

Design and Manufacturing Process of Plastic Injection Mold

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Abstract- One of the most common methods in producing plastic products is injection molding for many purposes ranging from a daily product to high-tech equipment. This paper is to display how to design a complete mold and to examine the material, forecast the possible defects, and optimize the design to achieve the maximum outcome of the products with minimum cycle time in each production cycle. The CAD/CAM software is applied as the analysis tool for the particular chosen product “Clothes-hanger”. In this paper, it will describe the behavior of plastic material starting from the filling phase until the end of the cooling phase in the injection process. The final result shows the possibility of having cavity designs of “Clothes-hanger” in one mold plate of the size 330mm×458mm×53mm.

Index Terms- Mold design, filling phase, cooling phase, Clothes-hanger, CAD/CAM software

I. INTRODUCTION

Injection molding is commonly used for manufacturing a variety of parts from the smallest components to entire body panels of cars[1]. This technique has developed from the production of the simple things like combs and buttons to major consumer, bottle cups, clothes-hanger and outdoor furniture [5]. The mold design for injection molding has developed a very critical aspect to achieve the optimum use of a mold plate [1]. In this time and condition, injection molding simulation software is the right tool to be incorporated in the mold process. It is that helps the mold designer and mold maker to get the maximum output of a mold plate for a certain product design [6]. The “Clothes-hanger” product is designed by using CAD/CAM software. In this paper, manufacture process have been proposed which can make medium carbon steel injection mold. This mold is built by using CNC milling machine.

II. DESIGN CONSIDERATION OF AN INJECTION MOLD

The choice of material to build a mold is mainly one of economics. Gates are a transition zone between the runner system and the cavity. The great importance is location of gate for the properties and appearance of the finished part. The runner is various for distribution of thermo plastic melt form the machine nozzle to the cavities. The sprue bushing and runners must be as short as possible to ensure limited.

Cooling system is very important to remove efficiently and dissipate the heat of the molding rapidly and uniformly. For efficient molding, the temperature of the mold must be controlled and this is done by passing a fluid through a correct arranged channel in the mold.

A number of several cooling channel schemes or layouts are usually used in injection molding. Cooling channels layout must be reasonable. When the wall thickness of the part is uniform, the distance of each channel to the surface of parts should be level. The injection mold cooling channel can be closer to the part to improve the cooling effect when the thickness wall areas need more cooling. The Fourier number is

$$F_0 = \frac{kt}{\rho C_p X_m^2}$$

Where F_0 = Fourier number, k = thermal conductivity, t = time, ρ = melt density, C_p = heat capacity, X_m = the distance from the surface to the center.

$$\frac{T_m - T_0}{T_i - T_0}$$

Where T_m = mid plane temperature, T_i = the initial temperature of the material, T_0 = the suddenly imposed surface temperature.

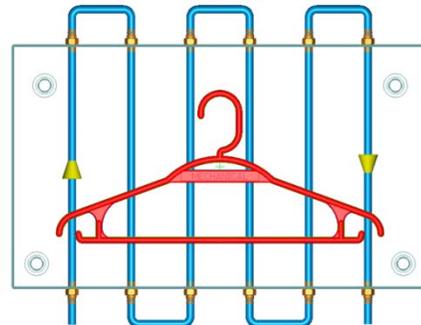


Figure1. Cooling Line Layout

Venting system is the process of removing trapped air from the closed mold and volatile gases from the processed molten plastic. The mold can be corrosion if inadequate venting.

III. INJECTION MOLD DESIGN

In an injection molding machine of Polypropylene are molded per hour:
Melting plastic temperature: $m^{\circ} = 20$ kg/hr
Mold surface temperature: $T_1 = 180^{\circ}\text{C}$ (entering)
 $T_2 = 40^{\circ}\text{C}$ (cooling water)

Temperature of the mold is not to exceed 5°C
 Polypropylene Heat Capacity: $C_p = 2200 \text{ J/kg}^\circ\text{C}$
 Liquid of Heat Capacity: $C_p = 4182 \text{ J/kg}^\circ\text{C}$
 Heat of Fusion: $\Delta H_f = 210000 \text{ J/kg}$

This is a straightforward application of the first law of thermodynamics that is the principle of conservation of energy. The heat for coming off the solidifying plastic in the mold must be taken away by the water.

$$Q_{\text{plastic}} = Q_{\text{water}}$$

The heat removed from the plastic is equal to the heat given off as the plastic temperature drops from 180°C to 40°C plus the heat of solidification which is equal to the heat of fusion but opposite in sign. As the plastic solidifies and the molecules stop moving randomly, heat is liberated.

$$Q_{\text{plastic}} = m^\circ C_p \Delta T + m^\circ \Delta H_f$$

$$= 20 \frac{\text{kg}}{\text{hr}} \times \frac{1\text{hr}}{3600\text{s}} \times 2200 \frac{\text{J}}{\text{kg}^\circ\text{C}} \times (180^\circ\text{C} - 40^\circ\text{C}) + 20 \frac{\text{kg}}{\text{hr}} \times \frac{1\text{hr}}{3600\text{s}} \times 210000 \frac{\text{J}}{\text{kg}}$$

$$= 2877.77 \text{ J/s}$$

The heat taken up by the water undergoing a 5°C temperature change is

$$Q_{\text{water}} = m^\circ C_p \Delta T$$

$$Q_{\text{plastic}} = m^\circ C_p \Delta T$$

$$m^\circ = \frac{Q_{\text{plastic}}}{C_p \Delta T} = \frac{2877.77 \text{ J/s}}{4182 \frac{\text{J}}{\text{kg}^\circ\text{C}} \times (40 - 5)^\circ\text{C}} = 19.6609 \times 10^{-3} \text{ kg/s}$$

Therefore:

$$m^\circ = 19.6609 \times 10^{-3} \text{ kg/s} \times \frac{3600\text{s}}{1\text{hr}} = 70.779 \text{ kg/hr}$$

The amount of water required to cool the plastic and keep the mold at 40°C,

$$m^\circ = 70.779 \text{ kg/hr}$$

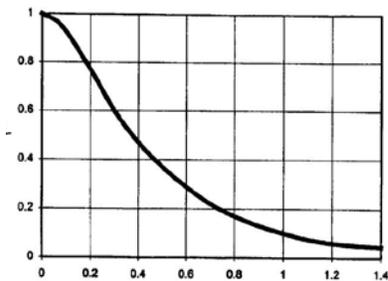


Figure 2. Flow Chart Time for Solidification of Plastic

At Polypropylene plate,

The initial temperature of the material: $T_i = 180^\circ\text{C}$

The suddenly imposed surface temperature: $T_o = 40^\circ\text{C}$

Mid plane temperature: $T_m = 90^\circ\text{C}$

The distance from the surface to the center: $X_m = 8\text{mm}$
 $= 8/2$
 $= 4 \times 10^{-3} \text{ m}$

Fourier Number, $f_0 = \frac{kt}{\rho C_p X_m^2}$ is the dimensionless Fourier number, and t represents time and X the distance from the surface to the center.

From figure 2,

$$\frac{T_m - T_o}{T_i - T_o} = \frac{90 - 40}{180 - 40} = 0.43$$

Therefore,

$$f_0 = 0.39$$

Thermal conductivity: $k = 0.18 \text{ w/m}^\circ\text{C}$

Melt density: $\rho = 730 \text{ kg/m}^3$
 Heat capacity: $C_p = 2200 \text{ J/kg}^\circ\text{C}$

$$t = \frac{f_0 \rho C_p X_m^2}{k} = \frac{0.39 \times 730 \times 2200 \times 0.004^2}{0.18} = 55.67 \text{ seconds}$$

For the one-dimensional plane

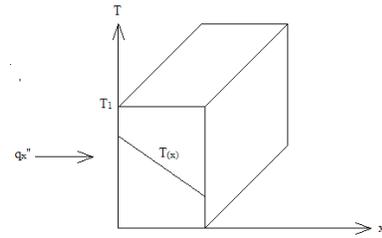


Figure 3. One-dimensional heat transfer conduction

The temperature distribution is linear. The temperature gradient express as,

$$\frac{dT}{dx} = \frac{T_2 - T_1}{L}$$

The heat flux, $q_x'' = -k \frac{T_2 - T_1}{L}$

$$q_x'' = k \frac{\Delta T}{L}$$

Normal area to the direction of the heat flow: A

Wide of temperature different: $b = L = 30\text{mm}$

Temperature difference: ΔT

Thermal conductivity: $k = 0.2 \text{ w/m}^\circ\text{C}$

$T_1 = 180^\circ\text{C}$

$T_2 = 40^\circ\text{C}$

$$q_x'' = k \frac{\Delta T}{L} = \frac{0.2 \frac{\text{w}}{\text{m}^\circ\text{C}} \times (180 - 40)^\circ\text{C}}{30 \times 10^{-3} \text{ m}} = 933 \text{ W/m}^2$$

IV. MOLD MANUFACTURING PROCESS AND SIMULATION RESULT

In this section, the mold manufacturing process must be able to execute directly from a CAD model. In order for this process to be completely automated are:

- Desire the mold cavity with CAM software
- Cutting Tools selection
- Fixture (location supporting, clamping surface, stability and fixture element function)
- Calibration for tools off-set setting and work-piece setting
- Generating Machine Tool paths using Master CAM

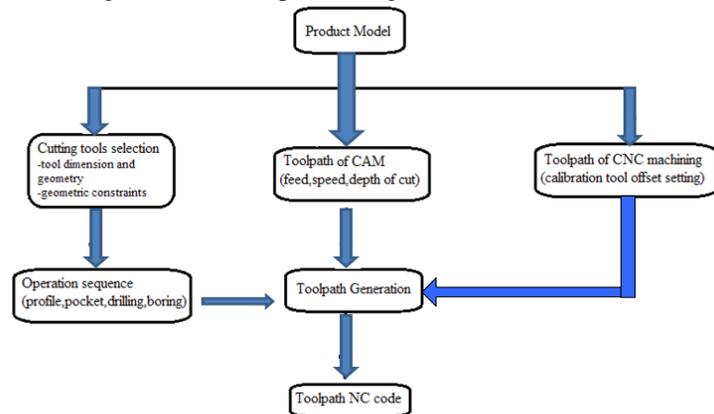
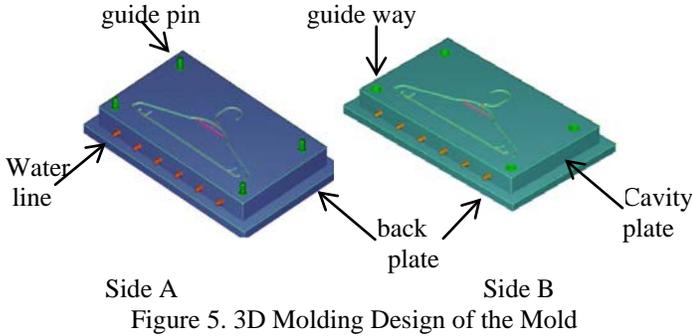


Figure 4. Process Planning Operation in Manufacturing Process

A rectangle single cavity (Clothes-hanger) mold have two half which in Side-A have guide pin and cavity plate, in Side-B have guide bush, cavity plate and injection port. Design for the cavity is handled in two different ways: the size of the part and the size of the mold. The creation of the core and cavity design from the part geometry can be automated by using solid modeling program.



Side A Side B
 Figure 5. 3D Molding Design of the Mold

The following describes each of option on the way down the path to machining.

- Area to machine
- Strategy
- Raster Angle
- Allowance
- Tolerance

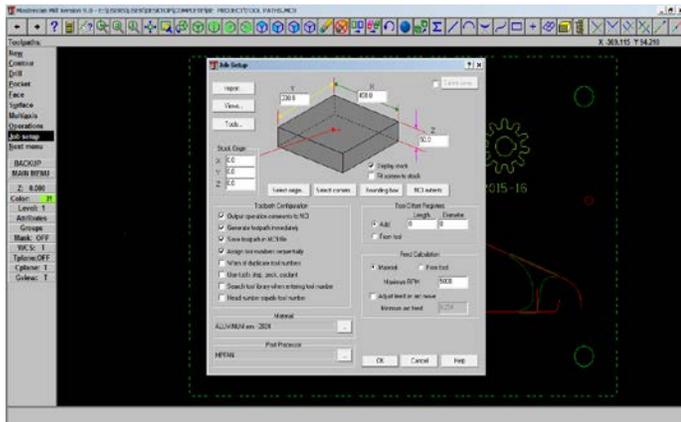


Figure 6. Job set-up Parameter

The Z-heights of the first and last passes establish the starting depth (relative to the 0, 0, 0 point established), and the ending depth of passes. The number of passes in between is calculated based upon the tool's Step Down setting- the distance that the tool will step downward for each new pass. This is set in the tool definition window.

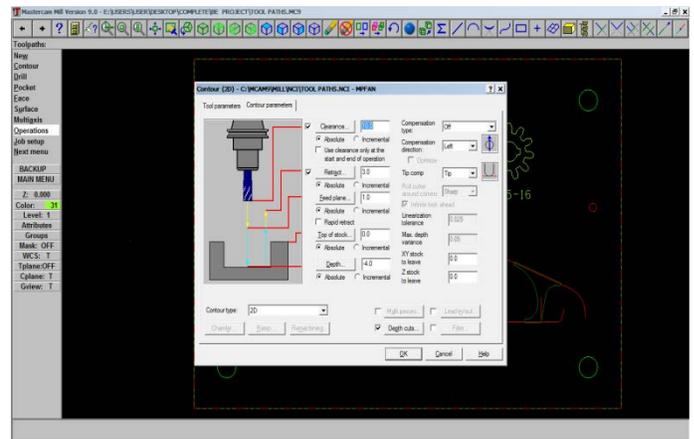


Figure 7. Tool Parameter

This mold is machined by using End mill tool (1/4 inch) and slot drill.

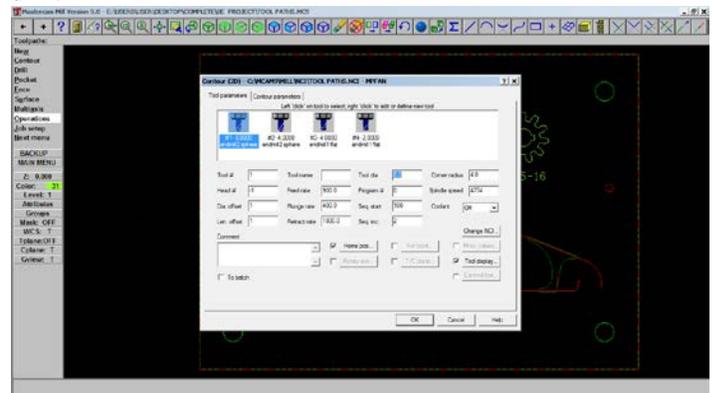


Figure 8. Operation Parameter

The result is that a series of paths traversing the surface of the material, stepping over and stepping down successively to cut away the material. Tool paths are shown graphically on screen in red, and will be written out in code during Posting.

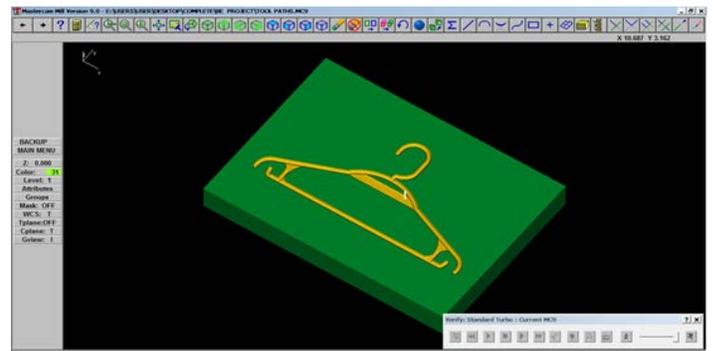


Figure 9. Verify Process

Posting is to be enabling the Milling or Routing machine to actually cut these tool paths out of the material physically, the machining instructions of the tool paths must be sent out to the machine as a coded set of machine instructions called G&M codes.

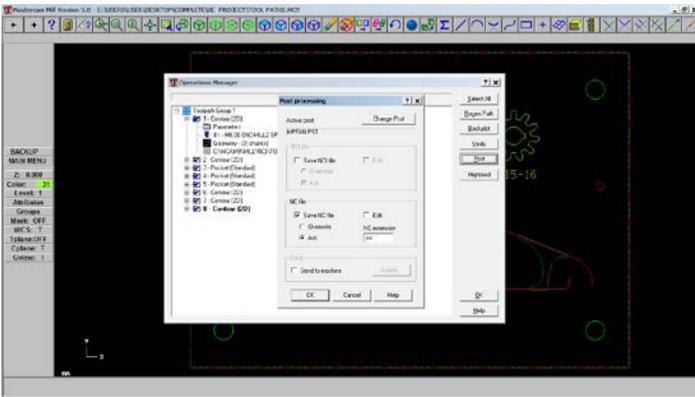


Figure 10. Post processing

V. CONCLUSION

Design and manufacturing process of plastic injection mold (“Clothes-hanger”) was designed in this paper. Many steps of mold making, most of which are very exacting work requiring highly skilled mold makers. The function of cooling system of a plastic injection mold is to provide thermal regulation in the injection molding process. And then efficient cooling is very important to the productivity to the process. Selecting tool holders and cutting tools is another important step in planning a CNC program. Jig and fixture is to be utilized by the selection of tools in correct position with respect the workpiece.

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