Topological Optimization Method and Its Application Research In The Rear Platen' 3-D Structure Design

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***Abstract*—The fundamental theory of Topological optimization was enunciated in this paper [*], and topological optimization method provided by ANSYS software was used to optimize the structure of rear platen of injection molding machine. The optimal structure was found out and it provides the theoretical base for further improving the platen's structure.**

***Keywords*—topological optimal, ANSYS, rear platen**

I. INTRODUCTION

Structure optimization is an important task during application. At present, the optimization has developed from the structure measurement to the structure feature and topological .As the evolution of economy construction project, design personnel need a much more system and scientific design way and plan, to fit the purpose of saving raw and processed materials, reducing cost and promoting the products' quality .To realize this purpose, structural optimization design is the best way. During all the levels of design optimization, the structural topological optimization brings the furthest notable proceeds. Compared to Finite Element Analysis, which just analyze and check designed parts, topological optimization design obtain the best blue print at the beginning design phases of parts .So it has a higher application value.

II. THE TOPOLOGICAL OPTIMIZATION METHOD

A. Topological Optimization Overview

Based on different requirements and solving difficulty, structural optimization usually can be divided into four different levels: Size optimization, shape optimization, Topology and layout optimization, and structural type and material optimization [1]. The object of topology optimization is to find the best topology, the best materials distribution program. Topology optimization can be divided into continuous body and rod-type structure. The truss structure can be understood as: according to some rules or constraints, some unnecessary bar can be removed from the matrix structure and optimal topology structure will be determined by the remaining bar; For Continuous body, topology optimization is, based on given external load and boundary conditions, to determine the location and quantity of Non-entities within an specific continuous region to meet the target function and constraints, it means applying optimization method to determine whether openings in a row are needed and how many holes need to be created to reduce the weight of the structure or improve the performance of the structure[2].

Because the improved topology can significantly improve the performance or reduce the weight of the structure, people have always been very concerned on the topology optimization study. Due to too much difficulty, foreign countries didn't start in this field until late 1980s. In the early 1990s, China began working in this area [3]. Because only axial force exists in frame, mechanical analysis is easy and optimization model is simple, a lot of development has been made in this field. Continuum topology optimization developed slowly because of the difficulty in describing model and huge algorithm computation. At present, Continuum topology optimization methods mainly used are homogenization method, variable thickness and variable density method and so on. Variable density method is successfully applied in planar structure of Multi-bound status stress, three-dimensional continuum structure, structure of collision, and frame design [4].

B. The Topological Optimization Method

1) The Homogenization Method

The Homogenization Method is a typical method for topological optimization with strict basic theory of mathematic and mechanics. In 1988,Bendsoe and Kikuchi advanced the Homogenization Method for topological optimization of series system including the basic idea of introducing microstructure into the material which buildup topological structure.

In the optimize process, take the geometry of micro-structure as a design variable, the microstructure of growth and decline to achieve its omissions, and generate intermediate size range from micro-structure of the composite material, thereby realizing the topology optimization model and optimize the size of the unified model. However, due to its certain disadvantages, it is mainly used in theory study of structural optimization.

2) Variable Density Method

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Variable Density Method, which is enlightened from The Homogenization Method, is another effective physical description method in structural topological optimization. Its main idea is to introduce a kind of fictitious alterable material, which its relative density is between0 to 1.

3) Evolutionary Structural Optimization

Evolutionary Structural Optimization arising recently, is another numerical value method resolving all kings of structural optimization problems. Based on a quiet simple concept, it gradually get rid of useless or low-effective materials and the residual structure will naturally optimize .It has an excellent currency.

C. The Topological Optimization of ANSYS

With in-depth study on structural optimization, the application software of structural optimization also has a great development. Since the 1980s, with the development of computer-aided design and computer graphics, the integration of structure optimization, finite element and computer-aided design have been developed rapidly and a large number of general structural optimization software has been developed. One category of them is the specifically developed structure optimization software such as ACCESS, DDDU, SAPOP, and SATROS and so on; another category is the structural optimization software extended from the existing commercialization finite element analysis software. Typical software in this category is ANSYS.

ANSYS provides a topology optimization method based on equal strength. Its optimization goal is to find the best materials distribution program on the basis of largest stiffness. Its topology optimization function is very simple. The objective function, state variables and design variables are predefined. After users input the structure parameters (material properties, model, load, etc.) and the percentage of materials to be omitted, the best material distribution program of objects to bear Single-load or load, the optimal structure, can be found through iteration [5]. It's actually variable density method.

D. The Summary of Rear Platen

Transfer templates are important parts in the Plastic Injection Molding Machine-Die devices, which can be used to adjust mold [6]. Because most of the time it works in the larger variable load, its strength and stiffness have great impact on the quality of plastic products. Because the platen has been designed with intuition and experience by manual calculation for a long time, the calculation model is rough and the design is conservative and lacks of a scientific basis and also has greater blindness. With the development of CAE and computer application, it is necessary to re-design the structure.

Because of complex structure templates and various forms of stiffener layout, it is very difficult to optimize the rear platen completely no matter size optimization; shape optimization or other structural optimization is used. So this paper will use the topology optimization method to study it and determine the template structure using topology optimization method provided by ANSYS software.

III. OPTIMAL PROCESS

A. Selecting Definite the Topological Optimal Question

1) Optimal Design Model

The topological optimization of Continuum structure is a continuous variable optimization problem, which is identified in the certain region to determine their location and the number of the non-entities region, namely in the continuum Ω electing a subset of Ω m, so as to meet [7]

$$E_i(x) = \eta(x)^q E_0 \qquad q \geq 1, 0 \leq \eta(x) \leq 1.0 \tag{1}$$

$$\int_\Omega \eta(x) d\Omega \leq V \tag{2}$$

In this formula, E_0 is the chosen material modulus of elasticity; E_i means the material modulus of elasticity; V is the volume of the Ω; $\eta(x)$ is a continuous variable; q is a punitive factor.

As mentioned above, ANSYS topological optimization's objective is to find the best materials distribution method optimize basis on the stiffness of the largest objects. The so-called greatest stiffness means when the structure meets the constraints of the situation, reduce its' structural deformation energy. This technology achieves through the use of design variables (η_i) to give each of the finite element an internal pseudo-density. Constraint function is in a given load and to meet the norms of the greatest stiffness the percentage of the material save, also called, volume constraint. Therefore the mathematical model of the rear platen's design optimization can be expressed as:

$$\begin{cases} \text{find} & \eta_i (i = 1, ..., n) \\ \min & \mathrm{F}(\eta_i) \\ s.t. & \int_\Omega \eta_i d\Omega \leq \alpha V \\ & 0 \leq \eta_i \leq 1.0 \end{cases} \tag{3}$$

In this formula, F is the rear platen's deformation energy; η_i is the element's pseudo-density; n is the element's number; α is the percentage of the material save; V is the rear platen's original volume.

2) 3D Solid Optimal Model

Topological optimization is the process of iteration based on finite element. The data calculated is enormous. In order to track changes easily, it requires the optimization model the simpler the better after considering various factors. The algorithm of optimization model should be with faster convergence and the number of structural analysis is reduced. Therefore the rear platen is simplified as follows: omitting all holes to facilitate the unit mesh; not considering the support at the bottom of plate, treating it as central symmetry; taking 1 / 4 model to compute, simplifying the optimization model is shown in Figure 1.

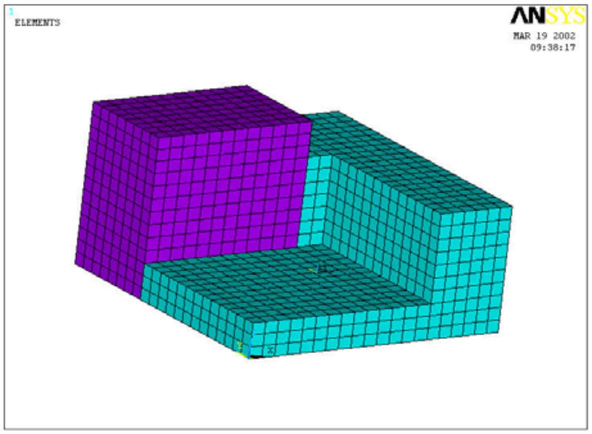

Figure 1. The rear platen's topological optimization model of the structure

B. Select the Element Type

ANSYS topological optimization function only provides two 3D modules: SOLID92 (10 nodes tetrahedron modules) and SOLID95 (20 nodes hexahedral modules). Here choosing the hexahedral 20 nodes SOLID95 as a mesh unit. Unit size is 40 mm. The total number of nodes is 15,635 and the total number of elements is 3214.

C. Designate the Optimization Region

Only the cell with the type of No.1 can be topologically optimized in ANSYS software. This restriction can be used to control what parts of model are to be optimized and not to be optimized. According to the structure of rear platen and optimization purposes, here the Load Bearing bulge is chosen as the region to be optimized. Please refer to the Figure 1, in which the unit with color 1 is the optimized region, while the second unit with color 2 isn't.

D. Define and Control Load Conditions

Applying constrains and loads according to the conditions of rear platen.

E. Define and Control the Optimization Process

Topology optimization process consists of two parts: defining optimization parameters and topology optimization. Optimization parameters include the percentage of material omitted, the convergence of tolerance and so on. Then single or multiple iterations are made. According to the characteristics of rear platen, 0.6 percentage of materials omitted is chosen and iterations are made.

F. Show Results

ANSYS provides a wide ways of topological optimization analysis Show: element node solution, pseudo-density nephogram, density extraction cell plans, objectives equation iterative curve, structural deformation energy, and so on. Lasted 10 hours, running 15 iterations, the nephogram Show the real platen iteration, as shown in Figure 2. Fig.2 has been clearly reflected the remainder of the shape and location of materials. In order to see the remaining modules more clearly, we can establish the units table, observe the different density modules cloud, understand the unit deletion trend, and use the biopsy results to show that the effects of different levels of shape. As in Figure 3 it is results map from optimization modules whose pseudo-density is 0.6 ~ 1.0, which shows the pressure-convex shape of the structure very clear. It's a fork-like structure, which is very different from the original structure.

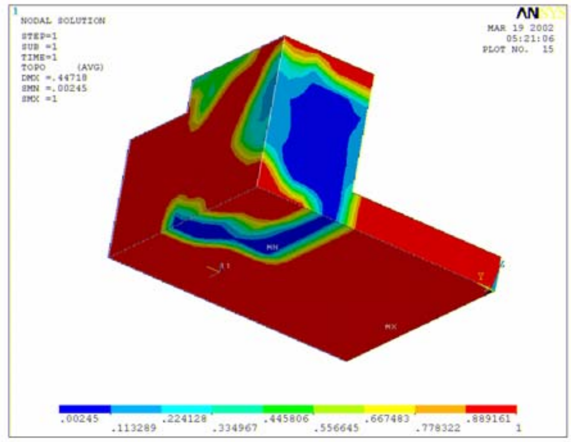

Figure 2. The results cloud after 15 times iterative optimization

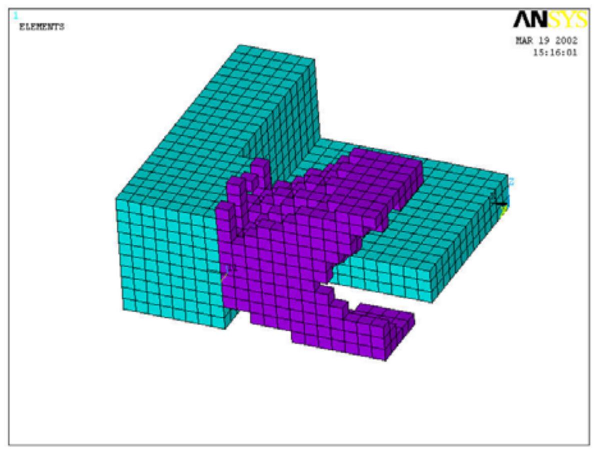

Figure 3. The pseudo-density cell topological

G. Finite Element Analysis of Template topology optimization

According to the results of topology optimization, take some modifications to the original structure template. Using 3-D design software to establish a template similar to the three-dimensional model, this three-dimensional model for finite element analysis, the results of the stress distribution in Figure 4. Compared with the original template, the deformation decrease 27.8%, stress drop 29%, weight lower 3%.

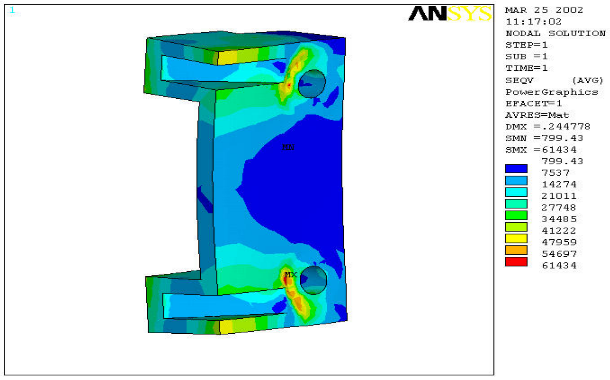

Figure 4. Equivalent Stress cloud of template topology optimization

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IV. CONCLUSIONS

- This paper takes the real platen of injection molding machine as an example, using ANSYS software topology optimization function for the three-dimensional structure optimization and design study. From the optimization results cloud can be clearly seen the real platen's location of non-entities regional and quantity, which can be abstracted a new structure shape, as a right direction for the real platen structure improvement.
- Topological optimization method offers a new type of design ways for the three-dimensional structural design. It entirely breaks the traditional, experiential and conservative design mode, changes the design from the passive safety check into a proactive optimization, has bright prospects for development in reducing costs and improving efficiency and will be certainly received more attention and a wide range of applications.

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