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Scientific molding in the plastic injection process to control process variables and reduce aesthetic and dimensional problems of molded parts in a maquiladora company in Ciudad Juárez, Chihuahua, México

El moldeo científico en el proceso de inyección de plástico para controlar las variables del proceso y disminuir los problemas estéticos y dimensionales de las partes moldeadas en una empresa maquiladora en Ciudad Juárez Chihuahua, México

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Abstract: The objective of this study is to analyze the scientific molding process in a maquiladora located in Ciudad Juárez, Chihuahua, Mexico, specifically to reduce aesthetic and dimensional defects in parts produced using this plastic molding technology. The research, developed using an applied research methodology, was conducted in a single maquiladora plant, in the molding area of the automotive parts production department. The main technique used was observation and process analysis based on customer requirements. According to the study, the current processes present opportunities for improvement, as the scrap rates due to aesthetic and dimensional problems are above the organization's target. Within the company, the quality department keeps a monthly record of the number of defects and their causes, with this data a historical record is obtained to demonstrate that most are originated by variations in the injection molding process, due to one or more of the variables present in it, such as temperature, speed, lack of mold seal, etc. A proposal and analysis of the technical characteristics of the scientific model are presented as an alternative for implementation in the improvement of automotive manufacturing processes.

Keywords: scientific molding, plastic injection molding processes, processing parameters.

Resumen: El objetivo del presente estudio es analizar el proceso del moldeo científico de una empresa maquiladora ubicada en Cd. Juárez Chihuahua México, específicamente para reducir los problemas estéticos y dimensionales en las piezas elaboradas bajo esta tecnología de moldeo de plásticos. La investigación que se ha desarrollado es mediante la metodología de investigación aplicada, realizado en una sola planta maquiladora, en el área de moldeo perteneciente al área de producción de partes automotrices. Como técnica principal se utilizó la observación y el análisis de los procesos a partir de los requerimientos del cliente. De acuerdo al estudio practicado, los procesos actuales presentan oportunidades de mejora ya que los porcentajes de desperdicio por problemas estéticos y dimensionales están por encima de la meta de la organización. Dentro de la empresa el departamento de calidad lleva un registro mensual del número de defectos y el motivo, con este dato se obtiene un histórico para demostrar que la mayor parte son originados por variaciones en el proceso de moldeo por inyección, por una o más de las variables que se presentan en el mismo, como, temperatura, velocidad, falta de sello de molde etc. Se presenta una propuesta y análisis de las características técnicas del modelo científico presentándose como una alternativa de implementación en la mejora de los procesos de fabricación automotriz.

Palabras clave: moldeo científico, procesos de inyección de plástico, variables de proceso.

1. INTRODUCTION

The automotive industry currently uses about 356,000 different parts to assemble a car, many of these parts are plastic parts made as different polymers through the plastic injection molding method. [1] mentions that "the injection molding process is a very dynamic and interactive process by nature, and this is a factor that should always be taken into account when there is a problem". Therefore, considering that the injection molding process is very dynamic and interactive, it is also understood that it can lead to various cosmetic and dimensional problems depending on the design of the part and the material used.

2. THEORETICAL FOUNDATIONS

2.1. Background

[1] describes in CIQA2 his thesis development: Troubleshooting in injection molding with the objective of "As the demand for plastic parts made by injection molding increases, problems related to this process tend to cause delays and significant economic losses. This is because injection molding involves a complicated mix of machine variables, mold complexity, operator expertise and material properties. Therefore, the continuous search for reducing cycle times and rejection rates, as well as improving part quality and optimizing the productivity of each machine, has led on the one hand to the development of new technologies, but has also increased the need for objective and systematic problem-solving methods that allow planning, optimizing, controlling and monitoring the process, which can be documented and widely used".

[2] in his thesis presented at CIQA "Scientific injection molding", he mentions "Scientific injection molding aims to accumulate information necessary to create histories of process behavior. With the information obtained from the history, the equipment and the different flow zones of the plastic materials through the process, it is possible to predict the problems that would occur in subsequent production batches and thus avoid them. This shortens the revision processes in the prototypes for the pre-production phases".

[3] mentions in his thesis at the University of Mar de Plata "Injection molding is one of the most widely used techniques for polymer processing. It offers advantages over other processing conditions, such as: good surface finish, possibility of processing complex geometry parts without the need of secondary operations, and low costs for mass production. However, due to the complex deformations and the thermal and pressure history that the molten polymer brings from its processing, residual stresses are generated. These 2 CIQA Centro de Investigación de Química Avanzada 13 stresses act internally at room temperature and have the same effects on the material as externally applied stresses, resulting in volumetric shrinkage and warpage in the final product.

[4] In his article published in Plastics technology Mexico, he mentions "Bubbles are one of the main

causes of molded parts rejections for cosmetic reasons. This annoying defect of the part not only causes problems in appearance, but also affects the physical properties. Bubbles are a common occurrence and are often difficult to fix." The variable that eliminated the problem was the injection speed.

[5] In their project "Methodology for plastic molding problems in parts with class A surface" developed at the Universidad Autónoma de Cd. Juárez, mentions that "Plastic injection molding is a process that requires a very systematic control of variables to achieve quality in the parts according to customer requirements. This control of variables is affected by multivariables and in many occasions the methodology used in solving quality problems is based on experience rather than on an engineering-based approach. In this project a causal model was developed in a double shot molding process with a design approach and improved the process parameters of time, temperature and tangential speed, using a factorial design of experiments that allowed improving the product quality to 90%.

[6] in his Thesis "Analysis of moldability of long parts obtained by plastic injection" developed at the National Autonomous University of Mexico" mentions "The objective proposed in the work was achieved, since a methodology for analyzing the moldability of plastic parts was proposed, it was tested with a case study, from which quantitative measures of the quality of the part were obtained, based on the parameters involved in the process. The proposed methodology proposes buckling as an evaluation criterion, since it is a common defect in long plastic parts and it can be quantified with the deflection of the part, likewise, it was possible to counteract the effects of buckling, identifying the range of variables that cause the defect".

[7] in their article "Reduction of defects in the injection process in a home plastics company" published in the Ingeniantes Magazine, mentions "The main contribution of this project is to obtain a quality product by improving the process. The use of the quality tools and the appropriate strategies that were employed, were able to reduce up to 3.33% of the existing defects; specifically, the determination of the multiple regression model was able to determine the appropriate operating parameters.

[8] mentions in his thesis Analysis of a foam injection molding process in a harness manufacturing company in Hermosillo, Sonora, presented at the University of Sonora engineering division, "In the injection molding process the quality of the molded parts is strongly influenced by the processing parameters and conditions, in the research work the critical factors that influence the waste of material are analyzed. To achieve the objective, the design of experiments technique was used in conjunction with some quality tools, such as histograms and capability studies. With the combination of these techniques, the analysis of results and the definition of optimal values for each parameter were performed.

[9] mentions in his article published in the journal engineering and industry that "Injection molding of plastic materials is a delicate process, which may be subject to molding defects that impair quality depending on molding requirements and conditions of materials and additives. [10] Refers in his thesis analysis of the moldability of long parts obtained by plastic injection molding to some of the many aesthetic problems and mentions: "Sink marks is a local depression on the surface of the part, which occurs in thick sections or located above ribs, housings and internal fillets.

Some causes are the following: material shrinkage in thick sections without sufficient compensation at the time of the cooling phase, i.e., excessive shrinkage in the section; low injection and packing pressure, as well as insufficient material shot; insufficient packing and cooling time; high melt and mold temperature.

[11] published an article in the journal materials where through a series of tests they subjected a plastic material to different mechanical and physical tests to conclude that the effect of the applied temperature can have a significant impact on the appearance of the molded part.

[12] comments in his article injection process control published on the Inter empresas website "There are companies focused on machine parameters, I call them "parameterized". They are those that focus, study, define and control the machine parameters, focused on ensuring that the machine parameters are not modified without justified reasons. Understanding machine parameters as those values of the process that are entered (inputs) in it so that it works as expected.

[13] mentions in his research on the control of variables in the injection process of plastic specimens that "The relationship of pressure against weight shows that it is one of the predominant

variables in the plastic injection process, determining that the higher the compaction pressure, the higher the weight."

2.1.1. Plastic injection process

The plastic injection molding process consists of passing a molten plastic material under pressure through a die or nozzle into a mold where it takes the predetermined shape, cools and is ejected to later start a new cycle.

The history of plastic injection molding dates back to 1868, when the Wesley Hyatt brothers developed the first plastic material called celluloid and years later in 1872 they patented the first plastic injection machine, which had a very simple system consisting of a syringe- shaped funnel which they operated manually with the help of a press to keep the mold closed.

[14] mention that it was until after the second world war, where the plastic injection molding took the momentum and its demand for the manufacture of plastic articles was very high and in their research article the molding in plastic injection process for the achievement of business objectives developed in the Faculty of management.

In their research article "Molding in the plastic injection process to achieve business objectives" developed at the School of Management, Finance and Economic Sciences of the University School of Business Administration of Bogota, they mention that plastic injection molding has been making its way in the industry bringing both technical and economic benefits in reference to other materials such as aluminum, bronze, iron, finding in this process the best solution to parts with specific requirements.

3. TYPES OF MOLDING

3.1. Injection molding

[15] They mention in their article recent developments in injection molding processes for polymeric materials. Injection molding is when a molten plastic is injected at high pressure into a metal mold. Its advantages are high precision, fast production and molding of complex parts. Some disadvantages are the high cost of the mold, and that it can be limited to certain materials. Some examples of its application are: automotive parts, toys, electronic components

3.2. Blow molding

[16] in the article blow molding of plastics describes blow molding as the creation of a hollow, hot plastic preform, which is then blown to give it its final shape. Among its advantages is that it is possible to manufacture thin- walled articles, complex shapes, bottles and economical containers. Its disadvantages are low precision and that it is limited to certain materials. Some applications are soft drink bottles, detergent containers, inflatable toys.

3.3. Compression molding

[17] As described by the authors, in this process the plastic material is placed in a mold and compressed with heat and pressure. The advantages of this process are that large parts can be molded, and the molds are low cost. The low precision and the fact that it is limited to certain materials are some of its disadvantages. Electrical insulators, container lids, boat parts, coolers are some of its applications.

3.4. Rotational molding

[18] In this process the plastic material is pulverized and placed in a rotary mold that is heated, distributing the material uniformly. This process is especially used to form large hollow parts, and its molds are low cost, usually made of aluminum. Unfortunately the quality is very poor as it generates parts with non-uniform wall thickness and low precision. Some examples of applications are storage tanks, children's toys and kayaks.

3.5. Process Variables

[17] mentions: "The variables of the injection molding process are four, speed, temperature, pressure and time, these variables must be applied in different magnitudes and proportions during the transformation cycle". With these variables a process can be created, but they are also the cause of most of the process problems.

3.5.1. Injection time

This is the time it takes for the screw to move from its loading position, to its transfer position. Cushion: This is the amount of material that remains on the front of the screw after it has transferred the plastic into the mold. It is recommended that the entire process have this cushion as it helps prevent wear on the machinery parts and also ensures, that the parts are completely filled.

3.5.2. Recovery time

This is the time it takes for the screw to return to its loading position, after it has reached its final position and the packing or holding time has elapsed.

3.5.3. Injection pressure

This is the maximum pressure reached by the screw due to the resistance of the plastic being transferred into the mold cavities.

3.6. Scientific molding.

[19] mentions: "The scientific molding methodology is applied in the plastic injection molding transformation processes starting with the selection of the part to be molded, together with the analysis of the dimensional structure which is specified in a drawing, then the data of the variables that are considered to be directly impacting are analyzed and then proceed to improve the process through a methodology that can be left in this case to the consideration of the expert". This methodology is of great help to make the plastic injection molding processes efficient by finding the ideal parameters for the processing of any plastic material.

The main tests to achieve the development of scientific molding are: Viscosity curve, gate seal and in some cases cavity balancing (applies only if the mold has more than one cavity). Viscosity curve: This test seeks that the viscosity of the plastic is constant, to avoid variations in the entry of the plastic into the mold cavities. Gate seal: It is a test that looks for the efficiency in the packing or holding time, where the screw is kept in front with pressure applied to prevent the material inside the mold from going back and in turn take the dimensions of the cavity. Occasionally this time is deficient or excessive. Cavity balancing: This test applies only if the mold has more than one cavity. If so, the test looks for all cavities to have the same weight, although not exact, it can have a maximum of 4% difference between cavities to consider that the mold is balanced.

3.7. Cosmetic and dimensional problems

3.7.1. Rebaba

It is the excess of material in the part, which looks like a thin film on the edges of the molded part and can obstruct its correct placement.

3.7.2. Sinking

The part presents superficial deformations, caused by an insufficient filling or a short holding time.

3.7.3. Stains

They can be generated by degradation, humidity, contamination or some other external factor in the process.

4. METHODOLOGY

The research that has been developed is through the methodology of applied research, carried out in a single maquiladora plant, in the molding area belonging to the production area of automotive parts. The main technique used was the observation and analysis of the processes based on the customer's requirements. This research is applied to the plastic injection molding process through the scientific molding methodology, performing a series of tests to optimize the variables of the process and keep it stable and repetitive.

5. RESULTS

Within the injection molding process there are innumerable variables, but the ones that in this case were sought to control, are those directly involved with the processing of plastic, where each of them alter the physical characteristics of the plastic to be able to pass it into the mold cavities where it will take the final shape and meet the required specifications. These variables to be used are identified on the basis and through observation and the degree of impact within the processing where it is determined how much influence they have within the control of the injection molding process.

The most important variables within the process are:

a) Injection time. This is determined through a test called viscosity curve, which consists of making several shots (term used in plastic molding to describe each time the plastic enters the mold cavity), and making notes of the time it takes to enter the cavity at each speed set on the machine and how much pressure; in order to graph each result and visually determine the optimum speed and the optimum time where the viscosity of the plastic breaks the pattern and aligns.

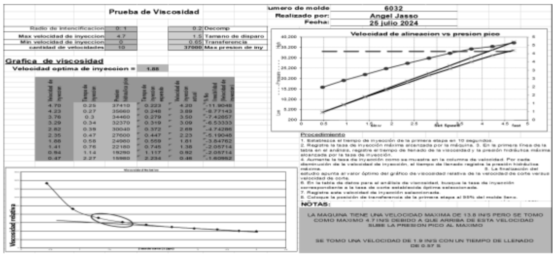

Fig. 1. *Pilot test*
Source*: own elaboration*

The previous figure shows the Excel document formulated to perform the viscosity curve test to determine the optimum speed and time to introduce the plastic into the mold cavities without affecting the physical and chemical characteristics of the mold, and thus, obtain homogeneity and consistency between each shot.

b) Injection pressure. Within the same test mentioned above (viscosity curve test) and through the same steps, the pressure reached by the plastic is observed depending on the speed used. Having the optimum time, the injection pressure to be monitored is also obtained.

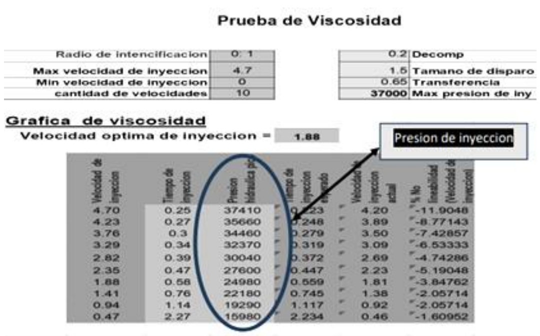

Fig. 2. *Injection pressure within the viscosity curve test.*
Source: *own elaboration*

In the previous figure it can be seen that the higher the speed, the higher the pressure on the plastic, and as the speed decreases, the pressure also decreases. The cushion. This is determined during the process, after calculating and performing the gate seal tests where it is determined how long and at how much pressure the spindle is kept forward in order to give the correct weight and shape to the molded part. Gate seal test. The following figure shows part of the Excel document formulated for the development of the gate seal test.

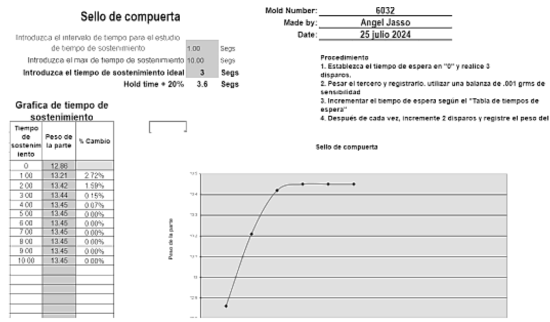

Fig. 3. *Damper seal test.*
Source: *own elaboration*

In the previous figure you can see how is a gate seal test, which basically consists of placing seconds and weighing the parts, when the weight of the part is constant it can be said that the gate is sealed and the part is completely filled and at the desired weight. The recovery or loading time of the screw.

The recovery, loading or plasticization time is obtained from the technical sheet of the resin to be processed, where the resin supplier suggests both the speed and the pressure at which the screw must rotate so that the plastic does not degrade and change its physical and chemical properties. Figure 4 shows an example of a resin data sheet where the supplier's suggestions for processing the plastic are shown.

Injection	Dry (English)	Dry (SI)
Drying Temperature	165 °F	73.9 °C
Drying Time	2.0 to 4.0 hr	2.0 to 4.0 hr
Suggested Max Moisture	0.20 %	0.20 %
Processing (Melt) Temp	540 to 570 °F	282 to 299 °C
Mold Temperature	150 to 210 °F	65.6 to 98.9 °C
Back Pressure	20.0 to 60.0 psi	0.138 to 0.414 MPa
Screw Speed	40 to 120 rpm	40 to 120 rpm

Fig. 4. *Resin technical sheet.*
Source: *own elaboration.*

The figure above shows a section of a technical data sheet for Hylon N1033HL resin where the supplier provides the conditions under which their resin should be processed, it is worth mentioning that these conditions are only taken as a basis as they may vary from machine to machine.

The scientific molding methodology is based on a series of tests, between eight and ten, developed for the control, optimization and detection of the variables that can influence the plastic injection molding process. In this objective, this methodology was summarized in only three tests, because based on experience and observation, these are the ones that have the most impact within the process and any change in these parameters completely changes the dimensional and cosmetic characteristics of the molded part.

The tests are:

a) Viscosity curve. The test is developed within an excel document formulated for this function, the procedure to perform this test is as follows:

• The injection time of the first stage is set at 10 seconds, this so that the test is not limited by time and is developed with real times.
• Next, the maximum injection rate reached by the machine is recorded.
• In the first line of the table in the analysis, the viscosity filling time and the maximum hydraulic pressure reached by the injection rate are recorded.

***Table 1:** Record of filling time and hydraulic pressure.*

Velocidad de inyeccion	Tiempo de inyeccion	Presion hidraulica pico
4.70	0.25	37410
4.23	0.27	35660
3.76	0.3	34460
3.29	0.34	32370
2.82	0.39	30040
2.35	0.47	27600
1.88	0.58	24980
1.41	0.76	22180
0.94	1.14	19290
0.47	2.27	15980

***Source:** own elaboration*

After the injection rate is increased, for each decrease in injection rate, the filling time registers the maximum hydraulic pressure.

• Completion of the study targets the optimum value of the relative viscosity versus shear rate plot.

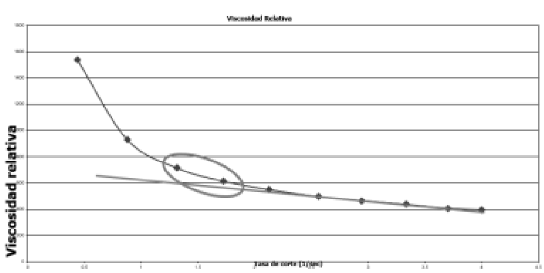

***Fig. 5.** Optimal injection value.*
***Source:** own elaboration*

b) Gate seal. The test is developed within an Excel document formulated for this function, the procedure to perform this test is as follows:

• The dwell time is set to zero and three shots are fired.
• The third shot is weighed and the weight is recorded.
• The waiting time is increased according to the waiting time table.
• After each increment, two shots are taken and the weight of the third shot is recorded.
• At the end, the optimum waiting time obtained from the study is established and reflected in the graph, this when the weight of the part no longer shows variation.

c) Cavity balancing. The test is developed within an Excel document formulated for this function, the procedure to perform this test is as follows:

• Five consecutive shots are molded, with the holding pressure, i.e., one hundred percent.
• Each part is weighed and the weight is recorded.

• Subsequently it is moved, the holding pressure is removed and the transfer position until a filling between fifty and eighty percent can be observed.
• Another five consecutive shots are molded where you visually see the short fill.
• Each part is weighed and the weight of the parts is recorded.
• If the percentage difference is less than allowed the cavities are balanced. If the percentage difference is greater than allowed the cavities are unbalanced.
• The allowed percentage of rocking in molds with two or more cavities is no more than 4%.
• If the cavities are not balanced, the mold needs repair.

5.1 Discussion

Scientific molding in the plastics industry, as demonstrated in this study, is an alternative to improve existing processes by identifying and measuring the variables pertaining to this methodology. The investment to be made by the companies, although important, finally represents an opportunity to improve their key performance indicators. The problem of dimensioning and aesthetic defects in the automotive industry represents losses in the assembly line of up to 20,000 dollars per minute stopped, charged to the supplier of the defective sub-assembly, so it is sought that the parts produced by molding are of similar characteristics with the customer's specifications, avoiding costs due to poor quality.

6. CONCLUSIONS

In the process, there are important points to be remarked: to achieve a successful implementation of the scientific mold, it is necessary the correct identification of the three variables proposed in this work such as a) viscosity curve, b) gate seal and c) cavity seal. Among the multiple variables of plastic injection molding, these three are considered the most relevant for the defects mentioned in this paper, such as dimensional defects due to burrs and aesthetic problems in one of the faces a, b, or c of the component. The correct description and measurement by means of the pertinent scientific molding tests allow organizations dedicated to the automotive industry to improve their quality and therefore their costs and with this their profitability by including methodology in their processes that have already presented great achievements in other organizations of the same line of business.

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REFERENCES

[1] J. R. Lerma, «Control del proceso de inyección: Parte 1», Plásticos Univers., n.o 263, pp. 14-15, 2023.

[2] B. Sauza-Avila, M. E. Aguirre-Márquez, C. B. Lechuga-Canto, S. S. Pérez-Castañeda, D. Cruz-Ramírez, y M. T. Lugardo-Bravo, «Análisis de costo de materiales en una industria automotriz», Ingenio Concienc. Bol. Científico Esc. Super. Ciudad Sahagún, vol. 10, n.o 19, Art. n.o 19, ene. 2023, doi: 10.29057/escs.v10i19.9741.

[3] D. Juárez Varón, R. Balart, M. A. Peydro, y S. Ferrándiz Bou, «Estudio y análisis del moldeo por inyección de materiales poliméricos termoplásticos», en 3c Tecnologia, Area de Innovación y Desarrollo S.L, 2012, pp. 40-53. Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://riunet.upv.es/handle/10251/33135

[4] «Flora Itzel Beltran Ramirez.pdf». Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://ciqa.repositorioinstitucional.mx/jspui/bitstream/1025/375/1/Flora%20Itzel%20Beltran%20Ramirez.pdf

[5] «Item 1022/169 | Repositorio COMIMSA». Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: http://comimsa.repositorioinstitucional.mx/jspui/handle/1022/169

[6] «Item 1025/375 | Repositorio CIQA». Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: http://ciqa.repositorioinstitucional.mx/jspui/handle/1025/375

[7] «Maria Cristina Ibarra Alonso.pdf». Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://ciqa.repositorioinstitucional.mx/jspui/bitstream/1025/397/1/Maria%20Cristina%20Ibarra%20Alonso.pdf

[8] «Moldeo científico: solución a problemas en la inyección de plásticos». Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://www.pt-mexico.com/columnas/use-un-checklist-para-solucionar-problemas-en-su-proceso-de-moldeo-por-inyeccion

[9] B. AG, «Moldeo por inyección: Control del proceso», Inf. Téc., vol. 63, p. 50, dic. 2001, doi: 10.23850/22565035.955.

[10] Plastico, «Moldeo por inyección: técnicas, materiales y mejores prácticas», Plastico. Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://www.plastico.com/es/noticias/moldeo-por-inyeccion-todo-lo-que-necesita-saber

[11] «Selmax - Custom Plastic Injection Mold Making & Production Molding», Selmax Corporation. Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://www.selmax.com/

[12] W. P. Rojas Campuzano, J. A. Palacios Salazar, y M. M. Miranda Ramos, «Sistema automático de adquisición y análisis de datos con machine learning para el control de calidad en una máquina de inyección de plástico», Polo Conoc. Rev. Científico - Prof., vol. 7, n.o 2, p. 4, 2022.

[13] A. Alvarado-Iniesta, R. Romero López, R. D. Molina Arredondo, y S. López Jiménez Rascón, «Sistema neuro-difuso para el control de atributos de calidad en inyeccion de plasticos», CULCyT Cult. Científica Tecnológica, vol. 10, n.o Extra 50, pp. 88-98, 2013.

[14] A. A. Iniesta, R. R. López, R. D. M. Arredondo, y S. L. J. Rascón, «Sistema neuro-difuso para el control de atributos de calidad en inyeccion de plasticos», Cult. Científica Tecnológica, n.o 50, Art. n.o 50, Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://erevistas.uacj.mx/ojs/index.php/culcyt/article/view/931

[15] «TEMA5_Moldeo_por_inyecci_n.pdf». Accedido: 5 de noviembre de 2024. [En línea].

Disponible en: https://rua.ua.es/dspace/bitstream/10045/16980/1/TEMA5_Moldeo_por_inyecci_n.pdf

[16] C. Caicedo, L. M. Crespo-Delgado, H. de la Cruz-Rodríguez, y N. A. Álvarez-Jaramillo, «Thermo-mechanical properties of polypropylene: Effects during reprocessing», Ing. Investig. Tecnol., vol. 18, n.o 3, pp. 245-252, sep. 2017.

[17] «CIQA: Centro de Investigación en Química Aplicada • A podcast on Spotify for Podcasters», Spotify for Podcasters. Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://podcasters.spotify.com/pod/show/ciqa

[18] «Scientific Molding Process: 6 Essential Steps for Success [INFOGRAPHIC]». Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://www.kaysun.com/blog/scientific-molding-steps

[19] «Rotomolding Mold, Wholesale Rotomolding Mold Suppliers, Manufacturers, Factory Price - Ningbo Xinghui Rotational Molding Technology Co. , Ltd.» Accedido: 5 de noviembre de 2024. [En línea]. Disponible en: https://www.xinghui-rotomold.com/Rotomolding-mold?gad_source=1&gclid=Cj0KCQiAoae5BhCNARIsADVLzZcUnlkICe46pbAWHs3QAwFmgHvdORmwe5H1H-bD_8oZxC3e6QpU4NEaArOFEALw_wcB