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The influence of input data on the results of injection molding process simulation

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Abstract: Computer analysis of the filling, packing and cooling phases of injection molding process requires data on the process conditions, physical properties of the plastic material and the material from which the mold is constructed. Some results of the numerical simulation of the injection molding process, using different input data for a processed plastic, were presented. The professional computer program Moldflow Plastics Insight ver. 4.1 included in the I-DEAS NX11 package, developed by the EDS Company, was used for calculations.

Keywords: CAE, Plastics injection simulation, Moldflow

1. INTRODUCTION

The analyses require accurate material-property data to generate the best predictions. Obtaining quality data is critical. Simulation results can be only as good as the material-property data used. To use a computer simulation of any engineering process, it is important to provide accurate information about material behavior under the conditions encountered during processing, such as temperature, shear rate, pressure, or cooling rate. Standard procedures can be provided to measure these properties under some ideal conditions. It is impractical (and, fortunately, unnecessary) to perform the measurements under all circumstances. Instead, it is more reasonable to find a good model that describes the material behavior under the conditions of interest. Such models can be derived from scientific principles or from semi-empirical rules. The model constants can be determined from limited experiments, then used to describe material behavior under other conditions.

Modeling material behavior in the field of polymer processing has never been an easy task, for several reasons:

- Material properties often vary from batch to batch (or from time to time).
- Using regrind or recycled materials can affect behavior during processing.
- It is difficult to measure properties at the high temperatures, shear rates, pressures and cooling rates typical of actual processes.
- Material behavior varies with changing conditions. For example, the temperature sensitivity of melt viscosity depends on shear rate as well as temperature.

Typical properties required for thermoplastics injection molding process simulation are:

- In the melt state: thermodynamic properties (density, heat capacity) and transport properties (rheological properties and thermal conductivity of the molten state).
- In the solid state: mechanical properties.

Polymer rheology is the most important property used in flow simulations. Most polymers exhibit two regimes of flow behavior, Newtonian and shear-thinning. Newtonian flow occurs at low shear rates, but with increasing shear, the viscosity tends to fall away in what is termed shear-thinning behavior. Viscosity also decreases with increasing temperature.

To incorporate the dependence of melt viscosity on shear rate, temperature, and pressure, the following 5-constant (n, τ^*, B, T_b, β), Cross-exp model is adequate for simulating the filling stage in injection molding [1]:

$$\eta(T,\dot{\gamma},p)=\frac{\eta_0(T,p)}{1+\left(\frac{\eta_0\dot{\gamma}}{\tau^*}\right)^{1-n}} \tag{1}$$

with

$$\eta_0(T,p)=B\exp\left(\frac{T_b}{T}\right)\exp(\beta\cdot p) \tag{2}$$

The Cross-exp model treats polymer viscosity as a function of temperature T and shear rate $\dot{\gamma}$. It handles both the newtonian and the shear-thinning flow regions found in polymer rheology.

To extend the modeling into the post-filling stage, it is more appropriate to employ the following 7-constant (n, τ^*, T^*, $D1$, $D2$, $D3$, $A1$, $\tilde{A}$), Cross-WLF model, which still represents the shear-thinning behavior according to equation (1), but replaces equation (2) with a more extensive model based on the WLF [2] functional form:

$$\eta_0(T,p)=D1\cdot\exp\left[-\frac{A1(T-T^*)}{A2+(T-T^*)}\right] \tag{3}$$

where:

$$T^*=D1+D3p \quad \text{and} \quad A2=\tilde{A}+D3p \tag{4}$$

T^* is a reference temperature and is typically taken as the glass-transition temperature of the material. That is, $D2$ corresponds to the glass-transition temperature at low pressure (such as 1 atm), whereas $D3$ characterizes the linear pressure dependence of $T^*(p)$.

2. EXAMPLE

The influence of the input data on the injection molding simulation results has been presented. An example of the influence of the proper rheological model parameter selection on the results of numerical analysis is presented.

As an example the effect of changing of the parameter D1 of Cross-WFL model on the pressure plot in the mold has been shown (Fig.1 and 2).

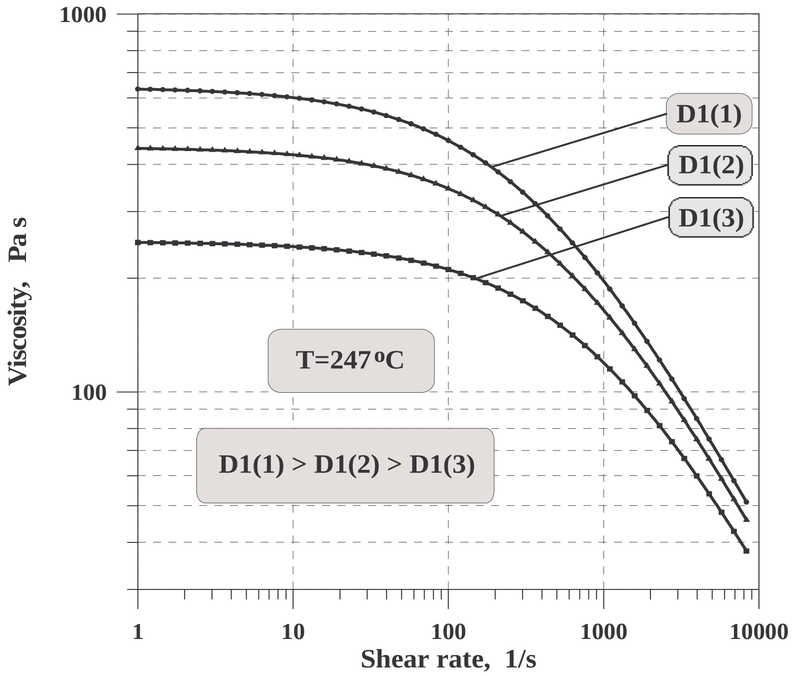

Figure 1. The effect of changing of theparameter D1 of Cross-WFL model on the flow cur

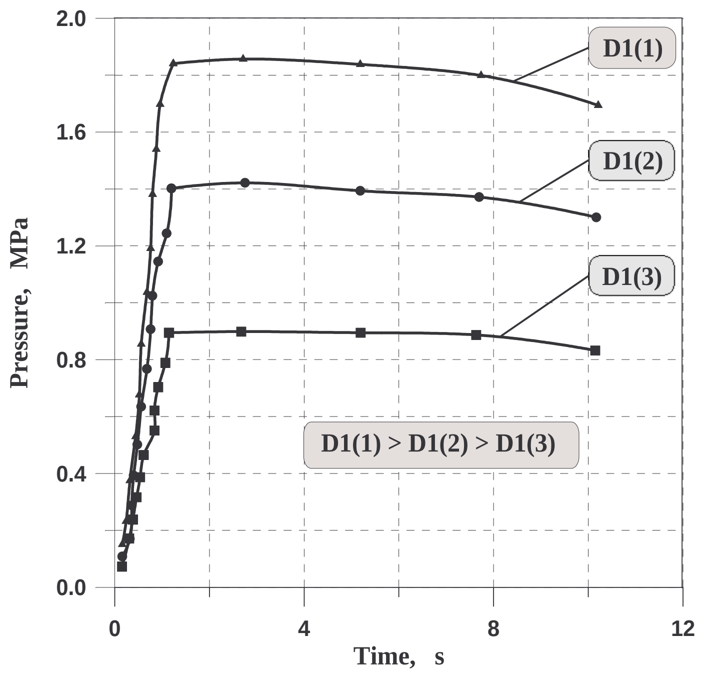

Figure 2. The effect of changing of theparameter D1 of Cross-WFL model on the pressure plot in the mold

The full text of the paper contains more detailed description of the problem.

3. CONCLUSIONS

Numerical analysis allows to draw the following conclusions:

- accuracy of determination of the plastic rheological model parameters has the essential influence on the results of simulation,
- results of the above experiments confirm that the conditions of plastic rheological properties testing must be standardized.

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