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Construction of Automatic Thickening System of Complex Body Surface Based on UG Secondary Development

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Abstract: The process of thickening body component structures during automotive design has several drawbacks. For example, each new CAS surface (initial vehicle body surface) requires the construction of a corresponding set of structural data (boundary changes, functional variations, performance modifications). Issues include small CAS corner radii that require manual rounding based on material thickness, intersections in B-surfaces after offsetting that necessitate manual trimming, missing or distorted B-surfaces requiring manual patching, and B-surfaces moving in the opposite direction, which requires logical reorganization and re-modeling. Utilizing the UG11 software platform and coding in Microsoft Visual Studio 2017, combined with UFun and NX Open secondary development technologies, and based on the needs and experience of industry engineers, a C++-based automation system for thickening complex body surfaces with an interactive user interface was developed. In this system, auxiliary surfaces and internal boundary-enclosed adjacent surfaces assist in quickly selecting and excluding surfaces for removal. The system uses commands such as offset surface, Ruled surface, N-sided surface, and Sew to automate the thickening of body parts and merge them into solid bodies. The system is packaged as a UG plugin, making it easy for users to install and use. This system significantly enhances the efficiency and reliability of body component design and modeling.

1. Introduction

Body parts play a vital role in improving vehicle safety and enhancing the aesthetic appearance, and their structure and design not only affect the overall performance of the car, but also directly determine the visual and tactile experience of the user. The mainstream car body design usually uses CAD software. This method shortens the development cycle compared to traditional hand-drawn image, but it requires technicians have a certain knowledge of modeling and be proficient in CAD software operation[1]. At present, some drawbacks are revealed when CAD 3D software processes body part modeling. For example, for the structure construction of body parts, a version of structural data (boundary change, function change, performance change) needs to be set up for each CAS surface (car preliminary modeling surface), and sometimes there are errors and omissions in the modeling process. In general, for cars of the same brand, the panels of different models have very similar shapes and features[2]. In the process of automobile design and manufacturing, the problems in structural design not only increase the work burden of R & D team, but also lead to the delay of production schedule and the rise of cost. It is worth noting that these design issues can affect the overall performance and safety of the vehicle, which in turn can adversely affect brand reputation and market sales. Therefore, by promoting the speed of structural design of body parts, it can optimize the allocation of resources, reduce production costs, and enhance the market competitiveness of products and user satisfaction.

Modern CAD systems come with Application Programming Interfaces (APIs) built-in. These kinds of API are particularly useful in supporting, and making it easier for Small and Medium Enterprises (SMEs) to develop their own customized and dedicated solutions. Repetitive work tasks commonly deemed mundane to humans can be replaced by lines of code, potentially saving thousands of work-hours down the line[3]. These apis enable developers to extend the functionality of the software, automate tasks, create custom applications, and integrate with external systems. UG software is equipped with external programs, data exchange and geometric operation interface, UG has a good open performance, provides a powerful development kit NXOpen and UFun, with a rich and complete application interface and development tools. This paper relies on UG software platform and related secondary development tools to promote the development of system functions.

Considering the large amount of manual repetition in CAS surface modeling of body parts, engineers may cause some modeling errors or deficiencies, it is urgent to accelerate the automatic design progress of CAS surface thickening of body parts. Based on UG software platform, with the help of secondary development technology tools, design ideas and modeling experience of industry engineers, and C++ programming language to build algorithm function in NX Open and Ufun system, this paper developed the automatic thickening function system of complex body molding surface and packaged it as UG plug-in, achieving the purpose of rapid design and modeling of body parts. There has been a marked improvement in efficiency.

2. Literature review

With the advancement of technology, the efficiency of automotive parts design is constantly improving. The use of advanced computing methods, optimization algorithms, automated design tools and intelligent manufacturing technologies is gradually changing the traditional process of automotive part design, making the design more efficient, accurate and innovative. Lee et al.[4] proposed a deep generative framework that simplifies the conceptual design process by combining generative models with tire performance evaluation functions to automatically design tire tread patterns that meet specific performance objectives. Fonseca et al.[5] designed a recycled carbon fiber reinforced plastic/metal hybrid (PMH) engine mount by combining topological optimization and free dimensional optimization techniques to achieve an efficient multi-material design.

UG secondary development technology plays an important role in the realization of product innovation design, manufacturing process optimization and enterprise efficiency improvement, and its research is developing in the direction of intelligence, integration and digitalization. Cao Shu et al.[6] developed a parametric design system of globoidal indexing CAM mechanism based on NX Open C and Visual Studio, and realized visual interaction design. Skarka et al.[7] completed the integration of design verification methods used in aircraft design with methods for determining structural features in the generated model, and implemented the entire combination into the Siemens

NX system.

UG software plays an important role in automotive design and manufacturing. The automotive industry's demand for complex design, high-precision simulation and high-efficiency manufacturing makes UG secondary development technology widely researched and applied. Wang Jianjun and Chen Dandan[8] established the parametric body coating process system through UG secondary development, which effectively improved the efficiency of virtual evaluation, KPI statistics and the creation of glue standard files. Wang Qi et al.[9] through UG secondary development tool and VC++ object-oriented language, using parametric modeling technology, established a special vehicle welding fixture parameter library and friendly interface, users can quickly get the fixture model by inputting parameter values. Li et al.[10]developed an intelligent CAD system to automate the trim line division, blade design, and interference check processes. The intelligent system is integrated with the NX 11.0 system through its NX open C++ interface, which has strong capabilities in the design of automotive trim blades. Zhang et al.[11] proposed an intelligent automotive trimming die design method based on template subtraction and bounding volume strategy, optimized the surface structure by geometric offset mapping algorithm, and developed a robust intelligent design system for automotive covering cutting die on the NX platform.

3. Approach

3.1. UG secondary development

3.1.1. Secondary development brief

UG secondary development refers to the development of industry-oriented and design-process-oriented application tools based on UG software platform, based on users' own needs and integration of relevant industry experience and knowledge. This project relies on UG11 software platform for development, and uses C++ programming language to realize the core geometric function and analysis function. In order to ensure compatibility with the UG11 software platform, the project was designed and developed using VS2017, and eventually generated a 64-bit executable file. UG supports rich interfaces and many mature and excellent development tools, suitable for ordinary users in different fields and application scenarios. With these tools, the communication and invocation of the basic functional modules on the UG11 software platform can be run by the user through programming. Some widely used secondary development tools and their functions are described below.

(1) The UG/Open API (UFun) is a powerful tool for secondary development, providing access to UG's core modules. It enables automation, function customization, and external system integration, with over 2000 functions available in C/C++, C#, Java, and other languages. It supports applications from geometric modeling to CNC machining and CAE simulations.

(2) NXOpen is the UG software after Ufun, to provide users with a more powerful, comprehensive development interface. NX Open C++ is the first object-oriented programming interface for UG software, taking full advantage of object-oriented features such as polymorphism, encapsulation, and inheritance. This interface provides full access to the class hierarchy, allowing users to override methods, customize classes, and create completely new types of persistent objects in NX. Consider the complementary interfaces of Ufun and NX Open in secondary development. Therefore, in the development and construction process of the project, they are combined to ensure more comprehensive, rich and reliable geometric function support.

(3) MenuScript is a menu scripting language belonging to UG software, which has many rules for writing customized menus. Users can not only edit and modify the existing menus in UG software, but also create menu items with custom content. Menu file allows to define the drop-down

menu in the graphics window, the main menu, the toolbar, the pop-up menu, etc., through any kind of text editor to edit the text file, you can efficiently make a custom menu consistent with the UG software style.

(4) Block UI Styler is a user interface design tool supported by NX Open, which includes a visual interface editor, toolbar, block directory and dialog window. With this tool, users can design dialog boxes that conform to the UG interactive layout. In the fast directory, users can choose appropriate controls according to the required requirements, adjust the placement and layout, and use the property editor to help edit the related properties of the dialog box and controls, and then realize the complete design of the dialog interface. During the design process, the controls in the block directory are updated synchronously with the dialog preview, helping the designer to view and modify the design effect in real time.

3.1.2. Secondary development process

As for the design of the automatic thickening system of the complex shape surface of the car body, the key tools such as UG/Open Block UI Styler user interface generator, MenuScript menu scripting language and Ufun and NX Open application programming interface are called for development. UG secondary development function system generally covers dialog box, toolbar, menu, application program (DLL), Ufun and NX Open API library functions. Users can use dialog boxes, toolbars, menus and other tools to achieve interactive interface design, dialog boxes by calling callback functions to trigger the corresponding controls, applications (callback functions) with the selected programming language, Ufun, NX Open API to complete the coding work. The corresponding UG secondary development function system flow is shown in Fig.1. Where UGII_USER_DIR is the user variable set on the computer, Startup and Application are the two folders in the software system.

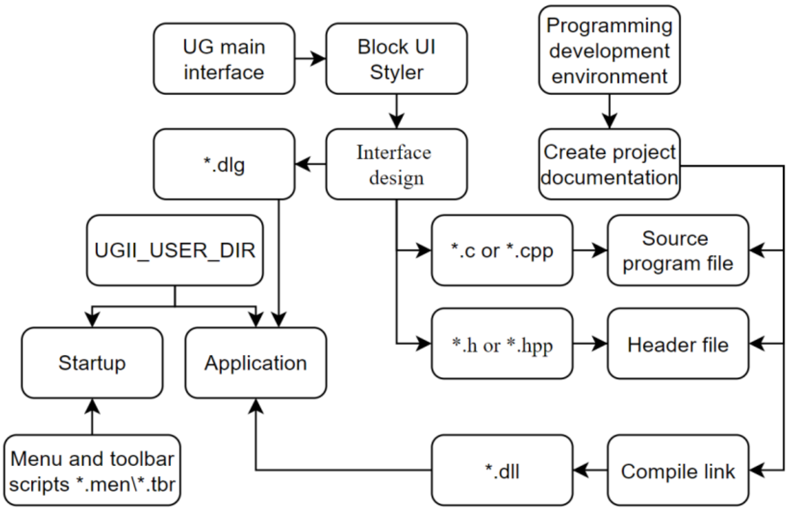


Figure 1: UG secondary development function system flow

3.2. Thicken Sheet

3.2.1. Overall scheme

CAS is based on the effect drawing design scheme, the use of professional three-dimensional surface software, the establishment of digital modeling surface, for the initial display of the car interior and exterior modeling[12]. If in the modeling stage, especially in the CAS stage, software can be used to intervene in the early analysis of the model in terms of regional regulatory requirements, ergonomic design, moving parts and process feasibility, and modify the modeling, there are many benefits in terms of reducing costs and improving quality. In the styling stage, especially in the CAS plane stage, if the software can be used to analyze the vehicle in advance in terms of process feasibility, ergonomic design, regional regulations and moving parts, and adjust the styling, it will bring significant benefits in terms of cost reduction and quality optimization [13].

The main problems in the thickening process of part structure modeling include the following: for example, the CAS fillet is too small, it cannot be thickened or the bias surface is rounded manually according to the material thickness; After CAS plane is offset, B plane is crossed, which needs to be trimmed manually repeatedly. After CAS plane is biased, B plane is missing and distorted, which needs to be supplemented manually. After the CAS plane is biased, the B plane moves in the opposite direction, so it is necessary to sort out the logic and reconstruct the plane. The specific problem is shown in Fig.2.

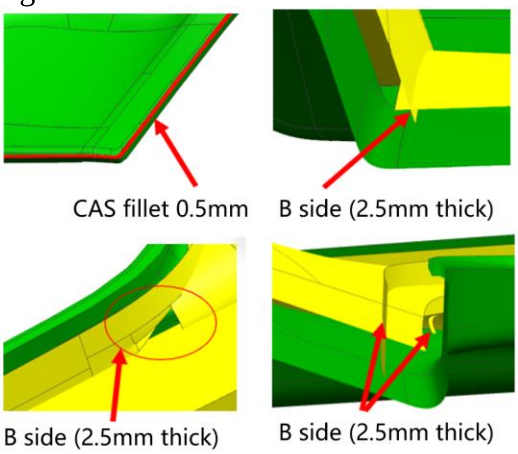


Figure 2: Part structure modeling thickening problem

According to the modeling rules provided by the technical side and the basic model, the thickening process of the sheet body (CAS surface) is analyzed and summarized. The automatic thickening process according to the modeling rules is as follows: select the correct sheet body, and exclude it by auxiliary selection or manual selection of the exclusion surface; The remaining surface is offset surface, if interference or void, after pruning or extension pruning and then stitching, then create a straight grain surface between the body and the offset surface, and then stitch all the faces into solid, if there is a surface missing, create an N-sided surface for repair and stitching. The specific process is shown in Fig.3.

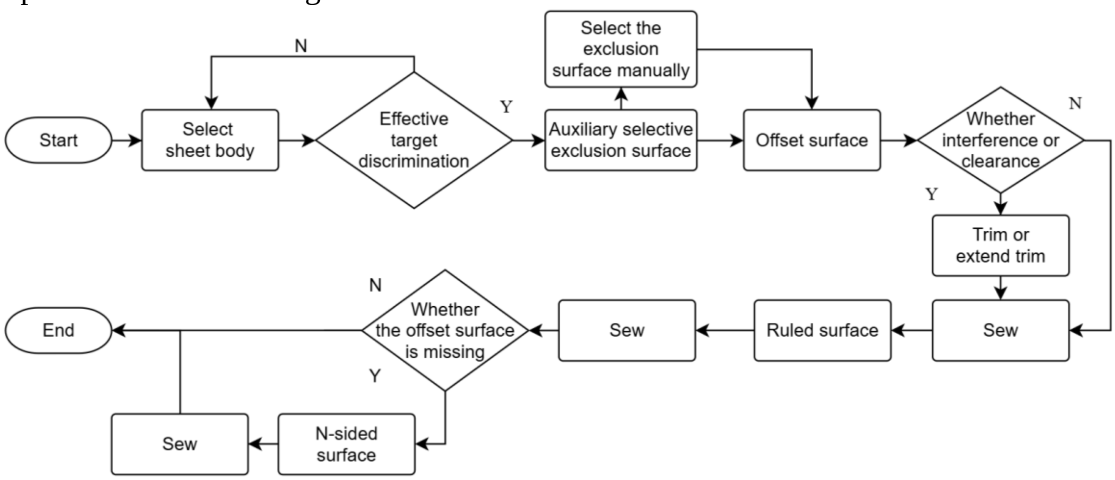


Figure 3: Automatic sheet thickening process

3.2.2. Auxiliary selective exclusion surface

Engineers need to select the corresponding surface on the sheet before bias surface. Some complex surfaces need to be excluded due to the huge amount of follow-up treatment, which seriously affects the development speed of the project, and manual selection of the exclusion surface is inefficient. This paper developed a function to assist the selection of the exclusion surface to ensure the efficient completion of the subsequent thickening work of the sheet. The following describes the implementation method of auxiliary selection and exclusion surfaces in the thickening process of the sheet. Fig.4 is the sheet model diagram with the description, and the five complex surfaces to be processed in Fig.4 have been identified by numbers.

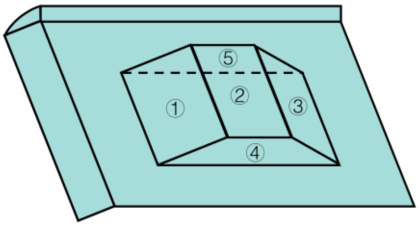


Figure 4: Aided selection excluded surface slice model diagram

First of all, the smooth large surface containing complex surfaces is selected as the auxiliary surface, which is conducive to more accurate selection of the excluded surface. Then, the program takes all adjacent surfaces of the inner boundary of the auxiliary surface as the excluded surface, that is, the five adjacent surfaces selected in the boundary box of the auxiliary surface in Fig.5 are judged as excluded surfaces and highlighted, and then determines whether to select the excluded surface. The original slice is copied for use, and then the excluded surface on the original slice is processed (the excluded surface is removed by canceling stitching, removing edges, deleting faces, replacing faces, etc.) and the processed slice is used as the slice to be biased.

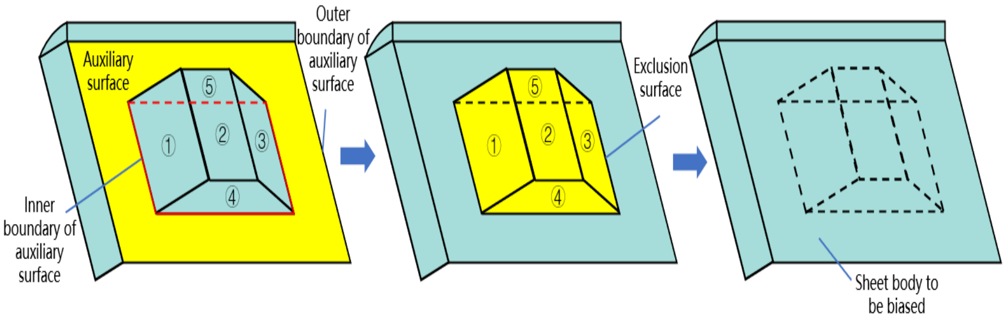


Figure 5: Auxiliary automatic selection of exclusion surface implementation method

3.2.3. Thickening method of sheet body

The system creates one feature for all surfaces or one feature for each surface and uses the offset surface command to obtain the best bias scheme. The system calculates whether there is interference between two pairs of offset surfaces, and records the interference information and interference curve. The system uses interference information and interference curve to trim the offset surface. The system takes the cut body, groups it according to the distance, calculates the body, removes the part that is not connected with the body, and then stitches the body. The system obtains all boundary edges of the suture body and all boundary edges of the original selected thickened body (note that the boundary edges of the alternate replicas are obtained if the exclusion surface is selected). The system matches the seam edge with the original edge, spells out the straight grain surface one by one, and all the bodies are sewn well. All holes of the sutured body were obtained, and all holes were repaired by means of N-sided curved surface. The demonstration effect of the method is shown in Fig.6.

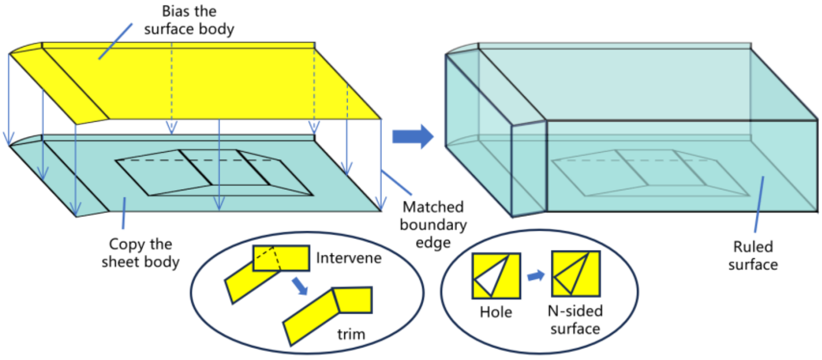


Figure 6: Sheet body thickening method

3.3. Automatic sheet body thickening system

The whole automatic body thickening system work flow is as follows: first, import the complex shape surface of the car body, open the user menu, then select the open body thickening dialog box, select the body, carry out auxiliary selection of the body exclusion surface, and thicken after determining the thickness and direction; Then select import bridge parts, select open parts bridge dialog box, select the bridge target, assist in selecting the bridge parts bridge surface, select whether to hide the bridge target, if you choose to hide, you can check and manually select the bridge surface, and then display the bridge target after completion, and finally bridge processing can be carried out. The specific work flow is shown in Fig.7.

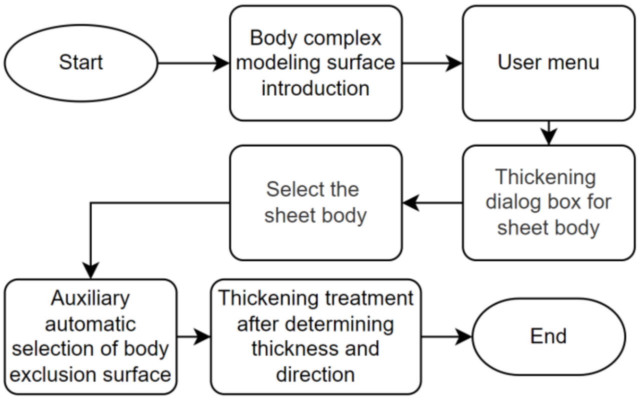


Figure 7: Automating thickening system workflow

4. Implementation

Next, the specific design and operation examples of the interactive interface will be explained in detail to verify the reliability of the project.

The body thickening function is demonstrated with the help of a no-bar stop pedal, according to the "Thicken Sheet body" dialog box in Fig.8; Select the body that needs to be thickened. After selecting it, the "Thicken Sheet body" dialog box will refresh and display the new parameters for the thickening function. Then, the user can choose to click "Quick selection of exclusion surface" to perform the auxiliary selection of exclusion surface, as shown in Fig.9(a), or click the crosshair button to manually select the exclusion surface; Then, after determining the thickening thickness parameters and thickening direction, click "Thickening" to start the automatic sheet thickening process, as shown in Fig.9(b); After the thickening is completed, the slice will be thickened into a solid, as shown in Fig.9(c). Click "Apply" or "OK" to save the thickening model data, and the process ends (if you click "Cancel", the thickening model and data will not be saved).

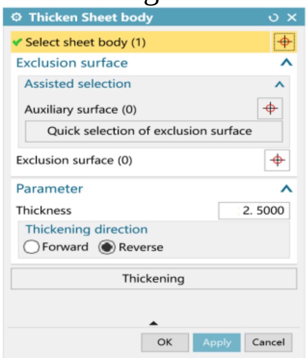
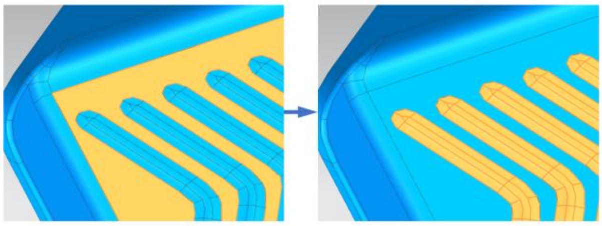
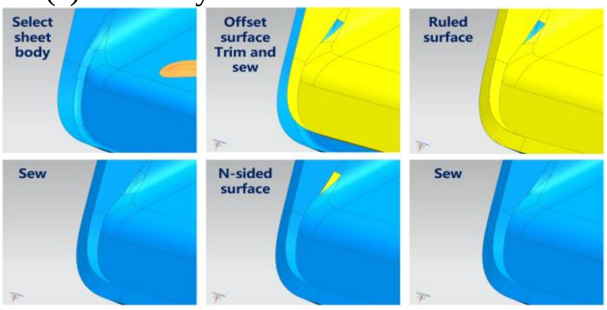


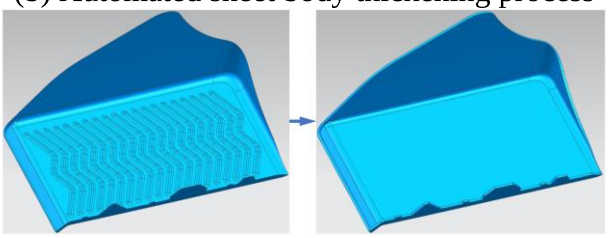
Figure 8: Automatic thickening of the interactive interface



(a) Auxiliary selective exclusion surface



(b) Automated sheet body thickening process



(c) Thickening of the sheet body is completed

Figure 9: Example of automatic sheet body thickening

5. Conclusion

In this paper, UG11 software platform is used as a CAD /CAE /CAM tool to realize 3D modeling, program coding and algorithm design are carried out in Microsoft Visual Studio 2017, combined with UFun and NX Open secondary development technology, according to the needs and experience of engineers in the industry. In this paper, C++ programming language is used to design an automatic thickening function system for the complex shape surface of the car body. The program in the system realizes the quick and automatic selection of the excluded surface by obtaining all the combinations of adjacent surfaces surrounded by the boundary of the selected auxiliary surface as the excluded surface. The excluded surface is removed from the original slice with the help of the commands of canceling stitching, deleting edges, deleting surfaces and replacing surfaces. The surface is generated by the offset surface command with the help of the offset surface. The system uses the straight grain surface command to generate the joint surface of the partial grain surface and the copy, and uses the N-side surface and the splicing command to perfect all the faces into a non-porous entity. The system is packaged and integrated as UG plug-in, which is easy to install and use, and the efficiency of body parts design and modeling is improved by reliability.

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