Automatic Finite Element Mesh Generation on 3D Surfaces Based on STEP

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Abstract. Computer Aided Engineering (CAE) have a vital value in die and mould manufacturing. For the purpose of enhancing the modelling ability of the existing CAE analysis system and improving the mesh generation quality and working efficiency, a system for automatic finite element mesh generation on 3D surfaces is designed and implemented. Applying the neutral mechanism for product information sharing provided by STEP, product model import and reconstruction process is first implemented. And then product model information extraction module is developed aims at preparing geometrical and topological information for finite element mesh generation. An improved strategy for automatic triangular mesh generation over 3D surface is adopted to realize the mesh generation of the system. Implemented results indicate that the presented system helps to improve the mesh quality and at the same time increase the process efficiency and reduce the time cost.

1. Introduction

As one of the most common methods of part manufacturing, plastic injection moulding has evolved over the years from producing combs and buttons to producing a vast array of products for many industries including automotive, medical, aerospace, consumer products, toys, plumbing, packaging, and construction [1]. Computer Aided Engineering (CAE) is applied in the plastic injection moulding areas to improve product quality [2-4]. To survive in this aggravation of the market competition, higher product quality is one of the must have requirements for the manufacturing company. More and more domestic die and mould manufacturing companies begin to apply computer-aided engineering (CAE) analysis software to enhance product quality and to increase work efficiency. However, there usually exist meshes with poor quality in the finite element model generated by those kinds of CAE software and engineers have to do mesh revision. Furthermore, the importing and exporting function of domestic plastics injection mould CAE software are still relatively weak. Thus it is essential to improve the interface function of domestic plastics injection mould CAE analysis software and realize its integration with all kinds of heterogeneous CAD systems. So it is of realistic importance to do the research on automatic high-quality mesh generation on mould surface based on STEP.

The paper is composed of following sections: 1. Model importing and reconstruction: Research and implementation of model importing and reconstruction based on STEP were done; at the same time STEP components based on geometric engine realized the direct connection and integration among heterogeneous CAD systems and CAE systems. 2. Model information extraction: Geometric and topologic information based on B-Rep model were extracted, which satisfied the need of finite element mesh generation system. 3. Advancing front technique was developed: Based on Delaunay triangulation method, triangular mesh generation method for 2D parametric plane was set up, and
triangular mesh was generated in 2D parametric plane by applying the new developed method. 4. Mesh generation.

2. Model Importing and Reconstruction
The quality of finite element mesh generation depends a lot on the integration of CAE system and CAD tools. Due to the incompatibility among different systems, product models generated from CAD tools may lose information while being processed in CAE systems. And this may result in severe problem. To enhance the integration ability between CAE system and CAD tools, a Standard for the Exchange of Product Model Data-STEP based method is presented. Following is a brief description of the process.

STEP provides a neutral mechanism for sharing and exchanging product information at all stages in the product life cycle, covering all aspects of products description and manufacturing specifications [5]. Geometrical model import and reconstruction is implemented based on STEP AP203 (Configuration Controlled 3D Design of Mechanical Parts and Assemblies) and AP214 (Core Data for Automotive Mechanical Design Processes) [6]. Due to its powerful ability in product modelling, CAD tools are widely used to build product model. And B-rep model (Boundary-representation) is commonly employed as the input description model in CAD systems. Then the model data is saved as STEP 203 file format which is STEP neutral file and could be exchanged among diverse CAX systems. STEP Data Access Interface-SDAI is applied and developed in the system to deal with STEP files generated from heterogeneous CAD systems in a unified way [7, 8]. To develop SDAI, early binding method is applied. In C++ programming environment, files in EXPRESS mode are compiled into C++ source codes, then they are bounded with SDAI classes. And these later are used in generating the proposed application system. By employing SDAI, engineers could extract product model’s geometrical information for further application. Geometric engine is adopted for mapping entity of STEP file into shape. At the end, STEP components functions are applied for realizing product model reconstruction and rendering.

3. Model Information Extraction
Product model generated and exported from CAD system is based on B-rep, the geometrical and topological information of the B-rep model is vital for the operation on product model. Pure geometry elements of the model such as points’ coordinates, length of the curve, area of the surface, distance of the points, angle of line, etc are described by geometrical information. While the relations of the entities inside a model and how they connect are represented by topological information. For finite element mesh generation, geometrical and topological information are essential and will be used as the parameters to input into FEM system for mesh generation.

![Figure 1. Example of product model information extraction](image-url)

Understanding how product model is constructed is vital to the process of model information extraction. Product model has a shell which is composed of connected faces. One or more closed loops
make up the boundary of the face. And each loop is connected by edges while edge is linked by vertex. By accessing the entity advanced_face of the closed_shell, boundary surface data of the model could be obtained. And after the face pointer is got, entity like loop, edge, vertex and their information can be fully extracted. Figure 1 illustrates an example of product model information extraction.

4. Strategy for Mesh Generation

Mesh generation for both surface element and inner element are the two procedures for 3D model finite element mesh generation. Triangulation of the surface is implemented by applying parametric surface mapping method [9-12]. First, product model which was produced from commercial CAD system is imported and reconstructed according to STEP file, afterwards geometrical and topological information of each surface is mapped and extracted to 2D parametric space. Employing advancing front method, product model surface element mesh can be generated on the parametric plane. Subsequently, the inner tetrahedron finite element mesh is generated by utilizing the 3D advancing front approach from the boundary surface of the product model towards inside.

An improved strategy for automatic triangular mesh generation over 3D surface is adopted [10]. Curvature based quadratic mapping approach is employed in mesh generation process. The process including following sections, (1) To transform 3D model surface into quadratic parametric space. (2) To define the outer loop, inner loop and parametric area. The outer boundary of the parametric space determines the outer loop. The inner boundary of the parametric space determines the inner loop. Parametric area is the region in between outer loop and inner loop. (3) To compose outer and inner loops. These loops can be made by linking edges which includes line, spline, circle and so on. (4) To apply Advanced Front Technique (AFT) in mesh generation in the parametric area [10]. Meanwhile, graded mesh control strategy is also discussed to improve the mesh quality. Following operations are applied to prevent the generation of highly distorted elements such that the overall mesh quality could be enhanced and also the mesh generation efficiency could be improved. (1) Associating 3D surface with Fist Parametric Space (FPS). (2) Adopting surface curvature to unify the physical meaning of FPS parametric coordinates. (3) Employing curvature measure parameter for the realization of mapping between FPS and Quadratic Parametric Space (QPS). (4) Utilizing self-adaptive coefficient to control mesh generation.

5. Implementation of Mesh Generation

3D surface finite element mesh generation system is implemented applying above mesh generation strategy. The system has following five main modules, (1) Geometrical model importing module. With this module, product models generated from general CAD tools could be able to be imported into the developed system. An efficient way is offered here for the system to integrate with heterogeneous CAD systems. (2) Product model reconstruction and browsing module. By adopting geometrical engine, operations like product model rendering and lightening and so on could be realized in the system. (3) Product model information extracting module. Product designer could extract geometrical and topological information of the model for further operations which including measurement of distance, angle, area, volume and so on. (4) Finite element mesh automatic generation module. (5) Finite element mesh displaying module. Figure 2 is an example of automatic finite element generation on 3D surfaces from this system.
Figure 2. Example of automatic finite element mesh generation on 3D Surfaces

6. Conclusion
Aiming at improving the mesh generation quality and working efficiency, a system for automatic finite element mesh generation on 3D surfaces is designed and implemented. Product models which were created from heterogeneous CAX systems could be imported, extracted, reconstructed and meshed within this system. With the fulfilled functions, the system has the capability of developing standard data access interface with commercial CAD systems as domestic injection mould CAE analysis software is relatively weak in geometric modelling. The presented work is expected to enhance the competitive ability of domestic manufacturing enterprise in globalization market.

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