

# Simulation of Injection Molding Process

MICHAL STANEK, DAVID MANAS, MIROSLAV MANAS, JAKUB JAVORIK

Tomas Bata University in Zlin  
nam. T.G. Masaryka 5555, 76001 Zlin  
CZECH REPUBLIC  
stanek@ft.utb.cz <http://www.utb.cz>

**Abstract:** Simulation analyses of plastics injection molding are a tool for increasing the quality of plastic products and tools, equipment used for shortening the time necessary for preparation of new products for the market and hence leading to lowering production costs. The simulation analyses are nowadays commonly used for production of thermoplastic parts. This article stresses on the fact that injection molding of rubber compounds could be from the calculation purposes analysed already in the constructive phase during the preparation of the production to achieve positive assets, till now related only to the thermoplastic parts.

**Key-Words:** rubber, injection molding, simulation, compound, process, mold, polymer

## 1 Introduction

Polymer injection molding is the most used technology of polymer processing nowadays. It enables the manufacture of final products, which do not require any further operations. Injection molding reduces the time required for curing; eliminates the need to preform the rubber prior to molding; reduces the amount of mold handling and scrap in comparison with compression molding. On the other hand it is very sophisticated and complicated process. For its simulation could be used special software. One of them is Cadmould Rubber.

Cadmould Rubber is the software generally called Computer Aided Engineering (CAE). It calculates the filling time, speed and vulcanization time in the mold and consequent after-curing depending on the material used and technological parameters. One of the most important outputs is, besides the representation of filling progress (weld lines, places where air bubbles may be held), the representation of pressure and voltage ratios in the component and determination of optimum technology. The technological parameters during rubber processing have crucial impact on the final quality of the product; simultaneously it is possible to project adequate period of the production cycle which may lead to significant savings. Original and patented calculative FEM net is worth mentioning, automatically prepared by Cadmould Rubber software, its features likened to complex 3D FEM nets, however enabling markedly faster calculations even though the thinnest walls are in their thickness divided into 25 calculation knots. This feature allows a very precise analysis having the possibility

to carry out range of control calculations. Cadmould Rubber enables designing different profiles of the runner system including the possibility of cold runners. It is possible to calculate multiple and compound molds, eventually apply the function of entering symmetrical cavities shortening the time needed for simulation calculations.

## 2 Enter Data for the Simulation

### 2.1 Part Design

The basic file format used by the Cadmould Rubber analysis is the STL. The part design to be simulated is converted into this format. STL is the default document for automatic net formation of the final elements. Even though the simulation software uses very good correction features, it is beneficial – also, besides other, due to the calculating times – to use STL file without crucial mistakes for the analysis, especially without gaps and without immersed false constructions. In most of the CAD software, the features used for creation of good transfer are of STL format. Nevertheless, not only the Cadmould software users, who do not have any CAD software, benefit from the software for creations and corrections of STL format, for instance 3Data Expert for STL, produced by DeskArtes. Fig. 1 shows an example of STL construction of a rubber part – Insulator – and automatically processed calculating net. A denser calculating net is created on the places of wall connection on the corresponding surfaces for more effective evaluation of potential sink marks.

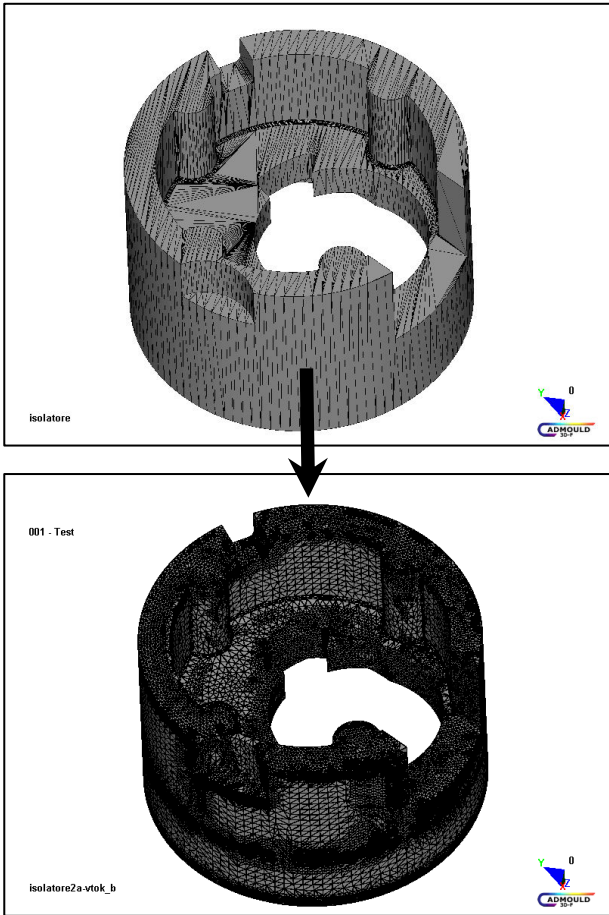


Fig. 1 STL model and calculating net Cadmould 3D-F of the insulator component

### 2.2. Runner System Design

With respect to the requirements of the customer, the user may create (according to his experience or template) runner system directly in Cadmould Rubber. It has got prepared smart constructive tools for this purpose.

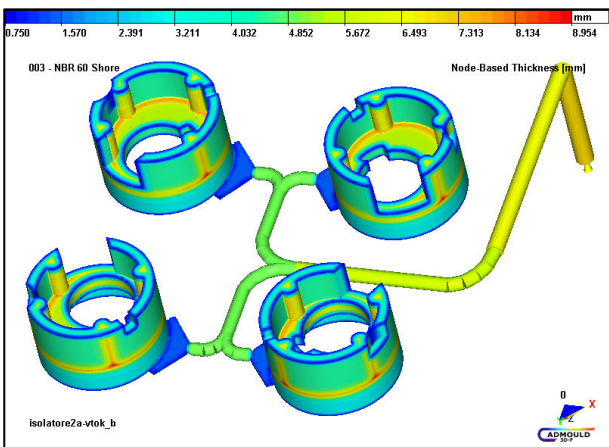


Fig. 2 Runner system for 4 shaping cavities

In case the runners are already designed in CAD, they may be saved as axis in IGES format and transferred to calculating software. The program user easily “wraps” the axis by canals of required diameter. An example of runner system for 4 shaping cavities is shown in Fig. 2.

### 2.3 Part Material

It is necessary to enter the exact rubber type from the material database Cadmould Rubber into the simulation calculations, which is editable by the user. However, it is beneficial to know approximate material data essential for the calculations. As it was told, rubber compound consist of different additives and different quantities, therefore each compound is the "original" and they have differences at flow characteristics and its behavior. These properties can be measured for example by Rubber Process Analyzer (RPA 2000). The amount sample of compounds should be approximately 100 g. These prepared samples of rubber compound which weighs about 5 g is placed into the measuring device and is closed by force 15 kN. Top and bottom side of the injection mold are heated with accuracy  $\pm 0.3$  °C.

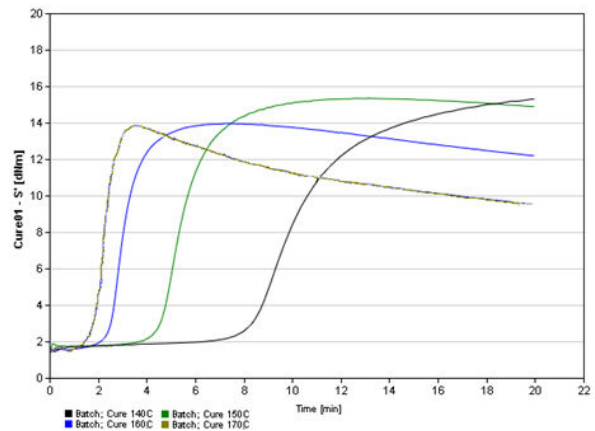


Fig. 3 Cure rate for different temperatures

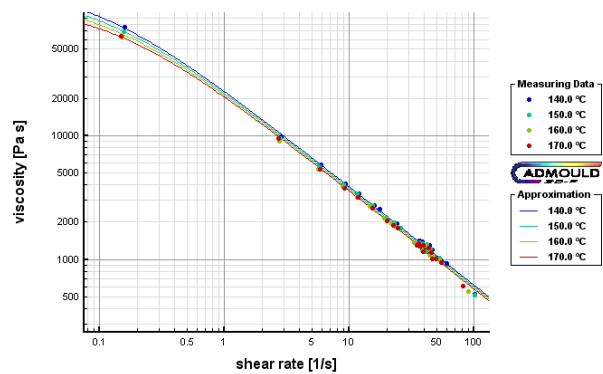


Fig. 4 Viscosity for different temperatures

The rubber compound contained vulcanization system is used for measuring the curing characteristics (Fig. 3) and without the vulcanization system is used for measuring the complex dynamic viscosity (Fig. 4).

These data are processed and imported to Cadmould Rubber program, where the analysis of injection molding process can be done now with real material.

#### 2.4. Technological Parameters of the Process

The determination of technological parameters is one of the outputs of the Cadmould Rubber simulation analyses. It is necessary to enter the whole estimated data for the first calculation to take place. These data are specified in the following calculations. It is however possible to input variations of chosen technological data and carry out automatic optimization of the technology in cases where is difficult to make prediction.

Overview of technological data:

- filling time,
- temperature of the injected material (preset value),
- mold temperature (preset value) – temperature spread on the shaping cavities surface area may be calculated using the Cadmould Cool software,
- cure time, eventually min. and max. percentage of vulcanized bonds,
- surrounding temperature (preset value),
- temperature transfer coefficient (preset value),
- after-curing time outside the mould, eventually min. and max. percentage of vulcanized bonds.

### 3. Some Results of Cadmould Rubber Calculations

Cadmould Rubber software offers many figures and graphical and table results, which may help the user analyse entered task. The results are available also in 3D cuts and animations. Some of them are stated below.

#### 3.1 Filling Progress, Filling Pressure and Material Temperature

Figure 4 shows the filling phase progress. Filling progress analysis can determine the position of weld lines, places liable to trapped air, places filled the last, places with incorrect filling progress etc. There

is possible to observing the injection pressure in each moment of cavity filling. The example is shown on Fig. 5. Average temperature of the material in wall thickness at the time = 208 s of the curing time is shown on Fig. 7.

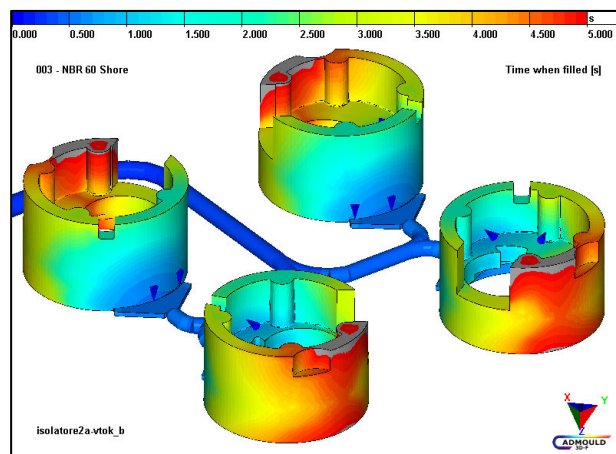


Fig. 4 Time progress of filling, state at 99.1% shaping cavity filling

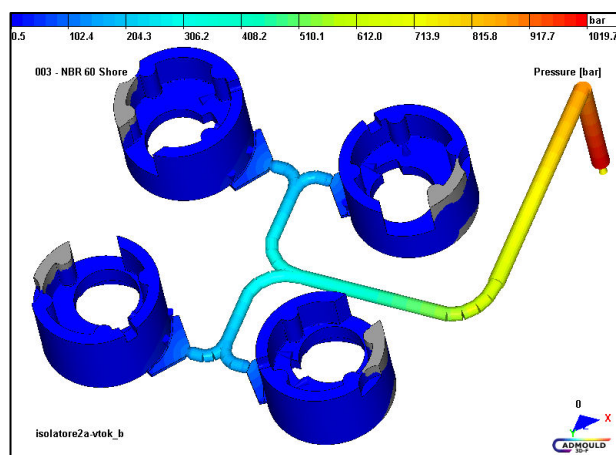


Fig. 5 Filling pressure, state at 98% shaping cavity filling

#### 3.2 Scorch

The scorch expresses above all time period during which the rubber mixture may be injected into the shaping cavities. Max. scorch = max. drop of filling safety: values related to the end of the filling time – Fig. 6.

Scorch time progress in the most crucial places of the shaping cavity (here the minimal scorch = minim safety drop time progress). Middle value of scorch time progress at the chosen point in the shape – Fig. 8.

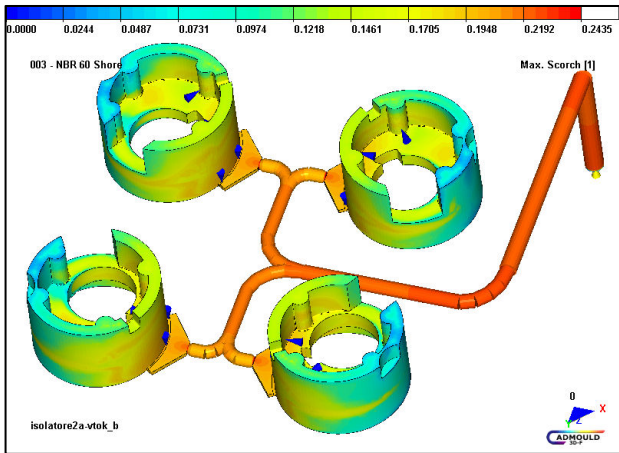


Fig. 6 Maximal scorch at the end of filling time

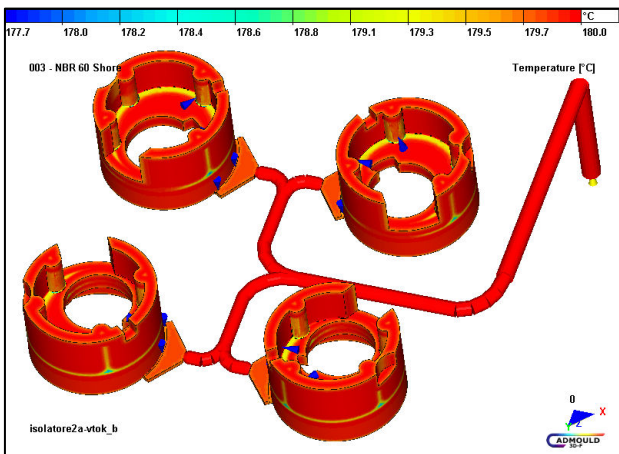


Fig. 7 Temperature of the material in 208 s with cure time

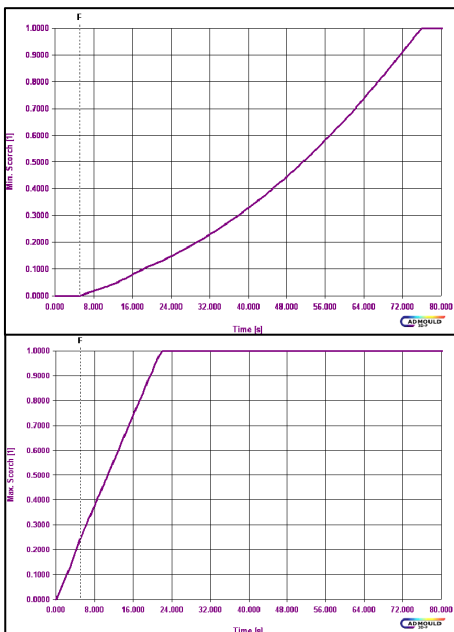


Fig. 8 Time progress of scorch of rubber compound – min. and max. scorch

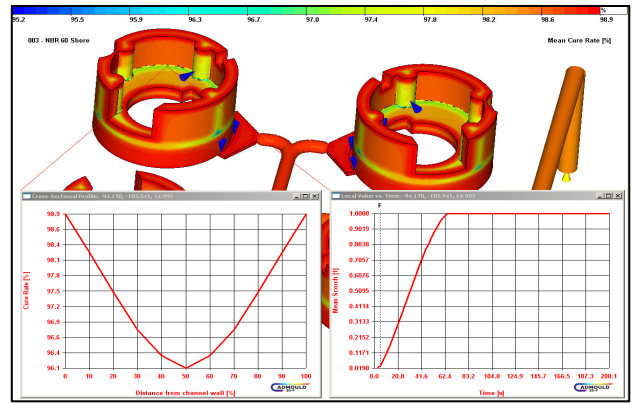


Fig. 9 Cure rate expressed by middle % of vulcanized bonds in 208 s, % vulcanized bonds in the wall thickness and time progress in the middle safety value at the selected spot

#### 4. Conclusion

The simulation analysis Cadmould Rubber represents quality and interesting calculation tool which may increase the quality of injected rubber parts, cut the costs connected to the mold repair and accelerate the preparations of new productions especially new tool design. It is evident from the experience with the situation analyses that it is better to analyze than try and repair.

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