Research on Computer Aided Design of Plastic Gear Solid Forming Die

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Abstract. The solid-state forming technology of thermoplastic parts is a new production process developed in recent years. This article uses the Plastic Advisor module to simulate the filling of plastic gears and optimize the process parameters. By setting different number of gates, mold temperature and injection temperature, the injection pressure, weld line distribution, air pocket distribution and melt temperature distribution are analyzed, and the best gate number, position and corresponding plastic gear molding are determined. Process parameters to reduce injection molding defects and improve product quality. Combining the simulation analysis results to design the three-dimensional injection mold of the plastic gear, the parametric design of the mold is realized, and the design efficiency of the injection mold is greatly improved.

Keywords: Plastic Gear, Process Parameter Optimization, Three-dimensional Injection Mold

1. Introduction

The solid-state forming technology of thermoplastic parts is a new production process developed in recent years. Compared with injection molding process and cutting process, solid-state forming has many advantages. However, due to the limitation of product tolerances, this process is currently only used in occasions where product dimensional accuracy is not important [1, 2]. Mold design is a typical serial route. The steps are mutually restrictive, the production cycle is long, and it is easy to cause the inconsistency of the design and manufacturing data of the molded parts, which increases the probability of rejects. Different from metal forgings, the shape of a solid molded part of a polymerized plastic material changes considerably after being ejected from the mold [3]. For a particular thermoplastic, when the wool is still in a certain volume, the mold size and subsequent shrinkage of the parts after solid forming are affected by multiple production process parameters [4]. Obviously, it can be seen from the number of process parameters that it is really difficult for the mold designer to calculate the solid forming mold. When processing gears, in order to make the accuracy qualified, the mold used not only requires some of its overall dimensions (such as the addendum cylinder) to be qualified, but also every tooth profile should be qualified [5]. For gears that transmit power, the correct tooth thickness and involute tooth profile must be guaranteed [6, 7].

In the process of plastic gear injection molding, often due to the unreasonable mold structure design and improper determination of the injection molding process parameters, many injection
molding defects of the gear are caused, which seriously affect the use and life of the gear. This article optimizes the molding process parameters of plastic gears, uses the injection molding simulation module Plastic Advisor to simulate the flow of the injection molding of the gear, and determines the best gate position and number of gear injection molding and the corresponding molding according to the position of the weld line and the bubble. Process parameters.

2. Plastic gear filling simulation
On the basis of the simulation results, the mold design module of Pro/ENGINEER Wildfire is used to design the three-dimensional mold of the plastic gear. The parametric gear mold design process proposed by the author is shown in Figure 1. Mold design and manufacturing can adopt a parallel process route. Mold design model and manufacturing model are built on a unified geometric model to ensure the unity and correctness of model data. It greatly improves the efficiency of plastic gear mold design, shortens the cycle of gear mold design, and improves product quality.

2.1. Parametric optimization of plastic gears
This article takes the output driven plastic gear on the copier as an example, the modulus \( m = 1.25 \), the number of teeth \( z = 48 \), the normal tooth with a pressure angle of \( 20^\circ \), the tooth width \( b = 34 \text{mm} \), the speed \( n_2 = 100 \text{r/min} \), and the working environment temperature is \( 50^\circ \text{C} \), gear material is PA66.

First use the Parameters command in the Part module of Pro/ENGINEER Wildfire to set the number of teeth, modulus, pressure angle and tooth width of the gear as the size driving parameters, and then use the Relations command to input the gear-related process dimensions such as addendum circle and tooth root The relational expressions of circle, index circle and base circle. In order to achieve precise modeling and parameterization of gears, after parameterizing the involute profile curve equation of the gear, use Equation command to input the parameterized equation to obtain the involute curve. Next, use other commands in the Part module to establish a three-dimensional parametric model of the gear.

2.2. Mold filling simulation

2.2.1. Optimal gate filling simulation program
PA66 has the characteristics of high strength, good wear resistance, toughness, fatigue resistance, oil resistance and water resistance, and meets the requirements for the use of driven gears on copiers. PA66 is a general-purpose thermoplastic with good melt fluidity and low specific heat capacity. The plasticization efficiency in the barrel is high, the solidification in the mold is faster, and the molding cycle is short. It can be molded on a plunger or screw horizontal injection machine. The melting temperature of this material is \( 260^\circ \text{C} \sim 290^\circ \text{C} \), and the mold temperature is \( 60^\circ \text{C} \sim 120^\circ \text{C} \). According to the performance of the copier gear, it is required to have good strength and wear resistance. Therefore, when simulating plastic gear molding, the main consideration is the filling quality of the part, the number and location of weld marks, and the location of air pockets at different gate numbers.
and different injection temperatures. First, when the mold temperature is 80 °C, the number of gates and the injection temperature are changed to analyze and predict the filling quality of the part to determine the number of gates. The proposed simulation plan for gear gate optimization is shown in Table 1.

Table 1. Optimization simulation scheme of gear gate

| Program | Number of gates/piece | Injection temperature/°C | Mold temperature/°C |
|---------|-----------------------|---------------------------|---------------------|
| 1       | 2                     | 260                       | 80                  |
| 2       | 2                     | 270                       | 80                  |
| 3       | 2                     | 280                       | 80                  |
| 4       | 3                     | 260                       | 80                  |
| 5       | 3                     | 270                       | 80                  |
| 6       | 3                     | 280                       | 80                  |
| 7       | 4                     | 260                       | 80                  |
| 8       | 4                     | 270                       | 80                  |
| 9       | 4                     | 280                       | 80                  |

2.2.2. Analysis of the simulation results of the optimization of the number of gates

It can be seen from the results that when using different gates, the parts have higher filling quality. When using two gates, although the total number of weld marks is small, due to the long process, there are more weld marks at the filling position of the tooth surface, and there are several weld marks perpendicular to the flow direction, which seriously affect the strength of the gear teeth. Although the air pockets formed when using 2 gates and 3 gates are mainly concentrated at the two ends of the part, some air pockets are still generated in the middle tooth surface part. If no measures are taken in the mold structure, teeth will be generated. Noodle quality defects. When using 4 gates, the total number of weld marks is more than that of 2 and 3 gates, but the positions generated are less in the tooth surface part, mainly concentrated at the end of the gear filling, and there is no perpendicular to the flow direction. Weld Line. When 4 gates are used, the air pockets are concentrated at the end of the gear, which is easy to escape through the parting surface exhaust method, and there will be no high temperature gas burns caused by poor exhaust and burn the product. The same results can be obtained by analyzing the simulation results of several other groups of schemes, so after the preliminary simulation, it is determined to use 4 gates to optimize the molding process parameters.

2.2.3. Injection temperature and mold temperature optimization mold filling simulation results

By comparing the results of injection time, injection pressure, clamping force and injection cycle of plastic gear filling simulation at different injection temperatures and different mold temperatures, the injection temperature and mold temperature are optimized. The simulation results are shown in Table 2.

Table 2. Simulation results of different injection temperature and mold temperature at 4 point gates

| Program | Injection temperature/°C | Grinding tool temperature/°C | Injection time/s | Injection pressure/MPa | Clamping force/kN | Injection cycle/s |
|---------|--------------------------|-----------------------------|-----------------|------------------------|------------------|------------------|
| 1       | 260                      | 70                          | 2.69            | 11.82                  | 22.50            | 41.43            |
| 2       | 270                      | 70                          | 2.48            | 9.92                   | 19.40            | 40.19            |
| 3       | 280                      | 70                          | 2.37            | 8.22                   | 15.20            | 41.59            |
| 4       | 260                      | 80                          | 1.44            | 12.23                  | 26.40            | 40.42            |
| 5       | 270                      | 80                          | 1.44            | 10.58                  | 21.60            | 42.17            |
| 6       | 280                      | 80                          | 2.48            | 7.94                   | 14.50            | 46.69            |

It can be seen from the table that when the injection temperature is 260 °C and the mold temperature is 70 °C and 80 °C respectively, the injection pressure is relatively large, and during the
filling process, the temperature difference of the melt is large, which is easy to cause warpage and deformation of the part. The temperature on part of the tooth surface is even lower than the melting temperature of PA66. After the part is cooled, the mechanical properties of the part will be affected. Solutions 1 and 4 are not suitable. When the injection temperature is 280°C, the mold temperature is 70°C and 80°C, and the injection temperature is 270°C, and the mold temperature is 70°C, the temperature difference of the melt is large during the filling process, and the injection time is longer, which is easy to lead to warpage deformation and stress generation after cooling of the part, solutions 2, 3, and 6 are not very good. When the mold temperature is 80°C and the injection temperature is 270°C, the melt temperature difference is 0.5°C, which is very small. The melt temperature is not only evenly distributed, but also the injection time is shorter, the injection pressure is appropriate, and the quality of the injection molded plastic gear is better. Therefore, based on the simulation results, it is recommended to choose option 5 to determine the injection molding process parameters with an injection temperature of 270°C and a mold temperature of 80°C.

3. Three-dimensional mold design of plastic gear

According to the simulation results of plastic gear mold filling, it can be seen that the gear adopts a 4-point gate gating system to fill the mold with good quality. Gear parts are mass-produced. In order to improve production efficiency, according to the characteristics of point gates, a 3-plate automatic deagulating mold structure is proposed to realize automatic separation of parts and aggregates. According to the simulation results, when using Scheme 5 for injection molding, the required injection volume is 52.49cm³, and the clamping force is 21.6kN. Therefore, the XS-ZY-125 injection machine is selected. The injection machine has a rated injection volume of 125cm³ and clamping The force is 900kN and the injection pressure is 120MPa.

According to the Molding Design module of Pro/ENGINEER Wildfire, the plastic gear to be molded is used as a reference part to create

Build the mold volume and parting surface, and use the parting surface to divide and extract the mold volume to obtain the required gear cavity, upper mold and core. Then use the Part module to edit the generated gear cavity, upper mold and core according to the corresponding process calculation and the structure on the mold, and add the corresponding structural features such as screw holes, pin holes and ejector holes to form The final shape of the gear 3D molded part.

Correction using multiple regression equation:

\[ m = Z_0 + Z_1 X + Z_2 X^2 + Z_3 X^3 \]  \hspace{1cm} (1)

Perform a curve fitting on the modified involute tooth profile. The regression coefficients of \( Z_0, Z_1, Z_2 \) and \( Z_3 \) in the formula are obtained separately by calling the statistical algorithm program in the local computer system.

According to the selected injection machine specifications and gear injection molding requirements, select a standard injection mold base or design a mold base that is compatible with it, and use the Part module of Pro/ENGINEER Wildfire to create corresponding three-dimensional mold base parts, and then use Pro/ENGINEER Wildfire's Assembly module assembles three-dimensional mold parts together according to the mutual assembly relationship between mold parts.

4. Conclusion

This article uses the Plastic Advisor module to simulate the filling of plastic gears and optimize the process parameters: (1) Using the Plastic Advisor module to simulate the injection molding of gears, you can visually observe the flow of plastic melt, the filling state of the part, the change of injection pressure, the change of temperature, the location of weld marks and bubbles. (2) The optimal number of gates, injection temperature and mold temperature are determined by setting different gate numbers, injection temperature and mold temperature. (3) According to the simulation results, the 3D gear injection mold was designed using the mold design module of Pro/ENGINEER Wildfire, and the
parameterized design was realized, which is convenient for the modification of the mold structure and the gear parts to achieve linkage, and the mold design is more reasonable and accurate. Unnecessary repetition in mold design shortens the mold design cycle and improves mold design efficiency.

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