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TEMPERATURE MONITORING DURING INJECTION MOLDING PROCESS

Raz, K.; Chval, Z.

Abstract: *The article deals with possibilities of modern advanced simulation methods for determining the basic principles in mechanical system thermal flow.*
Main aim of the article is to create comprehensive image about temperature changes of mechanical system. This paper uses results of experimental measurement and also results from advanced simulations using finite element method.
The result is a recommendation for temperature verification and comparing of approaches for the temperature determination. All analyses are performed on the example of injection molding process.
Key words: injection molding, temperature, thermal simulation, plastics

1. INTRODUCTION

Injection molding is nowadays an important manufacturing process and it is used to produce plastic parts due to low costs and production times.
During production process, plastic granules are fed to the machine through a hopper. The granules are forced against the wall of the barrel by a screw and melt due both friction heat generated and the conduction from the heating units along the barrel. The molten material is transferred to the tip of the screw and pressured against nozzle. This stage of process is called the plastification stage. Then the injection stage begins. It is characterized by the following four phases- filling, packing, cooling and ejecting.
Mold, as a main part of molding machine, has two parts into which the plastic material is injected. Surfaces of mold are precisely machined and they are forming the final shape.
One of the most important parameters during this process is mold temperature.
Generally, mold temperature is in range from 25 to 65 degrees Celsius. These values are highly material-dependent. Decreasing of mold temperature leads to higher time of filling and also higher production time. Also resultant parameters, such as shear stress and cooling time are dependent on mold temperature.
According this knowledge is important to know exact temperature. In real process is temperature measured using thermal sensors, but this is only in one place. During process is mold heated from previous operations we should know this starting temperature distribution in cavity of mold [1,2,3].

2. EXPERIMANTAL DEVICE

For our experiment was used injection molding press Babyplast (Fig. 1).
During injection process was used high density polyethylene HDPE Unipetrol Liten ML with melting temperature 220°C. On Fig. 2 is visible one half of mold, on which will be temperature monitored. Control systems of injection molding press are evaluating mold temperature as one constant temperature inside whole mold. As is visible on following simulations and measurements, temperature is not constant and values on control panel can be much lower than real temperature in mold cavity.

Fig. 1. Experimental injection molding device

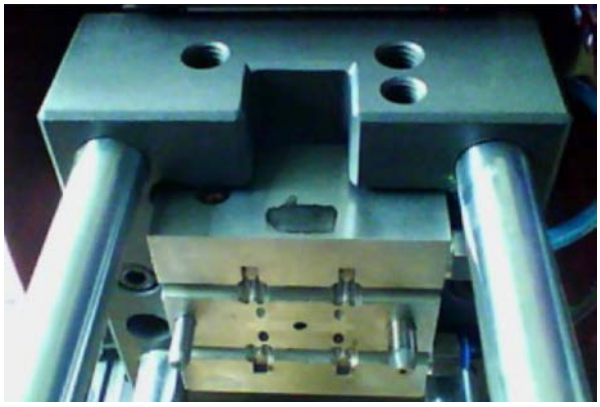

Fig. 2. View into one half of mold

3. TEMPERATURE MEASUREMENT

For getting exact values of temperature can be used different approaches. Each has advantages and disadvantages. In production process is important during starting production to get temperature and changing molding press parameters according these values.

3.1 Experimental measurement with thermographic camera

Modern approach is using of thermographic camera. We used Flir E6 device for measuring. Thermographic camera is device for quick measurement. Results are pictures with resolutions 160 x 120 pixels.
Problem with using this is in necessity to look on the surface. So it is not possible to get temperature when mold is closed. Using this method is possible to get values on visible surface mold, but temperature is affected by reflections of shiny parts.

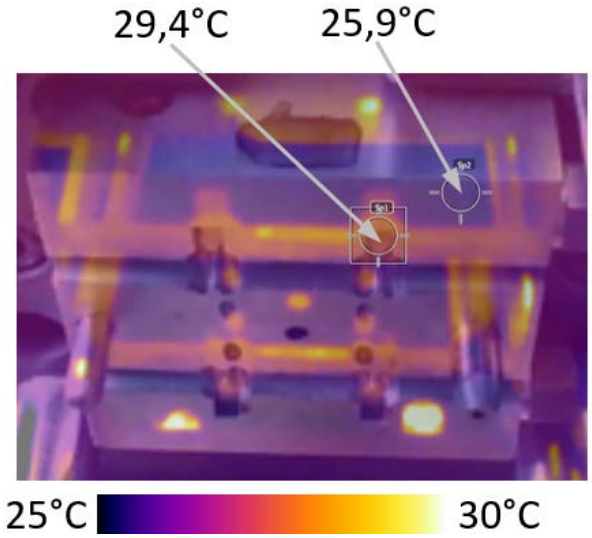

Fig. 3. View from thermographic camera

3.2 Virtual simulation of molding process

Fast method is using finite element method for simulations. There are more possibilities for that.

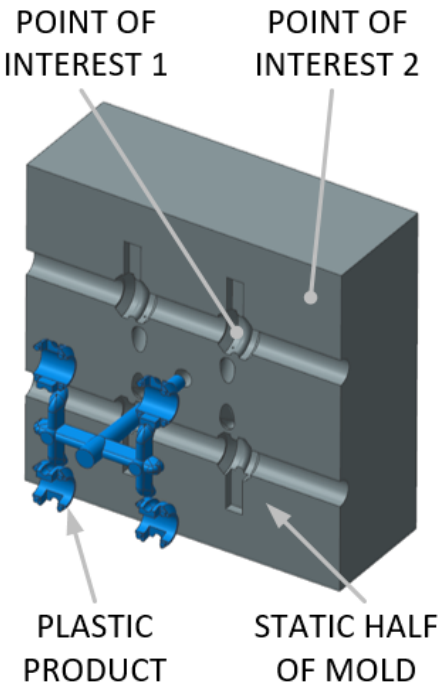

Fig. 4. CAD model used for FEM simulations

For virtual simulation was used precise model according Fig. 4. For companies are FEM simulations good chances for getting results in short time. On the other side, the cost of simulation software is relatively high.

Simulation using Moldex 3D

Moldex 3D is a commercial software for simulation of plastics injection process. For image about temperature in mold can be used temperature of part in time of ejection. This can be used only as a really coarse view on temperature because temperatures of mold and plastic part are not same, but at time of ejection are closer to each other [4].
This method is not suitable for getting temperature of mold, because of these problems.

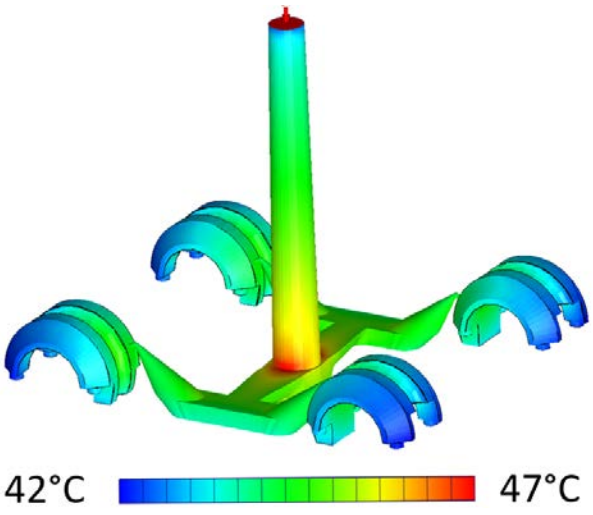

Fig. 4. Temperature of plastic part at the time of ejection

Simulation using NX Nastran

NX Nastran is one of the most complex simulation software used worldwide. For our problem was used advanced thermal solver with transient setup.
Initial conditions were 22 °C temperature of mold material and 220 °C of plastic.

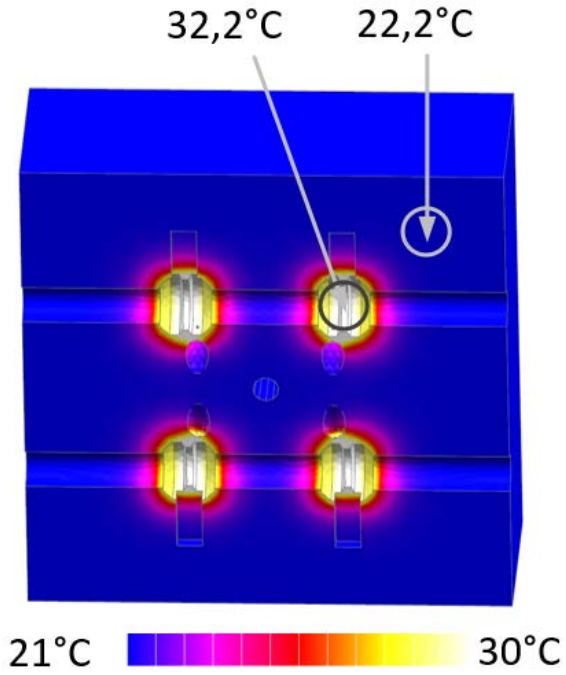

Fig. 5. Temperature distribution on one half of mold

Simulation shows us higher range of temperatures comparing with real measurement.
Biggest problem in this kind of simulation are values of heat transfer coefficients [5]. It is really hard to get exact values and it is absolutely necessary to perform their experimental determination. In our case were used default values in NX Nastran material library [6].

4. CONCLUSION

According results from our simulations and real measurements is obvious that mold temperature is not constant on surfaces of mold cavity and sprue.
Influence of mold temperature on quality of product is not so significant, comparing with parameters such as injection pressure, packing time, clamping force or injection temperature.
But influence of mold temperature should not be neglected. In following table (Table 1.) are values from different approaches.

Approach	Lowest temperature (°C)	Highest temperature (°C)
Thermo-camera	25,9	29,4
Injection simulation	42	47
Thermal simulation	22,2	32,2

Table 1. Table of temperatures

There are more possibilities how to get temperature results. Difference between them is significant.

- Using temperatures from injection process simulation has problem with not considering mesh and temperature distribution in mold. Other simulation modules have possibility to identify mold temperature, but are expensive.
- Real measurement with thermographic camera is accurate, but cannot be used during injection process and error caused by time delay of measurement is not possible to neglect.
- Results from simulation software such as NX Nastran are accurate, but highly heat transfer coefficients-depended.
- Using of thermal sensors inside mold is the most accurate method, but number of these sensors in mold geometry is limited and they cannot show us temperature distribution in whole cavity.

The most suitable option for measuring of mold temperature is in combination of methods mentioned above. It means creating a simulation, validating it by measurement at some specific points and then temperature controlling using thermal sensors in these points. Next step in this area of research should be creating an experiment for validation thermal FEM simulations.

5. ADDITIONAL DATA ABOUT AUTHORS

Ing. Karel Raz, Ph.D., researcher,
Regional Technological Institute,
University of West Bohemia, Univerzitni 8, Plzen, 306 14, Czech Republic.
Email: kraz@rti.zcu.cz.
Tel: +420 377 638 751.

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