Research on Key Processes of Plastic Stamping and Forming Machinery Manufacturing Based on CAD Technology

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Abstract. The paper adopts the parametric modeling technology of SolidWorks software, introduces CAE-driven design ideas in the stamping process, and realizes the parametric association and process of the blank grid and the tool grid based on the parametric tool grid model of the triangular face. The parametric correlation between the parameters and the parametric correlation between the design model and the analysis model ensure that the product design, process design and forming simulation model are updated simultaneously, and the parametric CAE analysis and the true seamless integration of CAD/CAE are realized. By establishing a unified design and simulation model, the system avoids surface loss and accuracy loss caused by model data exchange between traditional CAE software and CAD platform. Through the parametric application of the forming simulation of the automobile bumper produced by an enterprise, and the comparison between the simulation results and the experimental results, the practicability and accuracy of the system are verified.

1. Introduction
Drawing, trimming, and flanging are important processes in the forming of stamping parts. In the actual production process, to improve product formability and product quality, it is necessary to pass repeated test molds, which not only increases product development cycle and production costs, but also Moreover, the efficiency is low and the product quality cannot be guaranteed. Predicting defects such as wrinkles, cracks and spring backs in the forming process through finite element numerical simulation technology has become an important way for companies to improve product quality and reduce production costs.

Press CAD is a parametric design software based on AutoCAD. Press CAD realizes the parametric design of plane drawings. After setting the data required for the design, all drawings can be automatically generated, including mold assembly drawings and mold parts processing drawings. This is of great help to improve design efficiency, so many Companies use this software for stamping die design. Traditional software itself only has simple CAD modeling functions, and generally establishes a finite element analysis model through CAD model files in a common format. Due to the incomplete compatibility of CAD and CAE systems, this traditional way of importing data files will cause severe feature loss and precision loss during data exchange, and make it difficult for companies to achieve CAE-driven design requirements [1]. Therefore, the development of a CAD/CAE integrated software system with powerful parametric design and simulation functions is of great significance to stamping product design and die design.
In this paper, the SolidWorks environment is used as the underlying platform to develop a CAD/CAE integrated software system SW-FAX for the whole process of plastic forming for stamping parts. The system solver is based on the BT shell element and the finite element dynamic explicit algorithm. It takes into account the actual friction, blank holder force, and the actual process conditions such as the drawing bead and notch line [2]. It has the full-process simulation function of the stamping process, including drawing and trimming. Punching, trimming, shaping and spring back. At the same time, through the establishment of the parametric association between the blank grid and the tool grid, the parametric association between process parameters, and the parametric association between the design model and the analysis model. It avoids the problem of repeatedly establishing analysis models due to changes in design models and process parameters in traditional CAE analysis software, and greatly improves the efficiency and accuracy of stamping forming simulation. The practicability of the system is further verified by the formability analysis of the automobile bumper produced by an enterprise.

2. System Design

2.1. Overall design
The main function of the general post-processing system is to use visualization to analyze the performance of automotive plastics after forming, and provide functions such as query, modification and improvement, but the designer needs to operate at least two software to complete the design analysis process, which is cumbersome. The plastic forming post-processing system based on the CATIA platform is designed and developed in a targeted manner when the post-processing system functions are realized [3]. The system uses CATIA interface style and view style to design, requires simple and convenient operation, and realizes seamless integration with CATIA. When users use the system, they do not need to study the software for a long time, design and analyze directly, reduce the burden of learning software and the error rate of operation design, and improve the design efficiency. The specific realization functions of the system include: physical quantity information distribution query diagram, forming limit diagram, forming process animation simulation, contour patch display, patch display, grid display, mold information display, and user customization.

The system adopts object-oriented programming. The extraction of classes can reduce the complexity of the software and improve the maintainability of the system. It is the guarantee of the flow and stability of the system programming. The extraction of classes can also ensure the functional independence of the modules, the information exchange between the modules, and try to achieve strong cohesion and weak coupling of the modules. The system extracts several common object classes, including file reading class, data processing class, public area data class and functional information class.

The system is divided into modules according to the extraction of system categories. The system mainly includes two functional modules: data processing and view display. Among them, the data function module includes: data loading, data processing, public data area, etc. View function modules include: display mode, parameter information and function expansion, etc. The functional module framework of the system is shown in Figure 1.

![Figure 1. System functional framework.](image-url)
The data of the post-processing system takes the frame as the basic unit, which needs to be accessed at any time and does not need to be modified frequently, so the system uses a structure to store the required data.

Data loading: Use keyword comparison technology to read post-processing files, and classify and read different types of data to improve speed and reduce complexity. Extract the required data from the file and load it into the public data area.

Data processing: including data initialization, storage and access, data organization, data display, data attribute setting, data release, and how to use CAA's API interface function to call data to realize the view display function.

Public data area: store the global variables that each module needs to access at any time, because the data of the post-processing file is the source of the entire system, it involves multiple source files, and opens up a global variable workspace to facilitate access to data at any time.

Display mode: The system provides a patch display, contour patch display, grid display, etc.

Parameter information: According to the user's choice, provide information on physical quantities such as thickness, stress and strain.

Function expansion: forming limit diagram (FLD diagram), information query function, user-defined function, and animation simulation function.

2.2. Structured approach

Through system analysis, in the design stage of the system, determine the overall structure of the stamping simulation software system and the relationship between modules, define the interfaces between the modules, design the global data structure, determine the interface between the system and other software and users, and design functions Internal details such as the specific algorithm and data structure of the module. The structured system design emphasizes the top-down functional decomposition, and the system is decomposed into modules and sub-modules step by step. When dividing the plastic stamping simulation system into modules, the degree of coupling between the modules should be reduced as much as possible, and the cohesion of each module should be increased. Make full use of these two complementary design principles to maximize the independence of modules [4]. When modifying and maintaining a module, the scope of modification can be controlled to a minimum, and the impact on other modules will be minimized.

2.3. Object-oriented approach

Although the traditional structured software engineering method has improved the development efficiency of plastic stamping simulation software and the maintainability of the system to a certain extent, it still has the reusability and scalability of the software and the ability to embed other systems. The improvement is not large. The reason is that the structured method adopts a task-oriented view that is, designing for a certain task. This methodology creates a gap between the analysis and design stages, which leads to the problem domain of the analysis stage and the solution of the design stage. Inconsistent domains. The object-oriented method is a new software engineering method established to get rid of this inconsistency. Its guiding ideology is to establish a problem domain model according to people’s usual way of thinking, and to design software that expresses the solution method as naturally as possible [5]. Establish a concept that directly expresses the things that make up the problem domain and the interrelationships between them, and establish a description paradigm that suits the way people think. In the object-oriented method, objects and message passing respectively represent things and their interrelationships; classes and inheritance are description paradigms that adapt to people’s ways of thinking; methods are various operations that act on objects: the above concepts constitute object-oriented methods the basic content of learning. The basic characteristics of objects and classes are the encapsulation and inheritance of objects. Through encapsulation, the independence and information concealment of objects are improved; through inheritance, the interconnection between classes and classes are realized, resulting in such things as dynamic bunching and entity of polymorphism. The
object-oriented method improves the consistency of analysis, design and implementation, and makes the system reusable and expandable.

The rapid development of the finite element method and its application fields makes the software developed with it as the core required to have a high degree of reusability and scalability. At the same time, the finite element software has increasingly become an inseparable part of CAD/CAM software and requires it to have higher the ability to be embedded in other systems, using traditional methods to develop finite element software is difficult to meet these requirements. It is imperative to develop object-oriented finite element methods and technologies. Therefore, object-oriented methods are gradually being considered for the development of plastic stamping simulation software systems. It is a new attempt, and it takes time to explore. Object-oriented design uses the formalized analysis model to expand its structural part, improve the description of classes and object entities, and then form a complete software model. This software model can be realized with the help of a solution space object provided by a certain programming language, so as to obtain the required software [6]. The process of using an object-oriented method to design a plastic stamping and forming simulation system can be summarized as: A. Define the attributes of each object class; B. Determine the relationship between the class and the object, and between the class and the class; C. Define the communication mechanism between the objects, It is mainly to determine the message mode of the object and the message transfer between the objects, thereby forming the control flow and information flow of the system; D. Determine the state of each object and determine the method to achieve each state.

2.4. System process

The flow of the plastic stamping simulation system is shown in Figure 2. The functions of each part are as follows: A. Geometric modeling. Establish geometric models of punches, blank holders, dies and other tools and plastics. B. Pre-processing. Grid discrete tool/plastic, define material, contact, etc.; set tool/plastic position, establish analysis model; define or modify the load history curve such as displacement/velocity/pressure of the tool. C. Forming simulation. According to the input data, the plastic is simulated (the grid is adaptive to the deformation of the plastic), and the calculation results are checked from the front and rear processors. D. Rebound simulation. Observe the shape of the workpiece, adjust the mesh of the workpiece, modify the spring back analysis file, do the spring back simulation of the workpiece according to the input data, and check the calculation results from the front and rear processors. E. Post-processing. Draw the workpiece forming shape, attribute contours, travel history curve, etc. and display them in animation. F. Expert system. According to the results of simulation analysis, the quality of the initial design is evaluated, and the design is determined or revised through optimization analysis.

![Figure 2. System flow.](image-url)
3. Optimization of plastic stamping forming parameters

3.1. Parameterization of the blank grid
Because only when the die fillet size matches the initial plastic grid cell size, the system can accurately simulate the process of plastic flowing through the tool fillet, while ensuring the efficiency of finite element calculation, so the blank grid cell size should follow the concave the mold fillet size and mesh encryption level change. According to the stamping simulation experience, when there are 5 blank units that can wrap the die fillet with a 90° central angle, the stamping simulation accuracy can be guaranteed. From this principle, the size of the blank grid unit and the die can be derived the relationship between rounded corners and encryption level is:

\[ L = \frac{\pi r}{10^{2^N}} \]  

In the formula, \( L \) represents the mesh unit size of the blank, \( r \) represents the radius of the die fillet/mm, and \( N \) represents the level of densification during mesh division. By responding to the update message of the parameters such as the die fillet and the mesh division encryption level, the parameterized update of the blank mesh model is realized. The blank grid before and after the parameterization update is shown in Figure 3.

3.2. Parameterization of Tool Grid
In the CAD platform, since the curved surface is constructed based on the parametric mesh of the curved surface, the curved surface entity can be discretized into a certain number of small triangular patches. The SolidWorks software stores the information (including elements, nodes and their topological relationships) of discrete triangular patches on the surface through Tessellation, a subclass of Body. Therefore, by extracting the Tessellation information of the surface as the tool mesh data, the parametric association of the tool mesh model can be realized. At the same time, by adjusting the control parameters (such as the chord height of the patch, the angle tolerance, etc.), the Tessellation of the curved surface is changed to realize the control of the accuracy of the curved surface description. Taking the relationship between the surface chord height and the discretization accuracy of the tool surface as an example, the parametric relationship between the blank mesh and the tool mesh is explained [7]. Figure 4 is a schematic diagram of the chord height of the curved surface. The arc represents the tool surface, and the chord of the arc represents the triangular facet plane of Tessellation, and Sag1>Sag2. The number of triangles on the curved surface increases as the chord height of the curved surface decreases, that is,
the description accuracy of the tool surface increases with the decrease of the curved surface chord height. Therefore, this paper establishes the correlation between the radius of the die fillet and the chord height of the discrete surface to realize the automatic parametric update of the blank grid and the tool grid.

Through derivation and testing, the functional relationship between the chord height of the curved surface and the radius of the die fillet is shown in equation (2), and the correlation is shown in Figure 5.

\[
s = \begin{cases}
0.025, & r \leq 1.5 \\
0.025 + \frac{0.05(r - 1.5)}{3}, & 1.5 \leq r \leq 18 \\
0.3, & r > 18
\end{cases}
\] (2)

In the formula, \( s \) represents the chord height of the curved surface/mm, and \( r \) represents the corner radius of the die/mm.

Through derivation and testing, the functional relationship between the chord height of the curved surface and the radius of the die fillet is shown in equation (2), and the correlation is shown in Figure 5.

The parameterized automatic update of the tool mesh is realized by responding to the tool meshing function. When the die fillet radius size changes, the curved surface chord height is updated accordingly [8]. As shown in Figure 6, when the user changes the corner radius of the die from R5 to R2. The chord height of the curved surface has been changed from 0.083mm to 0.025mm, and the tool grid has become more refined.

Figure 4. Surface chord height.

Figure 5. The relationship between the corner radius of the die and the chord height of the curved surface.

Figure 6. The parameterized automatic update of the tool mesh.
4. Conclusion

Based on the SolidWorks platform, developed the sheet metal forming full-process synchronization simulation system SW-FAX, which solves the accuracy loss caused by the data conversion between the CAD platform and the traditional sheet metal forming simulation CAE software, and avoids the design model change. The problem of repeated modeling. Through the simulation of actual stamping parts forming, the SW-FAX system can not only accurately predict the forming defects such as wrinkles and cracks in the stamping process, but also the application of parameterized automatic update technology can reduce nearly 70% of the CAE modeling preparation work, which is effective It improves the efficiency of mold design and process design, and is an important way for enterprises to shorten the product development cycle.

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