Article

Journal Industrial Engineering

December 2021, Vol.5 No.15 24-29

Control system for parameter estimation in plastic injection for the automotive industry

Sistema de Control para la estimación de parámetros en la inyección de plásticos para la industria automotriz

ROMANO-RODRÍGUEZ, Ma. Natividad†*, MUÑOZ-RIOS, José Juan, PÉREZ-MARTÍNEZ, René and HERNÁNDEZ-MEDINA, José Juan

Instituto Tecnológico Superior de Tlaxco. División de Ingeniería Electromecánica. Mexico.

ID 1st Author: *Ma. Natividad, Romano-Rodríguez* / **ORC ID:** 0000-0002-3415-8629, **CVU CONACYT ID**: 640296

ID 1st Co-author: *José Juan, Muñoz-Rios* / **ORC ID:** 0000-0003-2162-8131

ID 2nd Co-author: *René, Pérez-Martínez* / **ORC ID:** 0000-0001-5981-8403, **CVU CONACYT ID**: 669754

ID 3rd Co-author: *José Juan, Hernández-Medina* / **ORC ID:** 0000-0003-4625-2660, **CVU CONACYT ID:** 5227576

DOI: 10.35429/JIE.2021.15.5.24.29 Received July 20, 2021; Accepted December 30, 2021

Abstract

In this work, a basic control system is established for the estimation of parameters in the injection of molds to cover product quality standards in the automotive industry. Estimates are made through mathematical tools and error analysis to determine the starting parameters for the injection process and that feed the injector program and then proceed to the adjustment of such parameters in a heuristic way. Establishing a control system to establish the initial injection parameters or those involved in the injection process would avoid waste of material, production times and the scope of the quality standards established by the IATF 16949 2016 standard.

Control, Injection, Parameters

Resumen

En este trabajo se establece un sistema de control básico para la estimación de parámetros en la inyección de moldes para cubrir estándares de calidad del producto en la industria automotriz. Se realizan estimaciones a través de herramientas matemáticas y análisis de errores para determinar los parámetros de inicio para el proceso de inyección y que alimentan el programa de la inyectora y luego pasar al ajuste de tales parámetros de una manera heurística. El establecer un sistema de control para establecer los parámetros de inyección iniciales o de los involucrados en el proceso de la inyección evitaría desperdicio de material, tiempos de producción y el alcance de los estándares de calidad establecidos por la norma IATF 16949 2016.

Control, Inyección, Parámetros

Citation: ROMANO-RODRÍGUEZ, Ma. Natividad, MUÑOZ-RIOS, José Juan, PÉREZ-MARTÍNEZ, René and HERNÁNDEZ-MEDINA, José Juan. Control system for parameter estimation in plastic injection for the automotive industry. Journal Industrial Engineering. 2021. 5-15:24-29.

* Author's Correspondence (E-mail: manatividadromanorgz@gmail.com)

† Researcher contributing as first author.

Introduction

The injection process cycle has four well-characterized stages: (1) the heating of the thermoplastic, (2) the entry of polymeric material into the mold, (3) the transfer of heat or cooling and (4) the demoulding of the part. The properties and quality of the molds determine the productivity of the process, since the production rate, that is, the cycle time, will depend on the speed with which the material can be heated, injected, solidified and expelled. Among these stages, cooling is the one that requires the longest time, so a good system project is essential not only to reduce the process cycle time, but also to improve the quality of the product (Corazza et al., 2012).

The parts of an injector are illustrated in figure 1, according to (Jurado, et al, 2019):

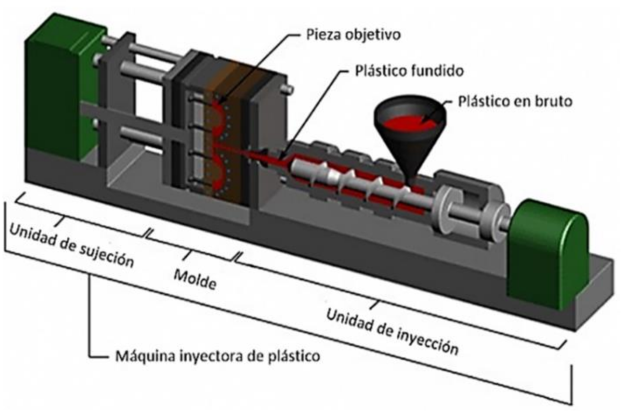

Figure 1 General injection process

Once the mold is placed in the injector, the process parameters are prepared and established to feed the injection machine program, in order to obtain a product that meets the quality standards established in the automotive industry of according to the IATF 16949 2016 standard. This will allow automotive companies to acquire injection products with the standard established to be part of the automotive models produced by these.

If a mold is to be used for the first time, it will be important to analyze factors such as: the technical data sheet of the material and the test parameters of the manufacturer or customer. However, a parameter review is performed to begin the molding tests.

Generally, parameters such as: cooling time, closing force, cycle time, among others, are calculated prior to the injection phase and at the end of this phase, the characteristics of the ejected part are verified, such as: lengths, finish, weight and other elements or tests requested by the customer or manufacturer, above all, the scope of the quality standard for automotive parts.

When they are already run molds, previously used, tested or improved, it is only valued that they comply with the established parameters of the process but that the required quality conditions are guaranteed within the standards established by the IATF 16949 2016 standard.

Within the process parameters the following are considered critical: injection time, mass cushion, maximum injection pressure. But they are also continuously monitored: The cycle time, the cooling time, the mold temperatures, the weight of the piece and the temperature of the dough.

In this work it is proposed to establish a control system of three parameters such as the closing force, the cooling time and the cycle time, in order to have them as a starting point to feed the injector program and start the injection process, we consider basic geometric structures such as circles, rectangles, and squares.

Justification

According to (Jurado, 2019), the importance of the injection process has caused various authors to have carried out a large amount of work and research to understand the effects of the injection process variables on the final properties of the molded part, among from which the works of Juárez, D., Balart, Peydró & Ferrándiz (2012) can be compiled, who coincide in the existence of previous studies that try to understand the injection process by analyzing the influence of certain process parameters with regarding certain effects that affect the injected parts. (Prada, 2017)

In (Boroat, 2019), they propose a model to quantify the interactions between several parameters, such as: the mold, the melting temperature of the polymer, the thickness of the geometry and the compaction pressure applied on the residual stresses and the contraction of flat pieces.

In (Bushko, 1995) they characterize the influence of four process parameters on the roughness of the final pieces obtained by injection, as a control parameter to guarantee the functionality and integrity of a surface.

With the fourth industrial revolution called 4.0, the use of digital technologies in industrial processes to make them more efficient is established, in this work a control system is proposed that allows to calculate three established parameters and with them make a first approximation to the data that they will feed the injector program, and then proceed to make adjustments to such parameters based on a basic interpolation process and acquire a “good” quality ejected part.

Description of the method

For the development of this work, a Battlenfeld PLUS 35/75 unilog B injection molding machine was used (figure 2). And a mold for the injection of a miniaturized set of wheels (figure 2a and 2b):

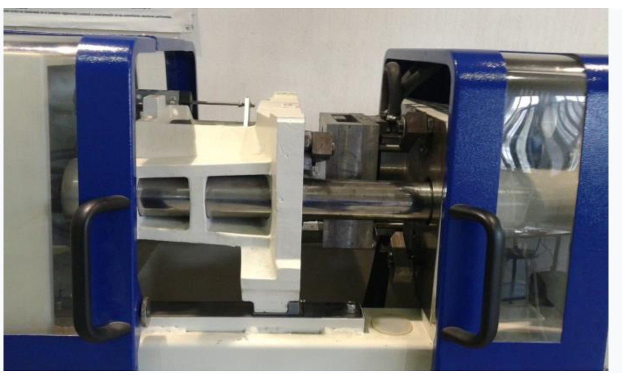

Figure 2 Battlenfeld injector mold

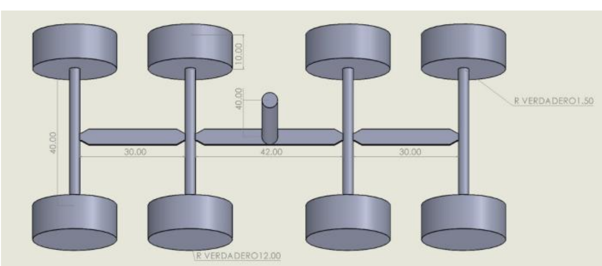

Figure 2a Miniaturized car tires design

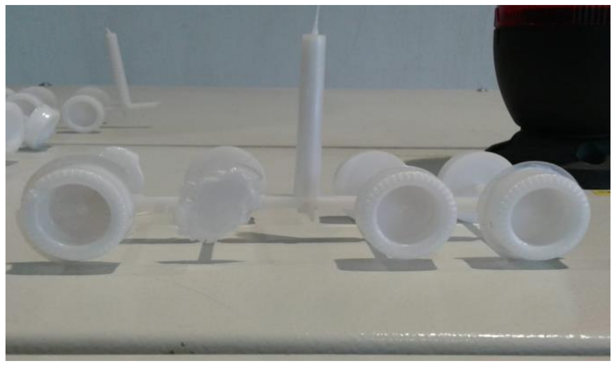

Figure 2b Ejected model in tests

Development

According to (Bigerelle, 2008) there are also some mathematical models to determine the number of cavities in a mold based on machine-dependent magnitudes, such as the closing force, the maximum injection capacity and the physical dimensions of the machine.

Next, the calculation of the closing force is established from the following formula:

$$Fc = Ap \cdot Pi \quad (1)$$

Where:

Fc is the closing force.
Ap is the surface area of element to be injected.
Pi is the internal pressure of the mold.

For the mold used in this work, the following data are considered (figure 3):

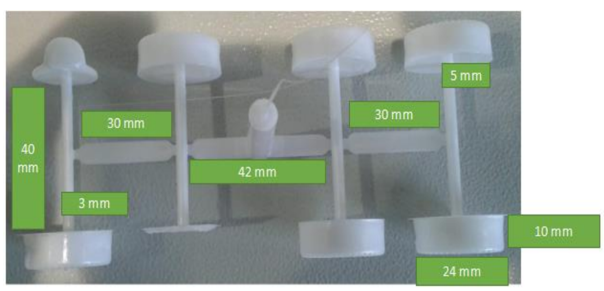

Figure 3 Considerations for surface area.

The projected area of the four sets of tires corresponds to four times 600 mm^2 plus the area of the casting, which was considered 510 mm^2, thus obtaining the value of:

$$Ap = 2910mm^2 = 29.1cm^2$$

The material used for injection into the tire mold is polystyrene (PS), which is why it is established:

$Pi = 400bar$

according to the specific properties for the injector Battlenfeld.

Then the closing force is calculated:

$$Fc = Ap \cdot Pi$$
$$Fc = (29.1cm^2)(400bar) = 11640kgf$$

Considering the empirical recommendation that the maximum closing force of the machine is approximately 20% higher than that necessary for the injection of the part in question. We will have the following:

$$Fc = 11640 + 2328 = 13{,}968kg$$

Now we will proceed to calculate the cooling time, using the formula:

$$t_k = \frac{s^2}{\pi^2 - \alpha_{eff}} \ln\left\{\frac{4}{\pi}\left(\frac{T_{melt} - T_{mold}}{T_{eject} - T_{mold}}\right)\right\}$$

Where:

t_k is the cooling time
s is the thickness of the wall
α_{eff} the thermal diffusivity
T_{melt} is the temperature of the dough
T_{mold} is the temperature of the mold.
T_{eject} the draft temperature

For the case of the mold of miniaturized rims, this boils down to:

$$T_k = (2.82)(16mm^2) = 45.12seg$$

We consider in the formula the constant 2.82 associated with the material used for the process, in this case, that of polystyrene (PS) and the thickness corresponding to 4mm.

Finally, we calculate the third associated parameter: the cycle time, defined as triple the cooling time.

$$T_c = 3(45.12) = 135.36seg = 2.256\min$$

With the values obtained through the formulas of the parameters: cooling time, closing force and cycle time, the injector program is fed to start the injection process of the miniaturized tires: (figure 4).

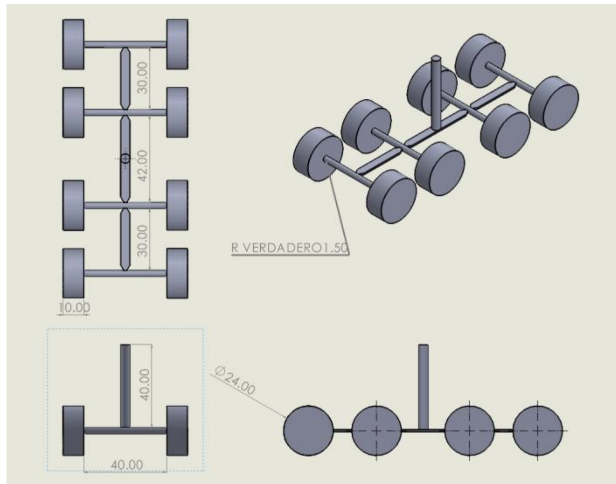

Figure 4 Different views of the injection model

Results

Once referenced to the start parameters, the first ejection tests are carried out. (Figure 5a and 5b).

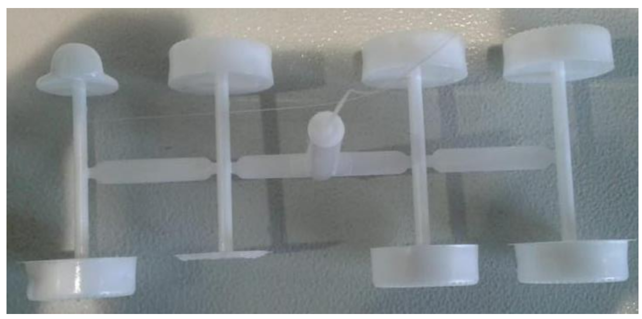

Figure 5a Part ejected during tests.

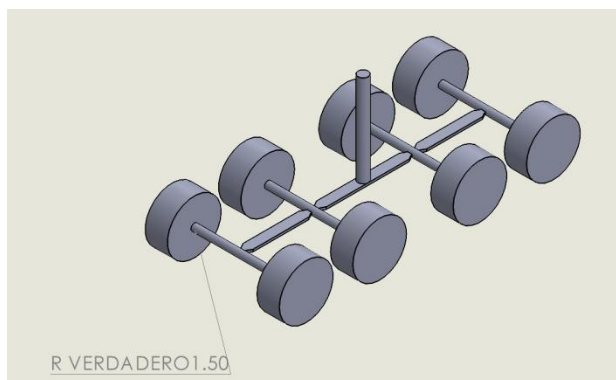

Figure 5b Final ejected part.

The parameters are adjusted through interpolation until the part is finished (see table 1).

ISSN 2523-0344

Closing Force	Cooling time	Cycle time
13,968 Kg	45.12 seg	2.256 min
14,000	45.00	2.000
13,990	43.00	1.500
13,970	40.00	1.250
13,950	38.00	1.000

Table 1 Variation of injection parameters for miniaturized tires

As a test of this control system to establish a starting approximation of the three parameters established in this work, a test was carried out with a part_X, in a company_X dedicated to the injection of plastics for the automotive sector, such a part is of geometry basic.

In the first row, the starting values are placed and other values are provided that approximate the real values required to obtain the ejected parts with the quality requirements under the IATF 16949 2016 standard (table 2).

Closing Force	Cooling time	Cycle time
2420 kN	43.12seg	2.5 min
2415	38.00	2.0
2400	35.00	1.5
2396	30.00	0.83

Table 2 Variation of injection parameters for part_x

Conclusions

In both processes, it has been seen that the parameters obtained by the formulas that define the closing force and the cooling time represent a good approximation in terms of their proximity to the real values required for the injection process, which avoids doing numerous heuristic tests. and material waste.

Regarding the cycle time, significant differences are seen with the real time of the process, especially in the practice in the injection of pieces within the company.

An important advantage of the proposed control system is not having a starting blind spot, but a better approximation to the values of the three parameters established in this work.

The control system was programmed, considering data such as the geometry of the part and using an interpolation method with two references, however it is proposed to carry out the program in a more robust way with a number of significant tests and using a Lagrange or interpolation type. It allows them to improve the estimation of the injection parameters established in this work, as well as to consider others that facilitate having a sufficiently precise approach to minimize times, avoid significant material waste and above all cover the quality indicators of automotive parts standardized by the IATF 16949 2016 standard, which for companies in the plastic injection industry, especially micro-companies, would be a competitive advantage to position themselves in the market.

References

Corazza, E., Sacchelli, C.,Marangoni, C.. (2012). *Reducción del Tiempo de Ciclo de Inyección de Termoplásticos con el uso de Moldes con Tratamiento Superficial por Nitruración.* Información Tecnológica, 23(3), 51-58. 2021, 25 Mayo, De SciElo Base de datos.

Jurado, P., Reveles, J., Plascencia, H.,& Aguilera, E.,. (2020). *Análisis de un proceso de inyección de plástico por interacción fluido estructural y cambio de estado.* Acta Universitaria, 29, s/n. 2021, Mayo 25, De SciElo Base de datos.

Prada, R., Acosta, J.. (Junio 2017). El moldeo en el proceso de inyección de plásticos para el logro de objetivos empresariales. Dimensión Empresarial, 15, 169-182. 2021,Mayo 25, De SciElo Base de datos.

Hassan, H., N. Regnier, C. Lebot, C. Pujos y G. Defaye, *Effect of cooling system on the polymer temperature and solidification during injection molding, Applied Thermal Engineering*: 29, 1786-1791 (2009).

Boroat, T. (2009). *Estudio y modelización de la procesabilidad mediante moldeo por inyección de materiales termoplásticos reciclados. Tesis Doctoral Universidad. Politécnica de Valencia (España).* 2009-05-21, doi:10.4995/Thesis/10251/5024.

ISSN 2523-0344

Bushko, W.C. & V.K. Stokes (1995). *Solidification of thermoviscoelastic melts. Part II: Effects of processing conditions on shrinkage and residual stresses.* Polymer Engineering & Science, 35 (4), 365-383, doi: 10.1002/pen.760350410

Bigerelle, M. A. Van Gorp & A. Lost (2008). *Multiscale roughness analysis in injection-molding process. Polymer Engineering & Science*, 48 (9), 1725-1736, doi: 10.1002/pen.21131.

Isaza, E., E. Salazar & Y. Moreno (2010). *Modelo para la determinación del número óptimo de cavidades en moldes de inyección de* plásticos. Revista Scientia et Technica, X (200), 1-6.

Zavaleta, M. (2019, Septiembre 11). Moldeo por inyección. 2021, Septiembre 03, de https://moldeoporinyeccion.com/ Sitio web: https://www.facebook.com/moldeoporinyeccion/photos/a.1816212621978862/2368366213430164/.