



INTEGRATION DESIGN AND ANALYSIS OF EXCAVATOR BOOM BASED ON CAD/CAE

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ABSTRACT

According to the existing problems in the development of actual product and working process of excavator working device's boom, the method of integrated design and analysis for excavator boom is put forward. The defects in the process of CAD/CAE integration are summarized, the integrated design and analysis system including parametric design of boom, database design, detail feature simplification of boom, mid-surface extraction and structure analysis is studied. The parametric model of boom is established based on parametric method, the management of model parameter is realized with the help of database technology and the rapid design of model is reached. Based on the feature of boom's structure, the simplification rule of model is determined and detail features of boom are simplified automatically by program. The mid-surface extraction process and method of model is studied, the dimensions of model are reduced and precision of mesh is enhanced. With customization technology, the customization analysis platform of boom is developed by secondary development of ANSYS Workbench code.

Key words: Boom; Parameterization; Model Simplification; Mid-Surface; Customization Analysis

1. INTRODUCTION

The advanced geometric modeling method of CAD and analysis and calculation ability of CAE are combined closely by CAD/CAE integration technology, it also adapts to the dynamic attribute of modern product design, such as parametric design, model modification and requirement of reanalysis.

A variety of CAD/CAE integration methods have been proposed so far[1-6]. They made a lot of efforts to integrate CAD and CAE closely, ideally and seamlessly, whether CAD and CAE application can be closely integrated and automated depends upon the following factors: the scale, scope, and purpose of the CAE analysis; the nature and dimensionality of the CAD model; and the amount of detail required for the CAE application. Sometimes, design models created by CAD system is often unsuitable for finite element analysis, so an appropriate idealization process including detail removal and dimensional reduction[7-14] is indispensable for analysis models in CAD/CAE integration. They have made many research efforts and provide some methods to achieve the

idealization process. However, at present, only limited automated capabilities exist, and these require improvement, some idealization processes are complex application range is restricted.

In this paper, the integration and analysis process of boom is realized by CAD/CAE technology in VC++ environment, the modeling and analysis system of boom's structure is developed. The system includes five modules:(1) Parametric modeling of boom, (2) Design of database, (3) Simplification of detail features, (4) Mid-surface extraction, (5) Customizing design. Users can build the parametric models rapidly and conveniently, by modifying geometric parameter values, the fast modeling process of boom's structure is realized. Via database access interface compiled with database technology, the modeling system can access geometric parameters and also can edit them in database, it establishes the data sources for parametric design and series modeling of parts. Besides, this paper uses feature simplified method to delete detail features that have a little or no effect to finite element analysis result, such as chamfer, fillet, boss and so on, by mid-surface extraction technology, the mid-surface structure of boom is got,

it will enhance the precision of grid and analysis efficiency. Firstly, the CAD/CAE integration system will build parametric model of boom with parametric design module, after detail feature simplification and mid-surface extraction process, the model will be imported into CAE software ANSYS Workbench by CAD/CAE interface technology, then, the model is analyzed automatically in ANSYS Workbench, thus, the CAD system and ANSYS analysis system are integrated by the way of data sharing. Stress distribution of part in actual working condition is displayed by inputting stress values, and the distribution of stress of model will also be displayed by cloud picture. Users can determine whether there is design flaw according to the result, Finally, the ideal model will be got after modification.

In this paper, section 2 presents the parametric design process of boom. In section 3, we propose a method of model simplification. Section 4 is the customization design of boom with ANSYS Workbench. Section 5 gives a conclusion to the whole paper.

2. PARAMETERIC DESIGN OF BOOM

There are two main parts included in the parametric design process of excavator working device: (1) Building the 3D model of excavator's boom, and extracting the parameters of the model, in the process of modeling, the model should be restrained necessarily. (2) Designing the user interface with VC++, including menus and dialog, then developing the geometric parameter database of boom with database technology, and the editing of geometric parameters is realized, meanwhile the secondary development functions of UG software is called in VC++ environment to achieve transformation of parameters, the main idea is shown in Fig.1.

Firstly, building a new project or opening the existing project, and selecting the model needs to build according to user's requirement, then inputting the parameter values or calling the values from database, the fast modeling is realized after finishing above procedures, finally, assembling the models and building the 3D model of whole machine. In the process of selecting design model, the reference model should be built, it includes determination of the design rules, extraction of main parameters, restraint of model, the main contents are as following statement.

2.1 The Establishment of Reference Model

It needs to analyze the structure feature of excavator's boom in the process of selecting design

model, determining the design rule, that is the design scheme of boom, for example, in the standard boom structure, the proportion between up-boom and down-boom is 1.1~1.3, the bend angle of boom is about between 110°and 140°, the total angle of bucket is about 180°, moreover, it also needs to determine the expansion ratio of hydraulic cylinder and other parameters

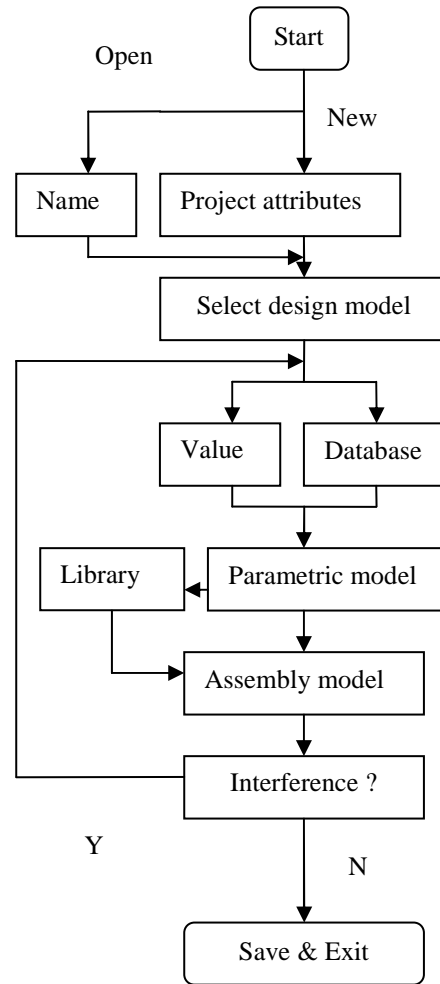


Figure 1 Parametric Design Process

In the process of parameter extraction, parameters that can ensure the basic outline of boom will be extracted, such as diameter of reaming, thickness of plate and so on, three factors should be considered in selecting the main parameters: (1) Ensuring the hydraulic cylinder can generate enough bucket digging force, (2) Ensuring the hydraulic cylinder has enough self-lock force, (3) Ensuring each part has enough angle range.

Parameter constraint model is the geometric model with constraint relations, and the constraint

relations can be modified by program in order to build new model. This paper takes modeling method based on draft, the addition of geometric parameters is realized in expression dialog of UG software, parameters and initial values will be input into the dialog while modeling, it is convenient to manage the parameters.

2.2 Submodules Of Parametric Modeling System

The specific content of parametric modeling system is shown in Fig.2, five sub-modules are included: (1) Foundation design, user interface, menus, and dialog are designed with VC++ in this process. (2) Reference model, including the determination of design rule, extraction of parameters, addition of constraints. (3) Database design, functions like design of data sheet, edit or query of parameters and so on need to be realized in this process. (4) Engineering maintenance, this module is used to manage models and components. (5) User management, it is convenient to operate and control the system.

2.3 Dada Management and Database Design

Because the parameters of boom model are too much, if they are input into dialog manually, the procedures are tedious and time waste, so the parameters are saved in a table with database technology, thus the parameter values will be called directly in this system, and the design efficiency is enhanced, the main idea of database is shown in Fig.3.

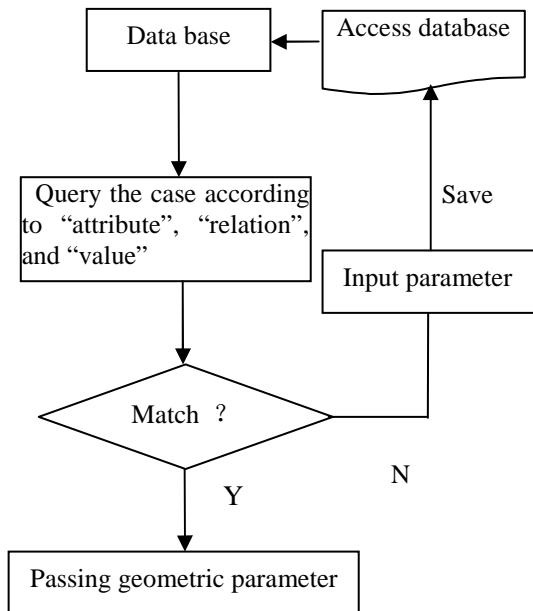


Figure2 Design Idea of Database

According to the process shown in Fig.2, the design of database is realized, operations like querying, inputting, deleting of parameters will be achieved. Parameter query is completed by the relationships between parameters, firstly, selecting a attribute, then inputting a relation of “>”, “<”, “=” and value, finally, the parameters match condition will be got, if not, we can add new parameters into database and save them, we also can modify or delete them according to real condition.

3 MODEL SIMPLIFICATION

Model simplification is divided into detail feature simplification and mid-surface extraction

3.1 Detail Feature Simplification

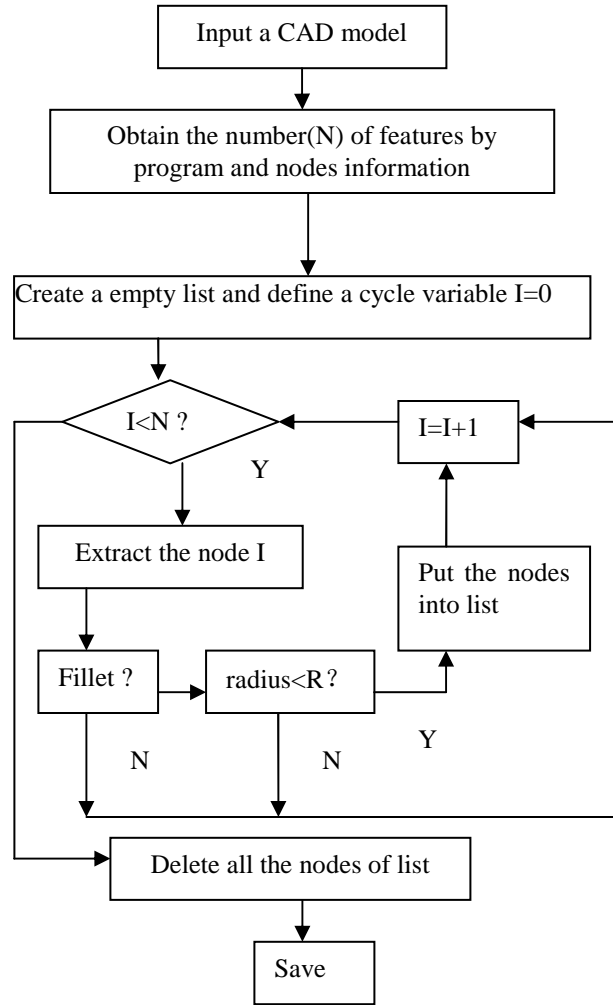


Figure3 Simplification Process of Fillet Feature

Detail features are about small structures in the model(like hole, slot, cavity, boss, fillet and so on), these features have a little or no influence to

analysis result in FEA, so they can be deleted or controlled. Before the simplification, it needs to distinguish the features of model, and find out the features which need to be simplified, this process is achieved by the secondary development functions of UG/Open API, the nature of feature distinguish is accessing model's geometric parameters. Taking fillet feature for example, first, we need to set a radius value R, through judging condition(>or<), features with the value is greater than R will be deleted, others will be saved, radius value R is set by user according to model's characteristic, simplification principle, and practical experience, the specific simplification process is shown in Fig.3

3.2 Mid-surface Abstraction

After feature simplification, it needs to extract mid-surface of the model, that is transforming the 3D model into low dimensional structure feature, and make it to analysis ideally. For example, a long and thin cylinder structure can be substituted by a one-dimensional bar element or beam element, some plate and shell structures can be substituted by mid-surface. The structure of excavator working device is constituted by plate, so it is convenient to extract the mid-surface of model. The main idea is shown in Fig.4.

Determination of faces should follow the condition of parallel, distance, overlap. Supposing there are two faces named F_1, F_2 , the normal vector of them are N_1, N_2 , the distance between them is d, the method of judgment is shown as following[12] [13]:

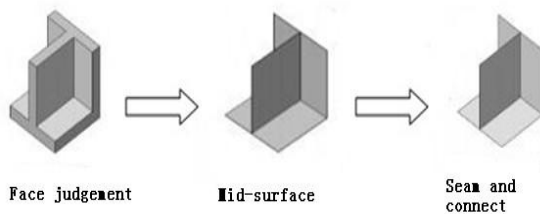


Figure 4 Process of Mid-Surface Abstraction

(1) Parallel condition: there are two situations, one is the two faces' normal vector direction (N_1, N_2) of model must be the same or opposite, that is $N_1 \bullet N_2 = \pm 1$, the other is that the two planes are approximate parallel, the angle should be less than the user defined angle (θ_{max}), that is $180^\circ - \text{angle}(N_1, N_2) < 2\theta_{max}$. Shown in Fig.5

(2) Overlap condition: when a face is

projected to another face, they should overlap or some overlap with each other.

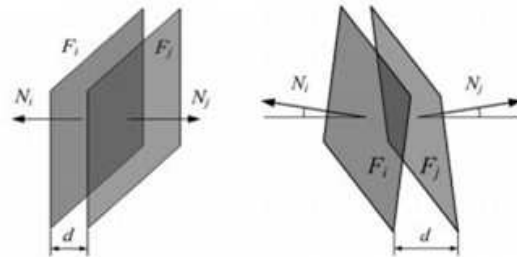


Figure 5 Judgment of Parallel Condition

(3) Distance condition: the distance between two faces should be less than user defined value t_{max} ($d < t_{max}$).

When the mid-surface is extracted, the some facets will be crossed or disconnected, so it needs to trim and seam them, and the ideal mid-surface will be got after these operation. As shown in Fig.6

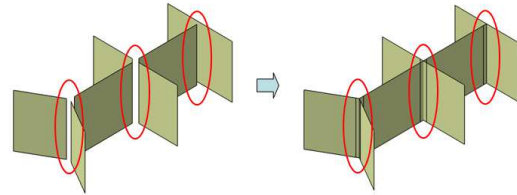


Figure 6 Process of Trimming and Seaming

4. CUNTOMIZATION DESIGN BASED ON ANSYSY WORKBENCH

Usually the products user faced are limited, sometimes it only needs to modify the exist product locally, if the model is analyzed directly every time, operations like adding constraint, loads, meshing will take too much time. So it is better to develop a program used to design the specific model, the analysis process will be realized by only inputting some values of geometric parameter and stress, this process is also called customization

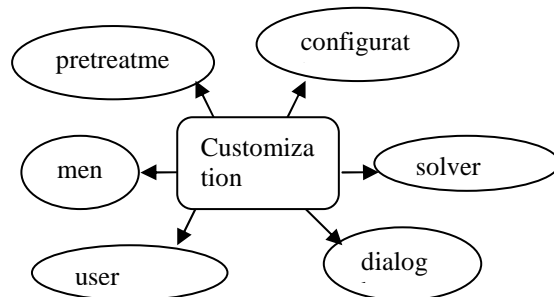


Figure7 Content of Customization Design

The content of customization design is shown in Fig.7, pretreatment of model is saving the mid-surface model of boom in the form of *.agdb

and *.dsdb, *.agdb has information of geometric parameters, and *.dsdb contains messages like material, meshing, constraint, load, they are used as reference models, design of solver is setting the type of solver and select reasonable compute method, the configuration of system environment is adding user defined functions, it is used to load the custom programs

The design of menus, interface, and parameters editor dialog is realized by the languages of XML(Extensible Markup Language), HTML(Hypertext Markup Language), Jscript. XML is used to design system interface, as shown in Fig. 8. Jscript is used to design menus, and HTML is used to design the dialog.

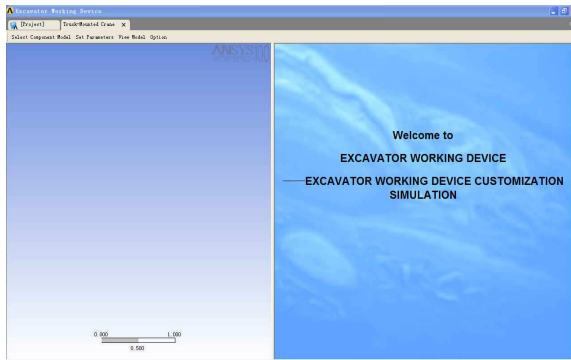


Figure 8 Main Interface

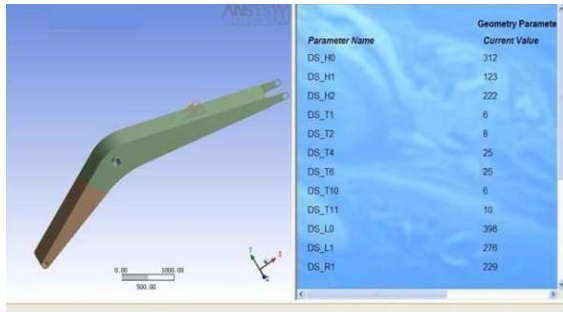


Figure 9 Interactive Interface

In the simulation platform of excavator's boom, the parameterization of model is achieved through interactive interface of HTML as shown in Fig. 9. This interface is generated based on web and script language, users can input parameter values according to actual situation, then these values are transmitted to the model by Workbench and update it. In this paper, all the CAD parameters are enumerated in script file, each parameter and its value is input into the corresponding form automatically. In the interactive interface, users can also modify values through dialog, when the values are determined, all the parameters are submitted to the simulation platform, finally, the model will be

analyzed after selecting AWE solver, as shown in Fig. 10-12

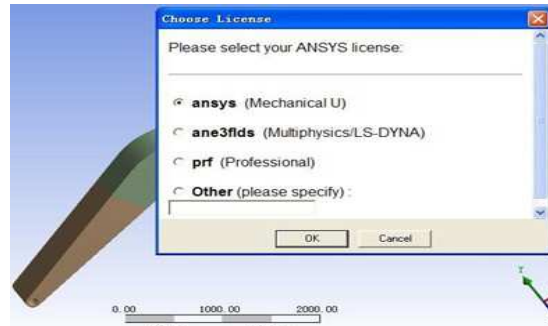


Figure10 Solution

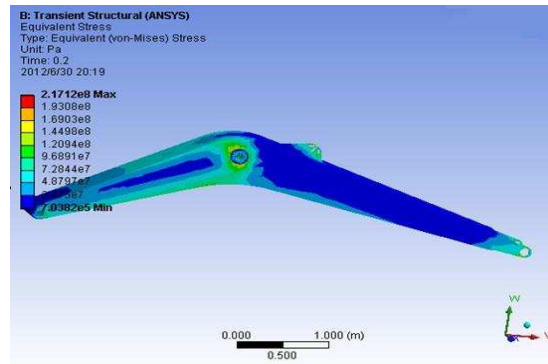


Figure11 Stress Contour of Boom

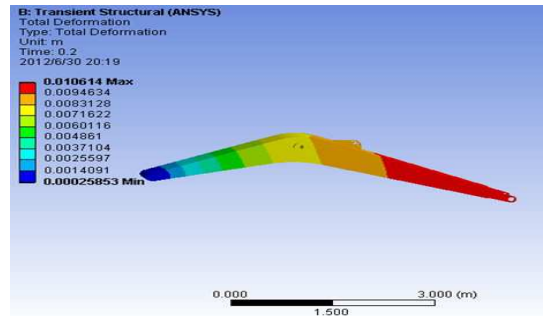


Figure 12 Deformation Contour of Boom

5. CONCLUSION

In the paper, the process of CAD/CAE integration system of excavator's boom is put forward, according to the problem in integration process, parametric model of boom is built, with database technology, rapid modeling process is realized, and the detail feature simplification and mid-surface extraction method are used in the system, it will helps to enhance the precision of model's grid and avoid messages missing in the transformation between CAD and CAE, meanwhile, with customization design method, analysis efficiency is greatly improved. This technology



helps to solve the problems in excavator boom's design and lay a foundation for market of simulation support platform.

However, there are a couple of limits of CAD/CAE integration process, since the simplification process needs information from the feature tree, so it should get the feature tree information by algorithm, the simplification method is for a number of specific models and it is difficult to implement with a generalized approach. Some processes are remained a range of manual work. So, additional methods should be researched to solve these problems to make the CAD/CAE integration process fast, efficient and practical.

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