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An example of simulation tools use for large injection moulds design: The CONTENUR^{TM} 2400 l solid waste container

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Abstract

Large containers with volumes above 1100 l are usually produced using procedures such as rotomoulding process. These techniques have no part weight or dimensional limits. T.I.I.P., injection moulding plastic group of the Department of Mechanical Engineering of the Zaragoza University, developed with CONTENUR^{TM} a new product under European norms for solid waste containers up to 2000 l volume; the result was a new main body up to 60 kg weight in one part. The design process combined several CAE tools (aesthetical design, mechanical design and rheological simulation) and, in last June, showed final result and passed different tests. Nowadays, more than 5000 samples are on the streets without basic modifications in the mould (more than 100 tonnes weight). The paper focuses on the methodology used to integrate tool and process design with product definition (i.e. injection pressure and clamp force versus thickness and part shape). Some parameters about process control in this particular mould (injection rate, temperature, viscosity, gate location, . . .) are detailed.

Keywords: CAE design; Container; Injection moulding

1. Introduction

CAE tools have constituted an authentic revolution in the last years within injection of thermoplastics. The sequential process until the final solution (including several setups such as development, test of prototypes, modification of figures, new test, . . .) has been replaced by a faster one consisting of a procedure with the designer, transformer and final client working together on the same computer files (“concurrent engineering”). Therefore, the timing for mould manufacture and completion has been reduced enormously; however, some interesting advices about CAE use are described in [1].

The Workshop of Injection of the Plastics Industry of the University of Zaragoza (T.I.I.P.), C.S.I.C. Associated Unit, has been working with CAE tools on injection of thermoplastics for more than 15 years, with enormous advantage for hundreds of projects made in different sectors (automotive, household-electric, packaging, toys, etc.). T.I.I.P. activities included several research projects (rheological characterization, semiautomatic mould design, . . .) working together with different European companies.

Nevertheless, this group has always been conscious of the necessity to arrange simulation with procedure of manufacture next to the machine, of such a form that has been collaborated and directed by the constitution of the Research Association of the Workshop of Injection of the Plastic Industry (a.i.T.I.I.P.) foundation, which provides services to the injection companies without a profit spirit (Fig. 1). This technological center has been supported by various national organizations such as the Aragon’s Government and Spanish Department of Industry through different programs and research lines (new processes like gas-assisted techniques or cascade injection moulding, new designs, process-measuring techniques using pressure and temperature devices . . .).

2. The CONTENUR Project

When, in 1999, the first Spanish company involved in the manufacture of containers for the collection of urban

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Fig. 1. a.i.T.I.I.P. injection moulding area, general view.

solid remainders (CONTENUR SPAIN, S.L.) went to the T.I.I.P.–a.i.T.I.I.P. Group to work jointly on the design of pieces of great size in injection, then arrived the moment for testing the real possibilities of these programs in this field.

The main objective of the project was the fast manufacture of containers of great capacity (2400 l and more) to compete with market products with welded metallic plate solutions or plastic ones made by rotational moulding with the inclusion of expensive reinforcement structures. Obviously, between all the pieces that constituted the set, the main challenge was the manufacture of a single part bucket.

The literature shows several part and mould design examples and failure advices [2,3], but it is not possible to find big plastic parts up to 40 kg weight and a mistake in this mould size will have no easy solution (tool transport to mould maker's manufacturing plant will be too expensive, and trial and error method is not available).

For the design of this element, the following aspects had to be considered:

- basic dimensions agreed with the European Norm EN 12574 [4];
- unloading resistance (discharge sides) (Fig. 2);
- high impact resistance for functional conditions and location (parking areas, for example);
- easily cleaning surfaces;
- friendly aspect, aesthetical design;
- minimum cost (not only for processing and assembly but also for on-street maintenance);
- restriction of the clamping force imposed by the installed press machine (big special machines with limited clamping range between 5000 and 10,000 tonnes);
- prepared for labelling, that is to say, with visible free and flat spaces;
- material restrictions: same materials used for other CONTENUR designs.

Special mention requires two limitations: minimum cost and maximum clamping force under mentioned limits. For a minimum cost, thickness is fundamental (by the cost of raw material), inasmuch as the time of manufacture; therefore,

Fig. 2. Boundary conditions for unloading operation, nonlinear material model, finite element model.

the cost of the machine derived approximately depends on the square of the thickness [5].

On the other hand, to reduce the closing force, the projected area of the piece and the distribution of pressures are strongly related with part thickness (narrow sections caused a high injection pressure, which could as well suppose a high force of closing).

The methodology applied, developed by Castany et al., not only for injection moulding but also for other similar techniques [6–8], is as given below:

(a) Determination of the feasibility of the product: clamping force evaluation and thickness part on an agreed basic geometry to adjust dimensions with the European norm. Only general design lines, and not functional details, were included in this step. Some basic results are shown in Table 1. These analyses were made with basic parameters for generic material family, high-density polyethylene (Table 2). For advanced steps, calculations were made using several temperature conditions.
(b) Material selection, combining melt flow index (MFI) and mechanical behaviour, and injection point locations were simulated, without even knowing the final geometry of the component. Best results were found for several injection points arranged around the bottom area in the main

Table 1
Results for simple plastic model, first analysis using simulation tools

Main body thickness (mm)/weight (kg)	Maximum injection pressure (MPa)	Required clamping force (kN)
6/52	96	166,000
7/60	71	122,000
8/68	55	94,000
9/76	44	74,000
10/84	35	59,000

Table 2
Computing parameters for basic simulations

Melt temperature (°C)	240
Injection time at constant ram speed	
In seconds	20
In percent	50
Mould temperature (°C)	40

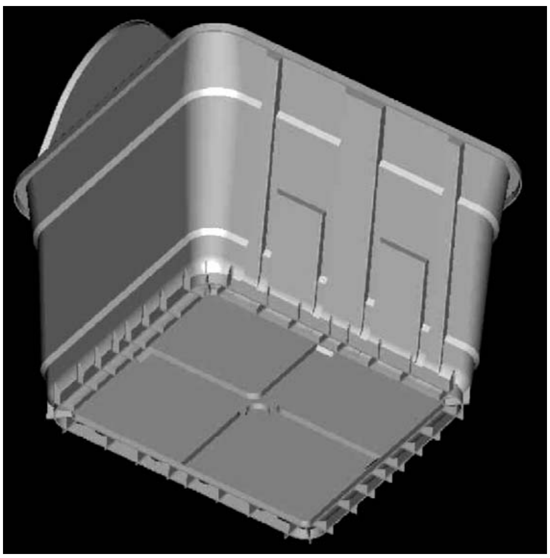

Fig. 3. Basic line, Pro-Engineer software, before final moulding arrangements.

body of the container. This criteria was also imposed by mould structure and part shape.

(c) Analysis of the body form and thickness of the part comparing constructive alternatives: its sidewall shapes, metallic elements of reinforcement and, if necessary, inclusion of the tubes injected with gas-assisted techniques to increase inertia of the sections, etc., were considered.

(d) Obviously, mould dimensions and the presence of undercuts supposed a problem added for the design of piece and mould. In this way, semicircular shape of the border of the upper container was a hard design problem; it was required for functional use but supposed an undercut area involving slides in the mould.

(e) Part volume was adapted and different aesthetic forms appeared—feasible conjunction of the possible thickness by manufacture with the thickness and forms by mechanical resistance. In this step, finite analysis, solid 3D design and filling simulation were made simultaneously (Figs. 3 and 4). The final part dimensions are shown in Table 3.

Table 3
Basic dimensions for 2400 l main body (mm)

Height	1600
Width	1480
Length	1600

With these basic magnitudes calculated in these four steps, the design team had an initial point for the final drawing of geometry and the inclusion of the elements of details like settling down of output angles, radios, position of accessories of the set (cork, skid, etc.). Industrial flow analysis was set in definitive way, fixing optimum positions for manifold working together with the mould maker, Kyowa Industrial Company with mould plants in the USA, Japan and Mexico.

The main aspects of the process and their simulations (other details cannot be presented in order to protect industrial know-how) are:

1. Model of the figure with geometries type 2.5D.
2. Location of the entry points to the cavity. The use of race tracks for a better control of the filling was considered, following rheological design rule for simultaneous end of filling at the end of the cavity (avoiding over-pack effect), especially considering the border shape with semicircular areas.
3. Optimal conditions of process: the selection of temperature and its relation with thickness and cycle strongly conditioned the permissible values for the design. Values between 210 and 250 °C were evaluated.

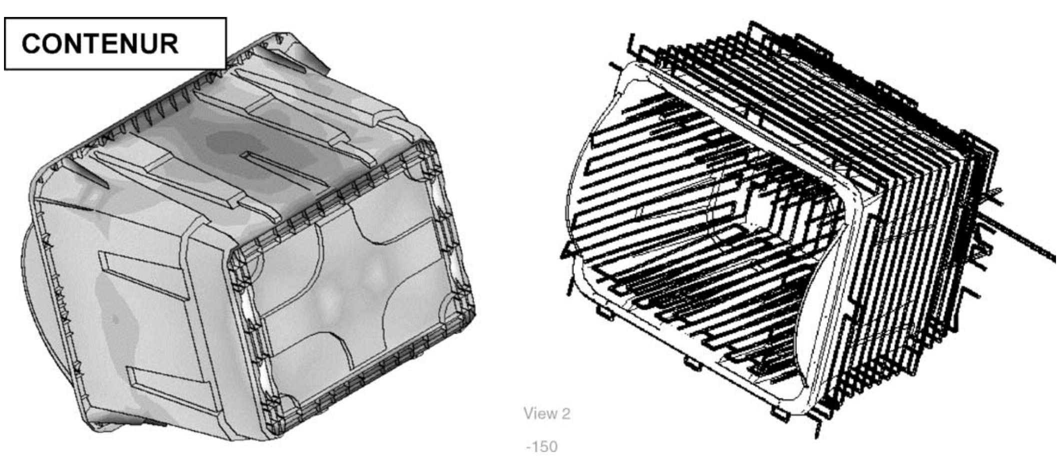

Fig. 4. Software C-Mold: plastic temperature at ejection and cooling lines layout.

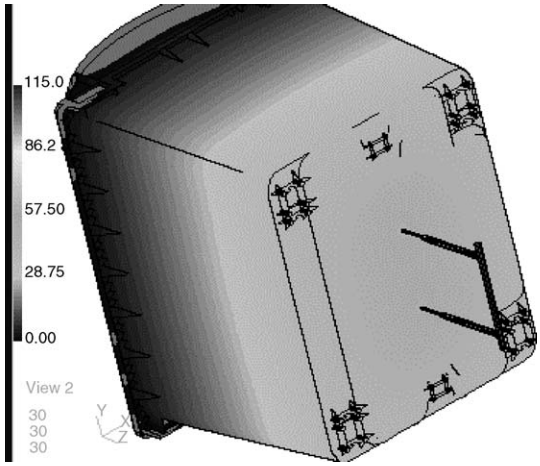

Fig. 5. Real container model used for testing industrial conditions in 2400 l mould.

4. The adjustment of the filling form by means of the correct programming of speeds became essential. At constant speed profile, the increase of pressure-supposed values of inadmissible force of closing by the limitation imposed to the dimensions of the machine. In the final arrangement for container mould, several ram speed stages were recommended.

This procedure was experimentally validated with real tests using already existing smaller dimension container (Fig. 5).

Typical ram speed profile calculated with CAE techniques is shown in Fig. 6, but this "function" cannot be translated to the injection machine without practical arrangements, because hydraulic systems are not able to follow all those gradients exactly. Anyway, around 15% less clamping force could be achieved after this optimisation procedure.

5. After the filling possibilities were fixed, this was verified with a new numerical model by the mould maker from the initial ideas sent by the design equipment and with the final hot runner system data necessary for the mould.

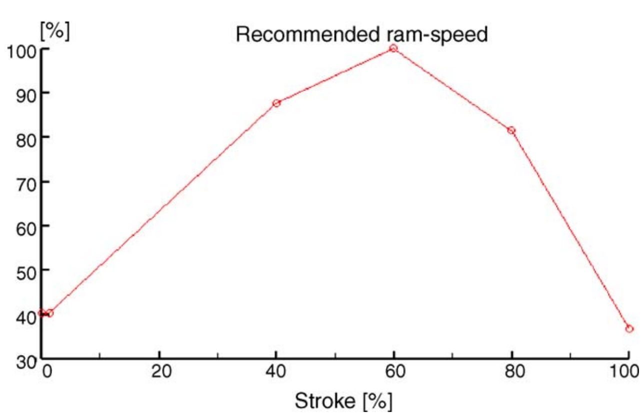

Fig. 6. Theoretical ram speed profile from computer results.

Fig. 7. Real sample in CONTENUR assembly plant.

The sequential technology was considered as a possibility with the purpose of reducing filling pressure, but the practical arrangement, the maintenance and possible shutdowns underestimated their use.

6. Finally, the analyses of cooling of the mould, packing and warpage induced by the process were developed. In this way, different constructive materials were used according to their thermal conductivity, adjusting cooling layout provided by Kyowa Industrial Company. Final mould weight was higher than 150,000 kg (up to 150 metric tonnes).

Actually, more than 6000 pieces were made without detecting any problem in the injection, expulsion or the life of the component in good condition (Figs. 7 and 8), and processing rates are similar with other existing 1000 l containers (20–25 parts per hour). Other components were simultaneously designed and, in fact, it was more complicated to get

Fig. 8. Complete 2400 l waste container, including all components.

fine results, for example, in container lids, obviously smaller than the body.

For the authors, the final conclusion is that CAE tools were basic in design process, and also compared with knowledge and real test using similar moulds.

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References

[1] C. Austin, Lean moulding: faster = cheaper = better, in: J.F. Stevenson (Ed.), Innovation in Polymer Processing Moulding, Hanser, 1996.
[2] H. Gastrow, Injection Moulds: 102 Proven Designs, Hanser, 1983.
[3] M. Ezrin, Plastics Failure Guide: Cause and Prevention, Hanser, 1996.
[4] European Norm EN 12574: stationary waste containers: containers with a capacity from 1700 l to 5000 l, CEN/TC 183/WG1, 2000.
[5] G. Menges, P. Mohren, How to Make Injection Moulds, Hanser, 1996.
[6] J. Fuentelsaz, Metodología para el diseño de componentes de plástico inyectados, Doctoral Thesis, University of Zaragoza, Spain, June, 1993.
[7] F.J. Castany, F. Serraller, I. Clavería, C. Javierre, Methodology in gas assisted moulding of plastics, J. Mater. Process. Technol. 143–144 (2003) 214–218.
[8] F.J. Castany, J. Fuentelsaz, F. Serraller, J. Lladó, F. Martínez, Simulación aplicada al diseño y producción de componentes inyectados, Plásticos Universales, 35, núm. 11, September, 1991.