

3-dimensional Injection Molding Simulation

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INTRODUCTION

3D injection molding CAE holds the key to complete a digital engineering system for plastics. 3D TIMON, developed and distributed in Japan by TORAY Industries, Inc., immediately creates mesh models from 3D CAD data; the only software available in the market to analyze whole injection molding process. 3D TIMON is characterized in terms of various analytical functions designed for 3D molded parts, such as plastic lenses, automotive parts with insert-objects. [1]

Accuracy of numerical analysis is indispensable because 3D injection molding CAE is now applied to design a mold without any trial productions or to set up mass-production conditions in a short time.

In this paper, some attempts to improve numerical analysis accuracy of 3D injection molding simulation are discussed.

EXPERIMENTAL

The schematic diagram illustrates a mold and position of three sensors for pressure measurements in Fig.1. The injection molding machine is FANUC ROBOSHOT 100iA, which exactly controls screw motion and pressure at the load cell. The number of resins for the experiments is 38 in total.

Due to the pressure profile data shown in Fig.2, the effects with each part (ex. sprue, runner, and product) are estimated for the pressure loss. Nearly 70% of the pressure loss in the mold with pin-gate (gate 0.8mm) is caused by the sprue and runner parts.

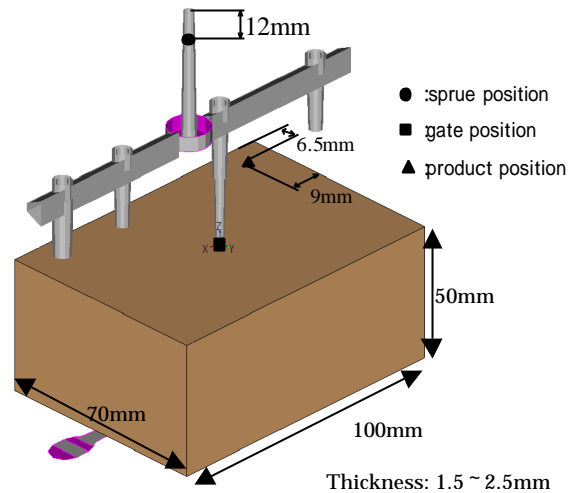


Fig.1 Experimental mold and Pressure sensor position

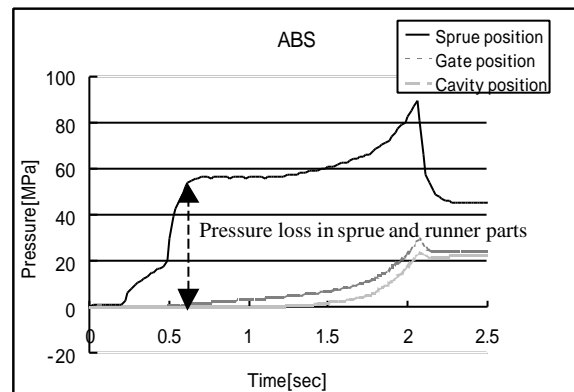


Fig.2 Experimental data of pressure profile per 8msec

THEORY AND MODELING

In injection molding CAE, non-isothermal incompressible filling analysis is treated on the assumption of non-Newtonian fluid considering the dependence of temperature and shear rate. Fundamental equations are as follows:

$$\frac{\partial P}{\partial X_i} = \mathbf{h} \frac{\partial^2 U_i}{\partial X_i \partial X_j} \quad (1)$$

$$\text{div} U = 0 \quad (2)$$

$$\mathbf{r} C_p \left(\frac{\partial T}{\partial t} + U_i \frac{\partial T}{\partial X_i} \right) = \mathbf{l} \frac{\partial^2 T}{\partial X_i^2} + \mathbf{h} \mathbf{g}^2 \quad (3)$$

$$\mathbf{h} = A \dot{\gamma}^B \exp(\mathbf{C}T) \quad (4)$$

where P is pressure, U is flow velocity, ρ is viscosity, ρ is density, Cp is specific heat, T is temperature, k is heat conductivity, $\dot{\gamma}$ is the shear rate, A, B, and C is the viscosity coefficients.

In analytical models, product parts are usually modeled by solid elements, but both sprue and runner parts are usually modeled by beam elements in order to shorten analysis time. In order to acquire the injection pressure accurately from nozzle touch part to filling end; it is particularly important to improve analytical accuracy in each of sprue, runner, gate, and product parts.

Improvements of the numerical analysis for accuracy are as follows:

- 1) Temperature and viscosity are calculated in 20 layers toward radial direction at a node on beam elements.
- 2) Average values of temperature and viscosity in fluidized layer at a gate node on beam elements are applied to a gate node on the solid elements because a node on solid elements has only mono-layer calculation point.

3D analytical model is shown in Fig.3.

RESULT AND DISCUSSION

The comparison of pressure profiles between simulation and experiment is shown in Fig.4 (ABS) and Fig.5 (POM).

3D injection molding simulation with those attempts to improve the numerical analysis accuracy shows very good agreement with experimental results of various resins. Multi-layer calculation in beam elements contributes to improvement of pressure loss prediction in sprue and runner parts. The treatment in a gate node helps to improve pressure loss prediction in products near gates.

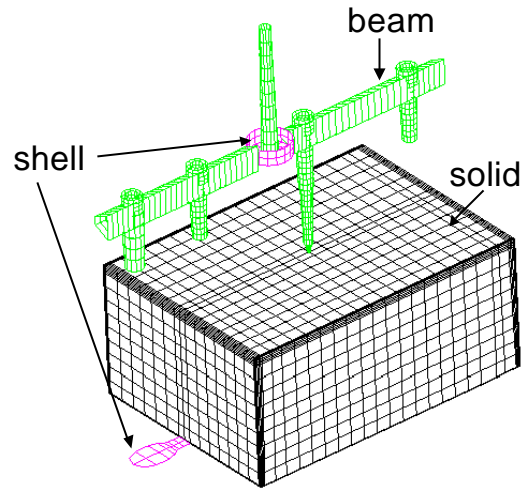


Fig.3 Mesh model of box (Element: 5904, Node: 7598)

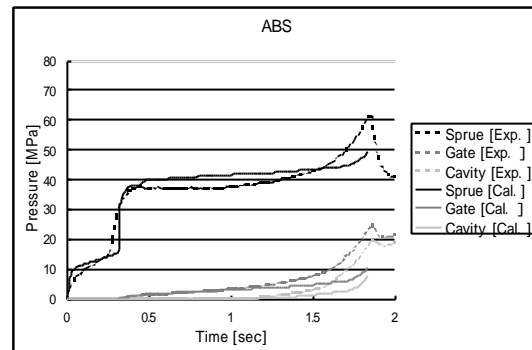


Fig.4 Analysis result compared with experiment data of pressure profiles (ABS: resin temp. 230, mold temp. 60)

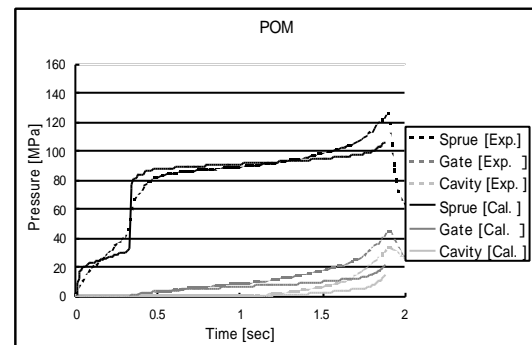


Fig.5 Analysis result compared with experiment data of pressure profiles (POM: resin temp. 200, mold temp. 70)

REFERENCES

1. R.Nakano, T.Tanaka. : *Proc. of 14rd Annual Meeting, The Polymer Processing Society*, 321 (1998)