

# Analysis and Research on Molding Technology and Thermodynamics

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## ABSTRACT

Injection molding technology forming the shape of a complex and precise size of products, suitable for high efficiency, high-volume production methods, has become part of thermoplastic and thermoset plastic molding process the most important. Moldflow software is based on the theory of injection molding technology finite element software. In this paper, UPS fan as an example, during the process of injection molding, the finite element model, gating system and cooling system layout, flow process analysis, the cooling process of analysis and warpage process analysis are expounded. And then on injection process causes of defects are analyzed, and finally through the optimization of process parameters the results have been satisfied.

## Keywords

Injection; finite element simulation; shaping

## 1. INTRODUCTION

Injection molding of large deformation has been a problem for mold enterprises. With the development of finite element technology and computer technology, numerical simulation has become the effective tool for process analysis and optimization design. The injection mold CAE software to calculate the deformation result is true specific process conditions and provide products, injection molding process parameters optimization for injection molding. With the help of numerical simulation analysis results, the deformation of the reverse compensation to product model, will provide a new idea to reduce product deformation.

### (1) Steady state problem solving

For steady state thermal analysis

$$[K_T]\{T\} = \{Q\} \quad (1-1)$$

The steady state thermal analysis can be divided into linear and nonlinear problems. In the linear problem, the overall thermal conductivity matrix is a constant matrix with no relation to temperature. For nonlinear problems:

$$[K_T(T)]\{T\} = \{Q(T)\} \quad (1-2)$$

In the steady state nonlinear problem, the overall heat transfer matrix and the thermal load matrix may no longer be a constant, but rather a function of the temperature T.

### (2) Transient state problem solving

For transient state problems

$$\left(\frac{1}{\theta\Delta t}[C] + [K_T]\right)\{T_{n+1}\} = \{Q\} + [C]\left(\frac{1}{\theta\Delta t}\{T_n\} + \frac{1-\theta}{\theta}\{\dot{T}_n\}\right) \quad (1-3)$$

For formula (1-1), ANSYS only supports the full method solver. ANSYS uses generalized trapezoidal rule algorithm to solve, i.e:

$$\{T_{n+1}\} = \{T_n\} + (1-\theta)\Delta t\{\dot{T}\} + \theta\Delta t\{\dot{T}_{n+1}\} \quad (1-4)$$

In formula (1-4),  $\theta$  is the transient integral parameter, The user can use the TINTP command input;

$$\Delta t = t_{n+1} - t_n;$$

$\{T\}$  is the temperature of the node at time  $t_n$ ;

$\{\dot{T}\}$  is the temperature change rate of the node at time  $t_n$ .

At the time  $t_{n+1}$ , formula (1-3) can be written as follow:

$$[C]\{\dot{T}_{n+1}\} + [K_T]\{T_{n+1}\} = \{Q\} \quad (1-5)$$

Substituting Formula (1-3) into Formula (1-5):

$$\left(\frac{1}{\theta\Delta t}[C] + [K_T]\right)\{T_{n+1}\} = \{Q\} + [C]\left(\frac{1}{\theta\Delta t}\{T_n\} + \frac{1-\theta}{\theta}\{\dot{T}_n\}\right) \quad (1-6)$$

Formula (1-6) takes into account both linearity and nonlinearity in transient analysis. Once  $\{T_{n+1}\}$  is solved,  $\{\dot{T}_{n+1}\}$  is updated by formula (1-6). ANSYS defaults time integral parameter as  $\theta = 0.5$ . The Crank-Nicolson method was used to solve (1-6) and it has second-order accuracy. When the time integral constant  $\theta = 1$ , the solution method is the backward Euler method. For all  $\theta > 0$  cases, the solution is implicit. In addition, the available range of t:

$$0.5 \leq \theta \leq 1$$

### (3) The first law of thermodynamics

$$\rho c \left( \frac{\partial T}{\partial t} + \{v\}^T \{L\} T \right) + \{L\}^T \{q\} = \ddot{q} \quad (1-7)$$

Notes:  $\rho$  - density;  $c$  - Specific heat capacity;

$T$  - temperature;  $t$  - time

$$\{L\} = \begin{Bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \\ \frac{\partial}{\partial z} \end{Bmatrix} \text{ - Vector operator;}$$

$$\{v\} = \begin{Bmatrix} v_x \\ v_y \\ v_z \end{Bmatrix} \text{ - Mass heat transfer velocity vector .To enter VX,}$$

VY, VZ with the R command .  $\{q\}$  - Heat flux vector(Output with TFX,TFY AND TFD symbol).

$\ddot{q}$  - The heat generation rate per unit volume (Input with BF OR BFE command).

## 2. VENTILATOR INJECTION FINITE ELEMENT SIMULATION

### 2.1 Establishment of finite element model

First import the fan model, Moldflow analysis software can import more model formats. In the mesh, even if all the parameters are the same, the mesh division is not the same. Such as STL, IGS and STP the three file format, the matching rate of IGS format files is much more than STL and STP format in the grid. But for some product models, the IGS file format will have a lot of overlap or missing surfaces which will make the grid more defects. Therefore, in the case of IGS with better quality, we proposed to give priority to the IGS format, on the other hand, the STL format is proposed. The fan model of this paper format is STL.

Grid type: there are three kinds of grid type Mildflow MPI, namely the surface mesh (Midplane), the surface mesh (Fusion) and the entity grid (3D), based on the analysis of types with the type of grid. In this paper, the UPS fan model grid type selection surface mesh.

Grid length setting: grid length is generally 1.5~2 times the minimum wall thickness of the product, which can guarantee the precision analysis. Of course, the grid is of higher accuracy, but the computational complexity and system model of the modified will be greatly enhanced.

The aspect ratio setting: in the grid of the surface model and surface model, aspect ratio refers to the limit size triangular height direction ratio. Aspect ratio has a great influence on the calculation results, the general requirements in the types of surface and surface types in the grid, the aspect ratio of a maximum value 6 recommended, and in the 3D grid type, values between 5~50 recommended, average at around 15.

Choice of materials: plastic is based on a mixture of polymer as main component which has plasticity under heat and pressure, and through the mold and molding equipment, can be processed into products and parts according to the various requirements. In this paper, the choice of materials is PC UPS fan model.

Injection molding process parameters selection: mould temperature using a default value of 90 ° C, the material temperature using a default value of 300 ° C, open time using the default value of 5S, injection and holding pressure and cooling time is 35S. Filling control adopts automatic filling control mode, velocity / pressure switch adopts filling volume percentage of 100%, holding pressure control adopts the relationship between pressure and percentage of time.

### 2.2 Simulation Result

#### (1) The filling time

From Figure 1, the the melt filling of the UPS fan is completed in 1.177s time. From the filling time result, there is 0.1s difference at the outer end of the injection time of fan blade. The gate position should be adjusted appropriately, then the molten material can reaches the outer end of the blade in the equal time .

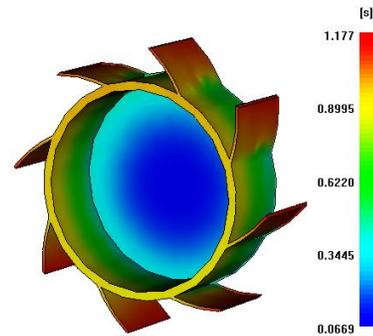


Fig. 1 The filling time

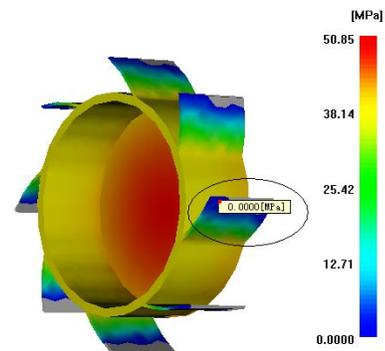


Fig. 2 Cavity filling pressure distribution

#### (2) Velocity / pressure pressure switch

From the results , the red oval logo can be seen, the pressure is 0MPa, showing that the melt without flow to it, as shown in figure 2. Therefore need to modify the injection molding process parameters or recreate the gating system to repair defects.

#### (3) Cavitation

Cavitation refers to the formation of gas mold cavity cannot discharge in time, direct damage to the appearance of the product quality,which should be avoided .Figure 3 shows the cavitation location UPS fan. Cavitation occurred mainly in the parting surface and the fan blade tip, so do not affect the quality of the products, can not be modified.

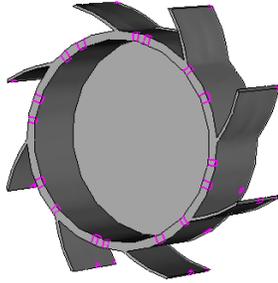


Fig. 3 cavity cavitation location

#### (4) pressure distribution

The pressure distribution is shown in the end of filling cavity and the pressure distribution in the channel, as shown in figure 4. At the end time maximum pressure cavity is 50.77MPa, in the local fan blade tip pressure is almost 0 MPa. Due to the volume of shrinkage stress will affect the product, so the requirements of uniform distribution of pressure as much as possible.

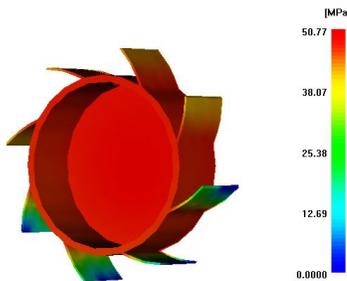


Fig. 4 the distribution of pressure in the cavity

### 3. FAN INJECTION MOLDING PROBLEMS

Through the simulation test of the fan the defects the following aspects can be seen. (1) The melt reaching to the blade end has a time difference. (2) After the filling, the holding pressure of the outer end of fan blade is 0MPa. (3) After filling products, fluid pressure difference is bigger, we should as far as possible to reduce the pressure difference. (4) After the cooling cycle, the highest temperature is higher than the top of the product temperature, affecting the products forming. (5) Due to the shrinkage, excessive warping deformation is resulted.

### 4. SECTIONS

The heading of a section should be in Times New Roman 12-point bold in all-capitals flush left with an additional 6-points of white space above the section head. Sections and subsequent sub-sections should be numbered and flush left. For a section head and a subsection head together (such as Section 3 and subsection 3.1), use no additional space above the subsection head.

### 5. CONCLUSIONS

Injection molding based on UPS fan simulation, and the simulation results were carefully analyzed, the improvement measures of the following are putted forward: (1) A gate settings from the initial plan, the four gates are redesigned which are evenly arranged in the circumferential direction. (2) Improving the cooling system, the distance between the center line of cooling water pipes and cavity obstacle of products should be changed from 20mm to 15mm. (3) The injection pressure should be up to 130MPa. (4) Extending the holding pressure time for a certain time, melt in the cavity can be pressured, compensating melt cooling shrinkage. (5) Increasing mold temperature can be more conducive to the melt in the cavity filling and solidification. Under the condition of improved scheme, simulation of the fan Injection again, defects of the above five aspects have been reduced obviously.

### REFERENCES

- [1] Wang Weibing, the Chinese version of the MOLDFLOW injection molding flow analysis case tutorial [M], Beijing: Tsinghua University press, 2008
- [2] Dan Yan, mold analysis technology based on MOLDFLOW [M], Beijing: Tsinghua University press, 2007
- [3] Wang Gang, mold application analysis of MOLDFLOW [M], Beijing: Tsinghua University press, 2005
- [4] Week Qiyang, basic and typical examples of MOLDFLOW [M], Beijing: Publishing House of electronics industry, 2007
- [5] Ma Wenqi, the Chinese version of the injection molding flow analysis case tutorial plastic forming simulation software technology and application of MOLDFLOW [M], Beijing: China Railway Press, 2006
- [7] Zhai Ping, principle and process of sheet metal forming, the Northwestern Polytechnical University press, 2010, 145-154
- [8] Xie Lansheng, Hu Hao, the springback finite-element analysis profile bending, aviation precision manufacturing technology, 2012, Vol.40 issue 5, 34-36
- [9] Jin Miao, Zhou Xianbin, etc., the large size of closed section aluminum profile stretch bending process research, Journal of Plasticity Engineering, 2011(11), Vol.10 issue 5, 46-49
- [10] Li Hongwei, the big section forming process, scientific technology, 2012 (2), 29-31
- [11] Frode Paulsen, Torgeir Welø, A design method for prediction of dimensions of rectangular hollow sections formed in stretch bending, Journal of Materials Processing Technology, 128(2009)48-66
- [12] Edmundo Corona, A simple analysis for bend-stretch forming of aluminum extrusions, International Journal of Mechanical Sciences, 46 (2010) 433-448