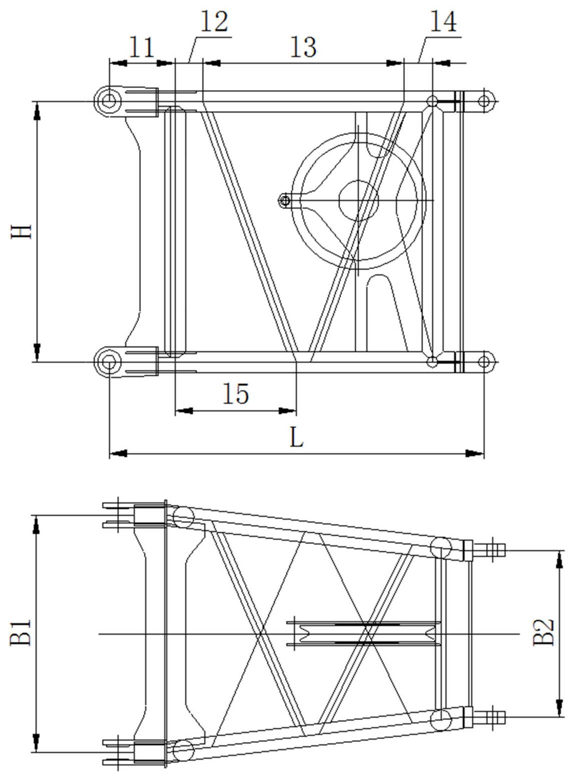

Fig. 6. *Schematic diagram of jib root ganglion parameter.*

The third step to write the corresponding class module of the extraction of the characteristics of the components and to create an input interface for the class module parameters. Boom section as an example in the Visual Basic 2005 code is as follows:

Truss boom section, through the boom section size parameter definite the point and the line to compose boom section.

```
Public Class Part
Public Name As String 'the name of boom section
Public Number As Integer 'the number of boom section
Public L(2) As Double ' Integral length of boom section
Public H(2) As Double ' Integral height of boom section
……
Public Alpha() As Double 'angle of the boom section
'point sets
Public Points As New Point Collection
Public Lines As New Line Collection 'unit sets
Public Mats As New Matial Collection 'boom section material
Public Secs As New SectionCollection 'the section of boom section
'boom section translation method
Sub Move(ByVal X As Double, ByVal Y As, ByVal Z As Double)
……
End Sub
'boom section rotation method
Sub Rotate(ByVal X As Double, ByVal Y As Double, _
ByVal Z As Double)
……
End Sub
End Class
```

After the completion of the above work, we can quickly generate the corresponding parts object according to the parameters of the input and use the method of the boom to automatically assemble the model and to get the data. To use the VB2005 programming to draw the line of boom diagram as shown in figure 7.

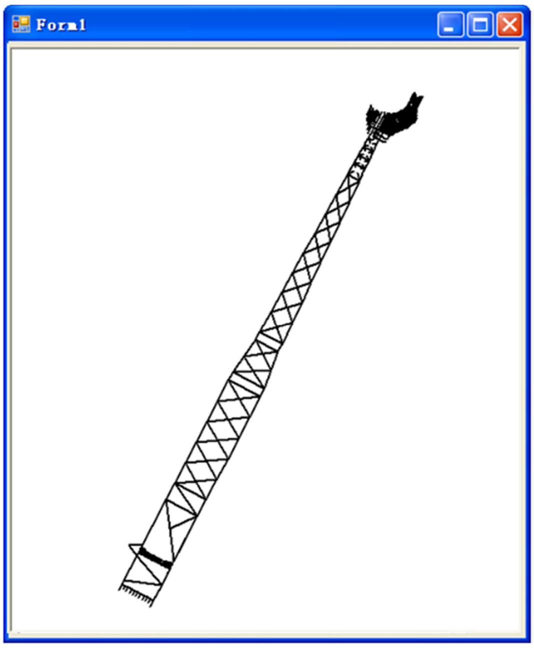

Fig. 7. *The diagram of line of the truss boom.*

3.2. The Establishment and Analysis of the Boom Model

After the assembly of the boom model is completed in the programming platform the finite element analysis of the APDL statement can be used in the ANSYS software in which the rod is simulated by BEAM188 element, the component is connected with the node degree of freedom coupling [10, 11]. The main statement of the APDL command stream generated by the output model in the Basic Visual platform is as follows:

```
For i = 1 To Points. Count 'generate node, points class for the user to write
Print #1, "n," & i & "," & Points(i).X & ","& Points(i).Y & "," & Point(i)s. Z
Next
For i = 1 To Lines. Count ' generate unit, lines class for the user to write
With Lines(i)
Print #1, "type,1 $mat," &. MatNum & "$secnum," &. PartNum &. SecNum; 'attribute parameter of output unit object
Print #1, " $e," &.P1 & "," &.P2 & "," &.P3
```

End With
Next
To get the ANSYS truss boom model and the VonMise generated by the nonlinear analysis are shown below:

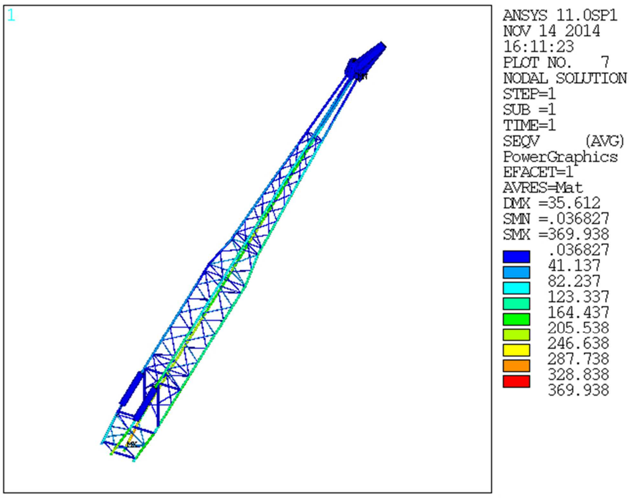

Fig. 8. *VonMise stress cloud of the boom in ANSYS.*

As can be seen from the above, the method can be used to facilitate the ANSYS output modeling process data, with a fast modeling, more convenient in the design of the truss.

4. Conclusion

The parametric modeling method of complex truss boom system is studied. Combined with the object oriented programming technology a new method for the rapid modeling of the modular and universal of the truss boom system is presented. In this paper, a new efficient method is used to create the ANSYS for second development. The effectiveness of the proposed method is verified by the rapid modeling and analysis of the actual crane boom.

This method improves the modeling efficiency of truss crane jib system or similar system. This method not only effectively solves the complex truss structure system computationally modeling problem of analysis cases but also improves the solution of high accuracy and efficiency of using the same component module to compose different complex truss structure and analyze its structural and design. In a word, this method makes the design and development efficiency of the complex structure of the crane truss boom which need to be calculated in a large number of calculation conditions improved greatly.

Acknowledgements

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