Design and Simulation of Production of Injection Pieces in Automobile Industry

Emilio Jiménez, Isabel Ruiz
Department of Electrical Engineering
Industrial Engineering Technical School
University of La Rioja, Spain
emilio.jimenez@unirioja.es

Julio Blanco, Mercedes Pérez
Department of Mechanical Engineering
Industrial Engineering Technical School
University of La Rioja, Spain
{julio.blanco;mercedes.perez}@unirioja.es

Abstract—This work shows a design and simulation methodology of a production process to manufacture injection pieces in automobile industry, elaborated to optimise the work in a real plant, and presented through a real example. The example consists in two inserts of an instrument panel for an automobile. The departure data are the design plane of the piece, the materials and additives used, the final specifications of the piece, and the production. The simulation methodology allows us to establish the rules to develop the mold, to specify the number of cavities, to determine the solidification and the cycle times, to locate the pieces and the tapping in the mold, to calculate the clamp force necessary in the injector machine and the dimensions of the mold, to analyse the results of the simulation (with Mold-Flow), to choose the appropriate injector machine, and to obtain the necessary information to develop the mold.

Keywords-design & simulation methodology; manufacturing; injection; automobile industry; work optimisation

I. INTRODUCTION

This work shows a methodology that integrates design and simulation [1, 2] in a production process to manufacture injection pieces in automobile industry, elaborated to optimise the work in a real plant, and presented through a real example.

The example consists of designing a production of 45,000 Polypropylene sets a year, each one formed by two pieces (Figure 1): a co-driver side insert and a driver side insert of an instrument panel of an automobile [3, 4].

The departure data are the design plane of the piece, the materials and additives used, the final specifications of the piece, and the production. The simulation methodology allows us to: a) establish the rules to develop the mold, b) specify the number of cavities, c) determine the solidification and the cycle times, d) locate the pieces and the inlets in the mold, e) calculate the clamp force necessary in the injector machine and the dimensions of the mold, f) analyse the results of the simulation (with Mold-Flow®), g) choose the appropriate injector machine, and h) obtain the necessary information to develop the mold.

In this work, not only the obtained solutions are described, but also the studied alternatives, in order to show the methodology of the process used, based on simulation. Also the part of the process related directly to the injection and the molds is the only one dealt with in the paper, without including, for reasons of article extension, the other aspects that have been kept in mind in the modelling and simulation of the global process; to be more specific: the election of the robot extractor of the piece, the system of court of inlets, the packing specifications, and the measurement of the work and performance analysis (including solidification and cycle times).

Figure 1: Position of the Pieces in the Car

Figure 2: Initial studied solution. Location of entrances of Material
II. LOCATION AND NUMBER OF MATERIAL INPUTS

The first problem that arises is the location and number of material inputs.

A first option there had 3 entrances, as can be seen in Figure 2. The main problem was that union lines appeared in the driver side piece. It could have been solved by means of sequential type inputs in cascade, but, due to the morphology of the piece, this solution did not make sense.

The second option consisted of two material entrances, as shown in Figure 3.

The simulation with Mold-Flow gives the following results (Figures 4).

We can see that basically two problems appear. On one hand the imbalance in the filling time of both cavities, with the corresponding over compacting of one of them; it can be observed in the images that, for a time lightly higher of two seconds, the co-driver piece has already been fully filled while in the driver piece there are still spaces to fill.

On the other hand, an imbalance is observed in the filling of the driver side piece in both ends of the figure, that is to say, inside that same piece, the filling does not finish at the same time, and this could also generate problems.
III. SPECIFICATION OF THE NUMBER OF CAVITIES

In order to calculate the number of necessary cavities, the first parameter to be considered is the demanded production, 45,000 cars/year; 3% of scrap and 4% of down-time are considered for our injector machine and 1% waste for the following phases of the chain. With all this, 48,600 sets/year have to be produced.

For a total of 220 days of work/year, 221 sets/day have to be manufactured. For a cycle of 70s. it is necessary a total of 4,297 hours of production a day.

With this it can be appreciated that a cavity is enough. The disposition of the pieces in the mold is the one shown in figure 5 and with the demoulding direction indicated by the arrows.

IV. CALCULATION OF THE CLAMP FORCE

The injector machine has to generate a clamp force bigger than the produced by the pressure generated by the material against the surfaces of the mold.

It is calculated with the following formula, where $Sp$ is the projected surface, $Pe$ is the internal specific pressure, $Sc$ is the configuration supplement (which is 1 in our case) and $St$ is the fluency factor that is also 1 for the polypropylene.

$$F_c = \frac{Sp \cdot cm^2 \cdot Pe \cdot K_p}{Sc \cdot St}$$

In order to calculate the projected surface, the application Unigraphics NX® was used and the following values were obtained (Figures 6 and 7):

They sum a total of 2,060,22 cm².

For the calculation of the internal specific pressure it is necessary to find the Rate Flow / wall-thickness (faith) for each one of the pieces. It is the relationship among the maximum distance that has to cover the material from its application point and the thickness of the piece in their maximum point.

Their values are the suitable ones in figures 8 and 9 for each one of the inserts.

This way, the obtained faith is:
This value is introduced in the graphic of Figure 10. Locating us in the red curve, for a thickness of 3.5 mm we obtain an internal specific pressure of 258 bars. Substituting the values in the initial formula, a clamp force $F_c = 2060.22 \times 258 \times 1.1 = 531.536.76 \text{ Kp} = 531.5 \text{ Tn}$ can be obtained.

![Figure 8: Maximum distance. Co-driver side](image1)

$\sqrt{291.7^2 + 267.655^2} = 395.9 \text{ mm}$

![Figure 9: Maximum distance. Driver side](image2)

$\sqrt{175.49^2 + 183.181^2} = 358.671 \text{ mm}$

![Figure 10: Graphic of Internal Specific Pressure](image3)

**V. Calculation of the Dimensions of the Mold**

In order to give an approximate value of the calculation of the mold dimensions, the experience will be taken into account. The front dimensions will be decided first. Our pieces resemble the polyhedron of Figure 11.

![Figure 11: Approximate dimensions of the pieces](image4)

As a general practice rule, a fourth part of the dimension of the piece in will be added in every direction, as Figure 12 indicates. This margin is added in order to have space for the lock wedges that avoid possible displacements and deformations due to the pressure.

![Figure 12: Front dimensions of the mold](image5)

Then, the height of the two halves of the mold is calculated. For the cavity side, 305 mm of piece are considered, 150 mm so that it supports the mechanical force that will take place, 120 mm for the hot runner, and 80 mm for the bearing plates (Figure 13).

For the core side, the same space for the piece and the mechanical resistance is considered, 150 mm of ejection stroke, 50 mm that this badge occupies, and 80 mm for the bearing plate (Figure 14).

![Figure 13: Front dimensions of the mold](image6)
This way, it is obtained that the minimum Shutheight of the mold is 1075 mm. The Opening Stroke between molds, so that the arm of the robot can enter and extract the piece without touching it, is 1055 mm. Then, the minimum Daylight between the plates of the machine should be of 2130 mm.

VI. CHARACTERISTIC CALCULATION OF THE INJECTOR MACHINE

Now the injector machine can be selected. The model Husky 1005 Tn has been chosen, whose characteristics are shown in Table 1. All the values fit with those that have been obtained previously.

<table>
<thead>
<tr>
<th>TABLE 1: INJECTOR MACHINE CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamp force</td>
</tr>
<tr>
<td>Tiebar Spacing (HxV)</td>
</tr>
<tr>
<td>Plates size (HxV)</td>
</tr>
<tr>
<td>Max. Daylight</td>
</tr>
<tr>
<td>Min. Shutheight</td>
</tr>
<tr>
<td>Max. Shutheight</td>
</tr>
<tr>
<td>Max. Opening stroke</td>
</tr>
</tbody>
</table>

VII. LOCATION OF THE INLETS

It had been seen that in the case of 2 material inputs it is possible not to have a well balance. This can be solved with a small inclination of the driver side input, as can be seen in Figures 15 and 16.
VIII. FILLING SIMULATION

The filling simulation of the pieces is shown in Figure 17 in 5 steps, where it is possible to see the perfect balance of the pieces.

The filling time is 2,585 sg. And for the study of temperatures, it can be appreciated in Figure 18 that the final filling temperature is very homogeneous, and it reaches 250.6º C.

Figure 17: Simulation with Mold Flow
Figure 18: Final filling temperature and study of temperatures

Figure 19: Pressure of Injection

Figure 20: Closing force
Noticing the union lines, it can be appreciated that the only ones that appear are unavoidable, and they are due to the morphology of the piece, as can be seen in Figure 21.

![Lines of union](image1)

Figure 21: Lines of union

Studying the pressures, a maximum injection pressure of 39.51 Mpa is obtained, as shown in figure 19; the clamp force is 530 Tn, as can be seen in Figure 20.

The switch-over, the moment to stop applying the injection pressure and starting the remainder pressure, can also be deduced; it is represented by means of the peaks in the graphs, and it takes place at 2.5s. Starting from there, a constant pressure of 32 MPa will be applied. The situation of the piece in this point is shown in Figure 22.

![Diagram of pressures](image2)

Figure 22: Diagram of Pressures

REFERENCES


