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USING MULTI-OBJECTIVE EVOLUTIONARY ALGORITHMS FOR OPTIMIZATION OF THE COOLING SYSTEM IN POLYMER INJECTION MOULDING

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ABSTRACT

The cooling process in polymer injection moulding is of great importance as it has a direct impact on both productivity and product quality. In this paper a Multi-objective Optimization Genetic Algorithm, denoted as Reduced Pareto Set Genetic Algorithm with Elitism (RPSGAe), was applied to optimize both the position and the layout of the cooling channels in the injection moulding process.
The optimization model proposed in this paper is an integration of genetic algorithms and Computer-Aided Engineering, CAE, technology applied to polymer process simulations. The main goal is to implement an automatic optimization scheme capable of defining the best position and layout of the cooling channels of injection mouldings. In this work the methodology is applied to a L-shape moulding with the aim of minimizing the part warpage quantified by two different conflicting measures. The results produced have physical meaning and correspond to a successful process optimization.

DEVELOPMENT OF THE OPTIMIZATION SYSTEM

In this work a methodology integrating computer simulations of the injection moulding process, an optimization methodology based on evolutionary algorithm (EA) and multi-objective criteria is proposed. This methodology is used to establish the configurations of the cooling circuits that lead to a part with lower warpage. EAs are a class of metaheuristics based on the concepts of the natural evolutions. The selection, crossover and mutation operators are applied to the current population that evolves during the successive generations (or iterations). The initial generation of chromosomes (initial population) indicating the configurations of the cooling circuits is randomly generated within the feasible search space and evaluated by the C-MOLD modelling routine. The quality of the cooled part is quantified by the fitness function (angle deformation) of each chromosome. Then a new generation is produced though GA reproduction and re-evaluated. The process iterates until an optimal or near optimal cooling system design is found. Figure 1 shows the interface for integrating C-MOLD and the GA-based optimization routine.

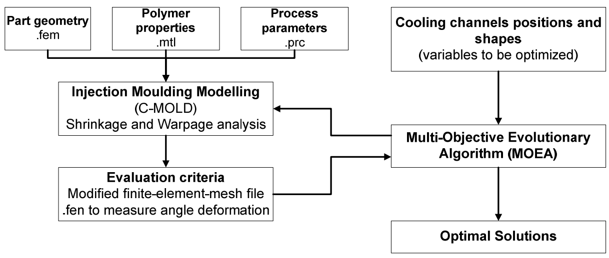

Figure 1: Interfacing optimization routine and C-MOLD software

CASE STUDY

The cooling system considered in this investigation uses cylindrical cooling channels and water as coolant fluid. The geometry is a rectangular L-shape moulding with a curved end as shown in Figure 2. The part is moulded in polystyrene, STYRON 678E, from Bayer. The cooling system was modelled by sixteen coordinates describing the locations of the two cooling channels, one in each mould side. Each location is defined by the y and z coordinates of the cooling line centre in the y-z plane and by the x coordinate describing the depth of the cooling line along the x axis (x is maintained constant along the optimization process). Another selected design variable is the cooling channel diameter.

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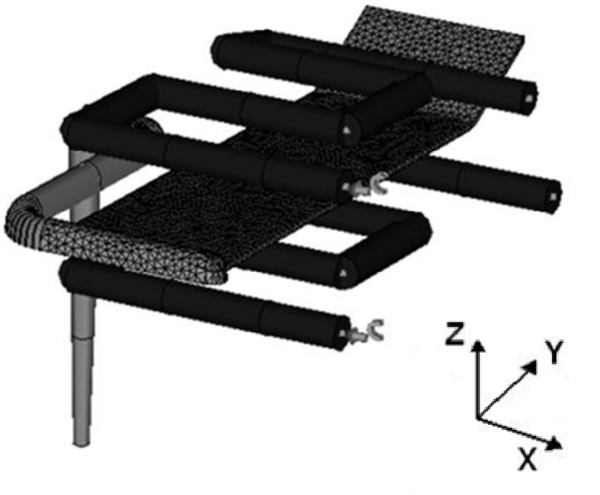

Figure 2: Moulding geometry, mesh and initial cooling system

Essentially, the optimization problem in the present investigation is to minimize the warpage of the part measured by the deformation angle and quantified using two conflicting objectives:

i) Minimize dispersion of angular measurements after moulding (θ_i) relatively to the angle of the cavity moulding (28.2 degrees);

ii) Minimize dispersion of differences $d\theta_i = 28,2 - \theta_i$, i=1,…,4, relatively to their mean value $\overline{d\theta_i}$.

The RPSGAe uses a real representation of the variables, a simulated binary crossover, a polynomial mutation and a roulette wheel selection strategy (Gaspar-Cunha and Covas 2004; Deb 2001). The RPSGAe was applied using the following parameters: 50 generations, crossover rate of 0.8, mutation rate of 0.05, internal and external populations with 200 individuals, limits of the clustering algorithm set at 0.2 and NRanks at 30. These values resulted from a carefully analysis made in a previous work (Gaspar-Cunha and Covas 2004).

RESULTS

The results obtained for the best cooling channels locations are shown in Figure 3.

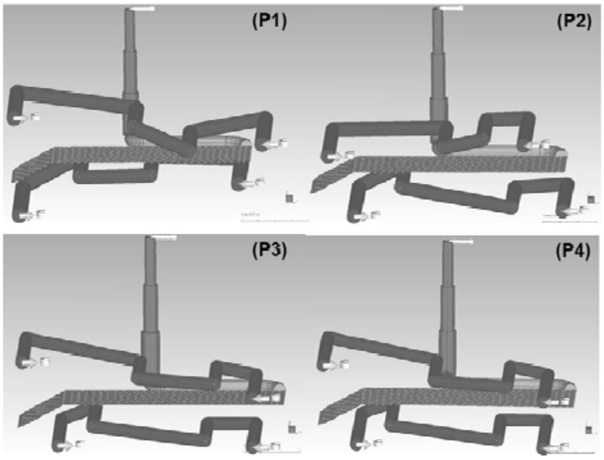

Figure 3: Optimal cooling channels designs

The upper cooling channels designs of Figure 3 represent two individuals, (P1) and (P2), of the initial generation in the multi-objective evolutionary algorithm. Their evolution along the optimization process produces the bottom solutions of Figure 3. Both points of the final population P3 and P4 have similar cooling channels layouts, and the criteria’s values determined for these two solutions are very similar too. This means that these two solutions can be considered as only one solution. Therefore, our design cooling channel optimization problem with hot runner system have a unique solution, with a cooling channel diameter of 7 mm.

CONCLUSIONS

In this work, a multi-objective optimization methodology based on Evolutionary Algorithms (MOEA) was applied to the optimization of cooling channels locations of a L-shaped rectangular moulding in order to minimize the effect of part warpage and deformation angle. The methodology proposed was able to produce results with physical meaning for optimization of cooling channels locations.

REFERENCES

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