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ANALYSIS OF THE SWITCHOVER POINT AND DIE TEMPERATURE INFLUENCE ON INJECTION TIME WITH USING CAD-CAE SYSTEMS

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ABSTRACT: The article deals with the fundamental characteristic and application possibilities of CAD-CAE systems in pre-production stages of parts produced by molding technology. The injection molding ranks among manufacturing methods where it is necessary at designs to accept various constructional demands but also possibilities of the technology. At the design of the product it is possible to hold the demands by using suitable software products enabling effective creating the model also following various factors.
KEYWORDS: Injection molding, die temperature, switchover point, injection time

❖ INJECTION MOLDING TECHNOLOGY

The injection molding technology ranks at the sometime among the most wide-spread Technologies of manufacturing parts and products from plastics. The principle of the technology is founded other thermal transformation of plastic from granulation on melting, transporting it into the front part of the injection chamber at effecting high temperature and pressure and following injection into cavity of the closed die. The melding is cooled here and thrower out as the ready product.

Development, economical effect and quality of plastic products of this technology put considerable pretensions not only on the level of fundamental knots of the injection machine but also on the level of snap, regulation, registration control and programming decisive quantities (temperatures, pressure, time and ways) that connect immediately with the quality of products. [6,7] The injection is a cyclical process with the average time of cycle at thermoplastics in the interval from 10 up to 120 seconds. The time of the cycle depends on properties of a polymer and a greatness of the product. From the technological point of view it is possible to divide it into the following phases:

1. Closing the die,
2. Injection,
3. Tighting pressure,
4. Cooling of the product,
5. Plastification and the back motion of the threading machine,
6. Ejecting of the product.

Simulate softwares are controlled and optimized means for disclosing places of possible occurrence of manufacturing or functional problems. They enable to users the simulation of technological processes and following removal of defects. It satisfactory with regard to production and function. It is possible to design formable and technologically right plastic parts with the support of computer simulation. Modelling or simulation of technological process allows realizing the experiments beside the real object, without actual interference into working. The most of effort in the computer simulation of the injection process is concentrated on the phases 2 up to 4. The process is limited by physical properties, plastic properties and geometrical complexness of the die. It is possible to divide the injection into four parts: (1) filling melting into the cavity of the die, (2) the phase of the tighting pressure for lowering shrinking and dimension changes in course of cooling, (3) cooling melting till it does not come to solidifying, (4) throeing out the final product from the die. During filling, repressing and cooling it comes in the material to thermomechanical processes that lead to local changes of material volume. After ejecting the product from the die the immediate unquable anisotropical shrinking sets. It results in rising gentle deformation [5]. Analysis brings shortening manufacturing cycle, increase of use and appearance properties of plastic parts.

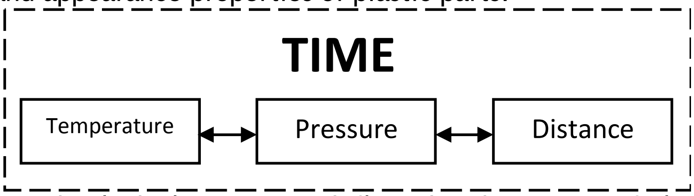


Figure 1. Main technological parameters influencing the process of plastics injection

- temperature – various temperatures, from melting temperature up to die temperature including surroundings temperature influence on the injection process,
- pressure – two elements that demand pressure and its regulation: injection and closing unit are situated on injection machine. They connect narrowly together,
- time – during the injection process many internal activities course. Some activities are parallel with the others, other activities must wait till the preceding activity completes. The time of cycle enables to obtain the precise picture how long a manufacture of product lasts,
- distance - regulation of distance is decisive for production of high quality products for reasonable price.

CAD - CAE SYSTEMS UTILIZED IN REGION OF PRODUCTS DESIGN THAT ARE PRODUCED BY TECHNOLOGY OF PLASTICS INJECTION

The systems CAD (Computer Aided Design) [3] are marked as means for graphical, geometrical and mathematical modelling parts and their properties. These systems enable to create not only double spacious (area) curves and objects but also triple spacious areas and bodies. A basis of work is interactive method of modelling on shapes and sizes of the designed product. Beside graphic activities CAD systems enable to realize also various engineer calculations and analysis.

Systems CAE (Computer Aided Engineering) busy with analysis of geometrical data obtained during the design in CAD system, that enables to simulate and study a behaviour of the designed products so, that their properties are at supposed working conditions optimum [1, 3]. From this it influences that simulated modules CAE are narrowly connected with project modules CAD and sometimes it is only hard discernible it that modules belong into CAD and that ones into CAE systems. Software packets CAE present the products for testing, analysis and simulation of designed objects properties. It enables to constructors to follow the object in the simulated limit situations and already during construction cycle so to eliminate faults in the product. The result is a possibility of product property optimization but first of all time and means saving and in final consequence it is the contribution for production ecology [2].

EXPERIMENTAL ANALYSIS

The object of simulation is the following the relation among the choice parameters influencing resultant quality of products produced by technology of plastics injection. The simulation was realized with use of the programme Autodesk Moldflow where the relation between the change of the switch over point value and the change of temperature. The programme Autodesk Moldflow ranks among the products of firm Autodesk, offers efficient detail simulations of the most advanced processes of plastic parts injection and dies creation with use of the largest global database of plastics. It enables a study of injection processes used at present and it grants the deep simulation and optimization of plastics parts production and dies connecting with them. It offers a possibility to simulate besides other also phases of filling and moulding. So it is reached a better idea of behaving melted plastic, it is gone before rising wasters owing to shrinkage and deformation of part and a products quality is raised by it. It is enabled also on the basis of model analysis to determine the most suitable placing a gate.

Before performing simulation it was necessary to create the part model that presents the complex geometry representing current products manufactured by the technology of plastics injection. The programme Pro/ ENGINEER was utilized for creation of the injected part model. Modelling in the system Pro/ Engineer enables the creation of the model in the form solid in the 3D modelling environment that at formation model utilizes the possibilities of direct graphical manipulation what enables quicker and more dynamic work. The solid models of the system Pro/ Engineer are geometric models offering qualities of modelled object as mass, volume, surface area, inertia and likewise.

The simulation was created according to the matrix in table 1 for gradual growth of temperature at simultaneous growth of the switch over point. The result is the creation of complex description for the relation between temperature, the switch over point and the resulting time of simulation. For the simulation the material Polystyrol 495 F was choice for that parameters of injection were chosen on the basis of the programme recommendation. The selection of the gate place was realized by utilizing the software analysis. Its results are illustrated in figure 2.

After performing analysis the programme divided a volume of the product model into some phases by a gate placing convenience. The region A (blue colour) represents the most suitable space for the gate placing, the region B (green colour) is suitable for the placing partly only as at the gate placing in this region it can come to lowering the resulting product quality. The last zone is the region C (red colour) that represents the least suitable space for the gate placing. On the basis of this analysis the gate was situated into the region A.

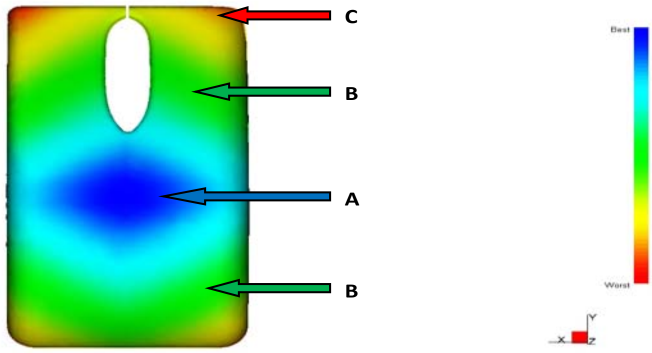


Figure 2. Analysis of the gate placing

Table 1. Inlet values of the switch over point and die temperature

Change of the switch over point value										
93	93.25	93.5	93.75	94	94.25	94.5	94.75	95		
Change of temperature for every value of the switch over point										
210	212.5	215	217.5	220	222.5	225	227.5	230	232.5	235

The results of the simulation were worked into table and graphical shape. In table 2 resulting values of injection cycle time at the switch over point value change and the temperature change.

Table 2. Resulting values of the injection times in dependence on the switch over point value change and the temperature change (fields with unsatisfying products are represented by grey color).

Time of injection		Change of temperature										
		210	212.5	215	217.5	220	222.5	225	227.5	230	232.5	235
Change of the switch over point value		9.53	9.45	9.37	9.43	9.30	9.16	9.00	9.00	8.98	8.98	8.98
	93.25	9.53	9.45	9.37	9.39	9.30	9.16	8.99	8.98	8.98	8.98	8.97
	93.50	9.68	9.48	9.45	9.39	9.17	9.12	8.98	8.98	8.97	8.96	8.96
	93.75	9.65	9.46	9.21	9.15	9.10	9.09	8.98	8.98	8.97	8.96	8.96
	94.00	9.65	9.46	9.21	9.15	9.03	9.02	8.97	8.96	8.96	8.95	8.96
	94.25	9.17	9.08	9.07	9.05	9.03	9.02	8.97	8.96	8.96	8.95	8.95
	94.50	9.17	9.08	9.07	9.02	9.00	8.99	8.95	8.95	8.95	8.95	8.95
	94.75	9.05	9.04	9.03	9.02	9.00	8.99	8.95	8.95	8.95	8.94	8.94
	95.00	9.02	9.01	9.00	8.99	8.98	8.97	8.95	8.95	8.94	8.94	8.94

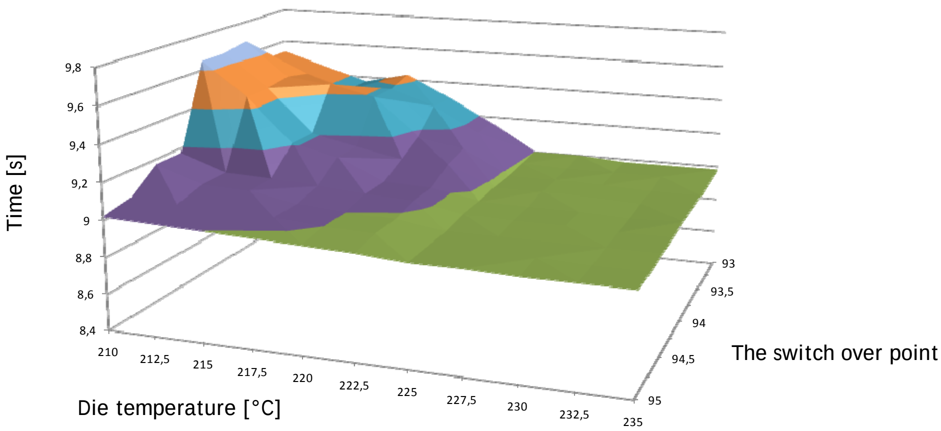
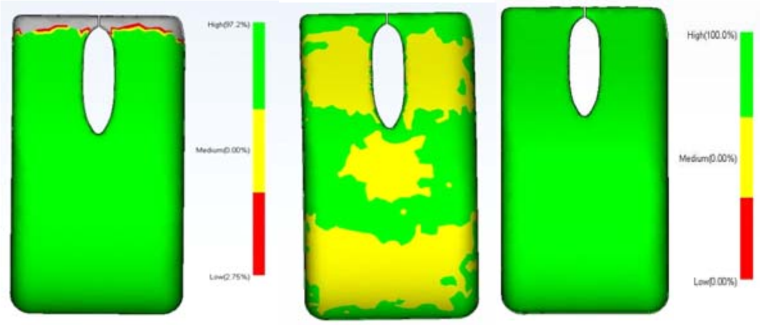


Figure 4. 3D representation of the injection time dependence on changes of the switch over point and die temperature value

After results working (figure 4) it is possible to follow shortening the cycle time at the followed increasing the switch over point value. The shortening time is positively influenced also by the growth of temperature values. From the results it is possible to follow also rise of possible uninjected products respectively products of lower quality at certain values of the determined temperature and the switch over point. At temperature 210°C the results presented unsatisfied qualities of the products (figure 5a) b)) for the switch over points in the intervals from 93% up to 94%, after increasing the switch over point value on 94.25% the result was evaluated as satisfied (figure 5c).

At increasing temperature on 212.5°C came to improvement of the results and pressings at lower value of the switch over point 93.75 present satisfying results. With the growth of temperature (at 220°C) it came to full improvement of products quality. From the results also a decrease of the injection time is clear. The cycle at higher values of temperature and the switch over point creates

94.5 % i.e. 8.94 second against the cycle time of satisfying product at lower values of temperature and the switch over point. From the standpoint of production effectiveness it is possible to consider also with lowering temperature on the value 225°C. It is a decrease 40% against maximum temperature also bringing down the value of the switch over point on 94.5. At given parameters the cycle time is stated on the value 8.95 seconds. It is 94.6% of time against the cycle time of satisfying product at lower values of temperature and the switch over point.



a) b) c)

Figure 5. The results of simulation – unsatisfying products a) uninjected product – material does not fill whole volume of the part b) the product contains parts of volume with insufficient quality c) the satisfied product fullfills the demands on quality.

❖ Conclusion

The contribution deals about application of CAD – CAE systems in the process of the parts design manufactured by the technology of plastics injection. The introduced experimental results remit on application of the software products in region of process parameters optimization at preparatory phases of process design of the concrete part injection.

They enable detail following of the output factors in dependence on changes of the inlet parameters without necessity to perform financially expensive experiments in manufacturing process. From the results submitted in this contribution it is possible to follow the dependence of time as the important factor on values of the switch over point and die temperature. Simulation enables in a great extent an expelling of unsuitable adjusting inlet parameters. The followed analysis of the results enables finding more advantageous intervals for the switch over point and temperature of die. It means theoretical shortening the cycle time on the value 94.6%.

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