Optimization of Injection Molding Process by MPX

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Abstract: Optimization of injection molding process serves for finding ideal conditions during production of plastic parts and observing their dimensions, shapes and properties. It is possible to determine the appropriate injection pressure, velocity, value and time of packing pressure, etc. by optimization. The paper is dealing with description of MoldflowPlastics Xpert (MPX) system and its usage in optimization of injection molding process on real part during its production.

Key-Words: Injection molding, Optimization, Process, Polymer, MPX, Production, Part, Defect

1 Introduction

Injection molding represents the most important process for manufacturing plastic parts. It is suitable for mass producing articles, since raw material can be converted into a molding by a single procedure. In most cases finishing operations are not necessary. An important advantage of injection molding is that with it we can make complex geometries in one production step in an automated process. The injection molding technique has to meet the ever increasing demand for a high quality product (in terms of both consumption properties and geometry) that is still economically priced. This is feasible only if the molder can adequately control the whole molding process, if the configuration of the molded part is adapted to the characteristics of the molding polymer material and the respective conversion technique, and the mold which satisfies the requirements for reproducible dimensional accuracy and surface quality is available. Typical injection moldings can be found everywhere in daily life; examples include toys, automotive parts, micro parts, household articles and consumer electronic goods.

2 Moldflow Plastics Xpert system

Moldflow Plastics Xpert (MPX) is a software and hardware solution that interfaces directly with injection molding machine controllers on the shop floor. MPX combines process setup, real-time process optimization, and production control according to set process parameters in one system. MPX is an advanced control solution for the automatic setup, optimization and monitoring of the process window of an injection molding machine. Unlike other control solutions, MPX can utilize the advanced simulation capabilities of Autodesk Moldflow Advisers (AMA) and Autodesk Moldflow Insight (AMI) software to provide an initial process configuration. MPX interfaces directly with the injection molding machine and provides on-line process correction with technology developed exclusively for the plastics injection molding industry. Nowadays, molding machine operators can consistently and systematically set up the process, perform an automated DOE (design of experiments) to determine a robust processing window, and automatically correct the process whether it should be drifted or go out of control during production.

The optimization process consists of three main parts: process setup, process optimization and process control.

Process setup allows users to automate the setup of the injection molding process through a series of velocity and pressure-phase setup routines designed to fix molded part defects systematically. The objective is to achieve a combination of processing parameters which results in one good molded part.

Process pptimization easily allows users to run an automated design of experiments (DOE) to determine a robust, “good parts” processing window that will compensate for normal process variation and ensure that acceptable quality parts are produced consistently.

Process control is designed to maintain the optimized processing conditions determined with Process Optimization, resulting in reduced reject rates, higher part quality, and more efficient use of machine time. Process Control can automatically correct the process – either be drifted or go out of

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control and also can send relay signals to alarm operators or to divert suspect parts.

2.1 Process setup (setup wizard)

Setup Wizard automatically calculates initial profiles based on tool or machine related parameters. Tender can choose from three Setup Wizard methods:

Automated Setup - calculates initial profiles based on the material and the values operator enters for velocity stroke/injection volume, part thickness and mold layout. Operator can also calculate the optimal temperature, screw rotation, and back pressure settings for plastication.

Assisted Setup - creates initial profiles using the values operator enters for velocity stroke, injection velocity, packing pressure, and cooling time.

Manual Setup - creates initial profiles using the values you enter for velocity stroke, injection velocity, packing pressure, and cooling time. Velocity stroke, injection velocity and packing pressure must be entered as a percentage of the maximum machine capability.

To use the Setup Wizard, operators need to provide some initial information on molding parameters or machine parameters, depending on the option they select. The Setup Wizard then calculates the initial velocity and pressure profile based on this information. The Setup Wizard makes initial adjustments to stroke length and cushion size to ensure a full shot and adequate cushion, and then develops a basic, un-optimized profile, which can be further refined with MPX Process Setup. Operators can also calculate the optimal temperature, screw rotation, and back pressure settings for plastication.

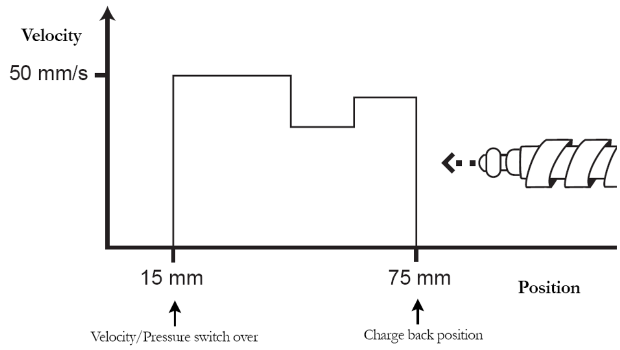

Fig.1 Velocity profile example

2.2 Process optimization

The purpose of MPX Process Optimization is to establish a robust processing window that produces acceptable quality parts while minimizing scrap. This is done by carrying out an automated Design of Experiment (DOE) that previously took many hours that can now be done in a few minutes.

The MPX Process Optimization DOE produces a series of parts using many different profiles. The amount by which the profiles are altered is determined by producing a number of parts and measuring how the part quality varies with the processing conditions. MPX Process Optimization then moves the profile set points so that they are positioned in the most robust position in the process window. With the tolerance boundaries of the process window known, the profile set points can be modified if they occur outside those boundaries. This means that the process is able to handle changes in small variables better, such as raw material variability and ambient temperature. Additionally, the process can be monitored so that the specifications for the DOE parameters are maintained. During production, the processing conditions will vary slightly. With a good set of profiles, these small changes do not affect part quality. MPX Process Optimization uses a Design of Experiment (DOE) to ensure that typical process fluctuations do not affect part quality, by finding a window of processing conditions for which good parts will be produced. DOE gets involved using a series of different profiles, which can be derived from MPX Process Setup profiles or directly from the Profile Wizard. Each profile is changed by a small amount. The operator creates a series of parts with these profiles, and records which of the parts have defects. MPX Process Optimization uses this information to adjust the profiles that were generated by MPX Process Setup, so that the profiles are positioned in the most robust position in the process window (Fig. 2.).

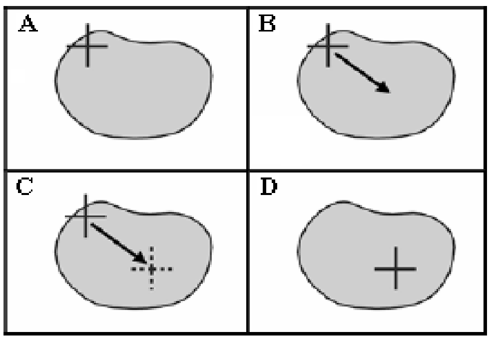

Fig. 2 The process window

It is possible to eliminate any combination of visual, dimension, warpage and weight defects using MPX Process Optimization. Different processing conditions are systematically varied, depending on the chosen DOE settings.

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2.3 Process control

MPX Process Control helps to maintain optimal machine operating conditions during production. MPX Process Control graphically monitors variables specific to the injection molding process (Fig. 3.) and automatically determines acceptable quality control limits. Once a robust set of processing conditions has been established, it is possible to use MPX Process Control to monitor the critical parameters that define the profiles during production. MPX Process Control detects any tendency of the process to drift away from the center of the window. It can then produce a warning with recommendations for corrective action or it can make corrections, depending on the cause of the drift. MPX Process Control detects any tendency of the process to drift away from the center of the window. It can then produce a warning with recommendations for corrective action or it can make corrections, depending on the cause of the drift.

MPX Process Control has two main roles. It displays control charts of process parameters monitoring any changes that occur. Control charts are a great benefit to process engineers who want to know when and why part quality varies. For example, examination of the control charts may reveal steadily decreasing controller performance, an indicator that maintenance may be due. Alternatively, the material, tool, or environment variation may cause the process change. It can also automatically fine tune injection molding machine set points to compensate for any changes in process parameters. This ensures that gradual changes in processing conditions do not lead to bad parts or injection molding machine damage.

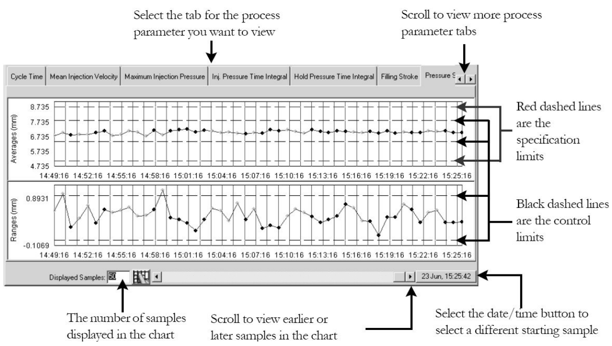

Fig. 3 Viewing the control charts

3 Injection molding process optimization

The next chapters describe the injection molding process optimization procedure. The description will be shown on real chosen part usage MPX software and hardware directly connected to the injection molding machine Arburg Allrounder 420 C.

3.1 Injection molded part – electrotechnical cover

The eight-cavity injection mold was used for production of the molded part (cover – Fig. 4.). The cover is a plastic part used in electrotechnical industry. The basic dimensions of the part are: (39x15x16) mm. The material of the product is PP (polypropylene) and its properties are described in Table 1.

Table 1 Properties of injected material (PP)

Solid density	891,63 kg/m3
Elastic modulus	1340 MPa
Melt flow index	21 g/10min
Shrinkage	1,3 %
Recommended processing	
Mold temperature	40°C
Melt temperature	240°C
Ejection temperature	101°C

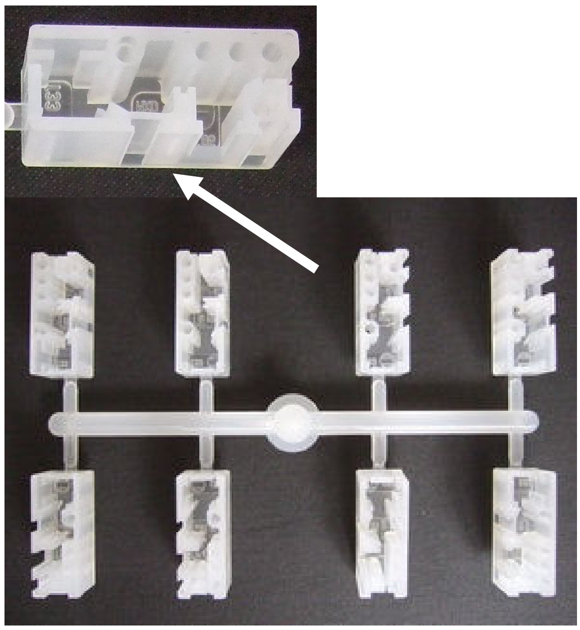

Fig. 4 Injection molded part – cover

3.2 Process settings taken from AMI analysis

Injection molding process of the cover has been analyzed in Autodesk Moldflow Inside (AMI) software. The values (example on Fig 5) taken from this analysis have been used for comparison with

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optimized values and for upload to MPX software for next part of process optimization.

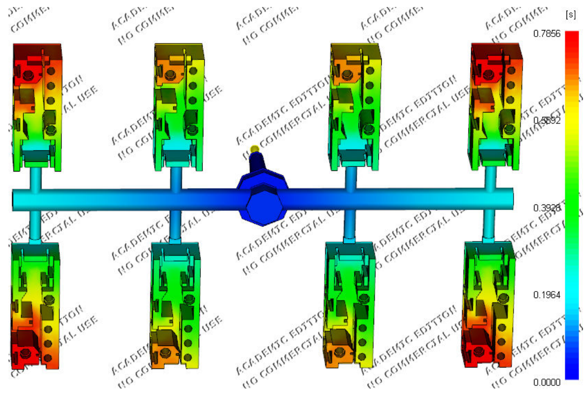

Fig. 5 Fill time – 0,7856s

3.3 Optimization of injection molding process

Cooling of the injection mold has been made by circulating water with temperature of 40°C. Temperatures of the heating zones are described in Table 2.

Table 2 Temperatures of heating zones

Heating Zone	1 – Feed	2 – Transition	3 – Metering	4 – Nozzle
Temperature [°C]	205	210	220	230

3.3.1 Manual setup

Table 3 Manual setup – results

	Initial Profile	Final Profile	Difference
Velocity [mm/s]	67	75	
Displacement (start - end) [mm]	18,1 - 90,6	47,7 - 90,6	
Pressure [bar]	1060	160	
Fill Time [s]	1,09	0,57	-0,52
Packing Pressure Time [s]	6,43	6,43	0,00
Cooling Time [s]	15	10,39	-4,61
Total Time [s]	22,52	17,39	-5,13

The initial and optimized velocity and pressure profiles are shown on the next figures (Fig. 6 and 7).

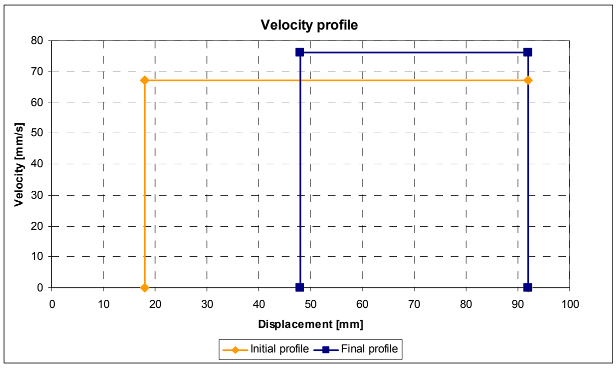

Fig. 6 Velocity profile – manual setup

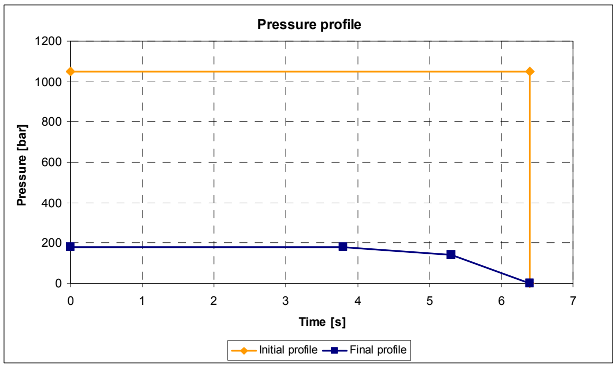

Fig. 7 Pressure profile – manual setup

3.3.2 Data from AMI analysis

Data for this optimization has been obtained directly from the AMI simulation by the special file format (*.fpo) including all process settings and material characteristic.

Table 4 Data from AMI analysis – results

	Initial Profile	Final Profile	Difference
Velocity [mm/s]	56	100	
Displacement (start - end) [mm]	10,4 – 52,0	24,7 – 62,9	
Pressure [bar]	130	187	
Fill Time [s]	0,74	0,38	-0,36
Packing Pressure Time [s]	67,08	14,95	-52,13
Cooling Time [s]	212,42	11,63	-200,79
Total Time [s]	280,24	26,96	-253,28

The initial and optimized velocity and pressure profiles are shown on the next figures (Fig. 8 and 9).

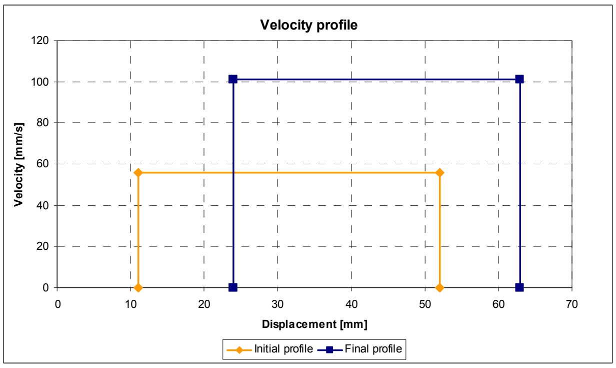

Fig. 8 Velocity profile

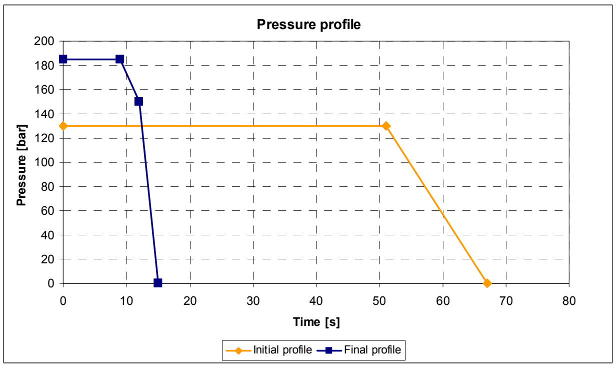

Fig. 9 Pressure profile

3.5 Some defects on part appeared during optimization

Different defect have been on the parts during the optimization process. Examples are shown on the next figures.

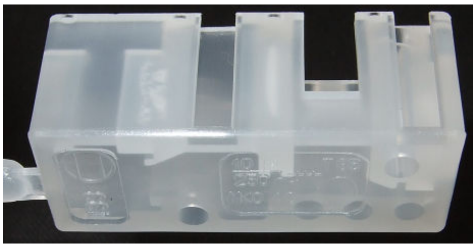

Fig. 10. Defects on part – voiding marks

Fig. 11 Defects on part – sink marks (right)

The defects appeared on part should be simply defined to the system by the picture menu or typing the value into dial box.

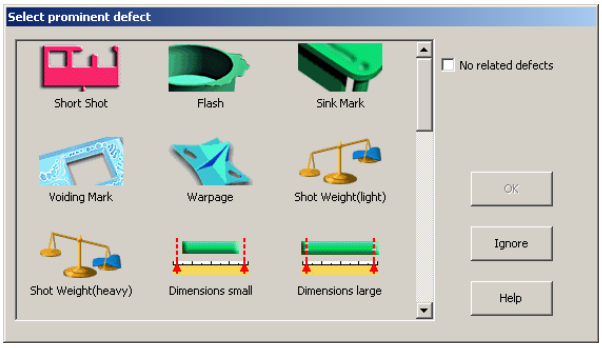

Fig. 12 Menu for defects selection

4 Conclusion

This work deals with optimization of injection molding cycle and using software MPX. The MPX system enables very effective optimization of the injecting process and ensures optimum process parameters leading to eliminating possible product defects. The aim of optimization is not only correct process conditions setting and eliminating all defects made during production, but also minimizing the total time of the injecting cycle which has a great economical impact.

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