DEVELOPMENT OF AN ALGORITHM FOR THE DOSING OF POLYMERIC MATERIAL IN INJECTION MOULDING

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SUMMARY:

The proposed software solution will calculate the amount of granules to be injected into the mould by comparing real-time values transmitted by a series of sensors with ideal values from a database. This system will monitor key parameters such as injection pressure and time, cooling time, melting temperature, etc. By analysing these parameters in real time, the software solution will dose the ideal amount of granules that are required for injection, thus ensuring that the part fits the desired specifications. The computer system will also take into account the type of material used as well as the injection volume. In this way, manufacturers will increase the efficiency and accuracy of the injection process, reducing the amount of residue and ensuring product quality.

1. Introduction

In-mould injection technology has advanced significantly over the years, including the use of innovative software solutions that have revolutionised the industry.

The use of computer-aided design software is one of the most important innovations in the field of injection moulding. Engineers can use CAD software to create complex 3D models of their products, which can then be translated directly into mould design. This technology has significantly reduced the time needed to create moulds, while allowing for more precise and accurate design.

Another significant advance is the use of simulation software such as Moldflow Analysis. Engineers can use simulation software to predict how the plastic will behave during the injection moulding process, allowing them to optimise mould design and process parameters. This reduces the number of design iterations required and reduces the risk of end-product defects.

Throughout production experience, it has been observed that an injection programme made at one point in time does not achieve its initial results as time goes by, regardless of the time of day or season.

This is due to disturbing factors acting on the injection process such as ambient temperature fluctuations, different material batches, cooling water temperature fluctuations, non-return valve closing behaviour and others. Therefore, periodic intervention is required to compensate for these disturbances through small periodic program adjustments (switch point, pressures, speeds).

Given these facts, a pertinent solution that could improve the injection process would be a computer system that adjusts the dosage of polymeric material in real time from injection to injection.

2. Current status

In order to understand how to approach this problem, a detailed analysis of the injection unit is necessary. It serves to plasticise the material, to pressurise it into the mould and to maintain the pressure in the compression stage. In its composition, there are the following elements:

- **Nozzle** (the fitting at the head of the injection cylinder through which the plastic material passes from the cylinder into the injection mould);

- **Screw** (the active part of the injection moulding machine and is built in several versions);

- **Cylinder** (ensures the heating and homogenisation of the material as well as the generation of the necessary pressure);

- **Hopper** (is placed on the injection moulding machine cylinder in the area of the feed hole);

- **Injection moulding machine table** (the mechanical assembly on which the entire injection unit is mounted);

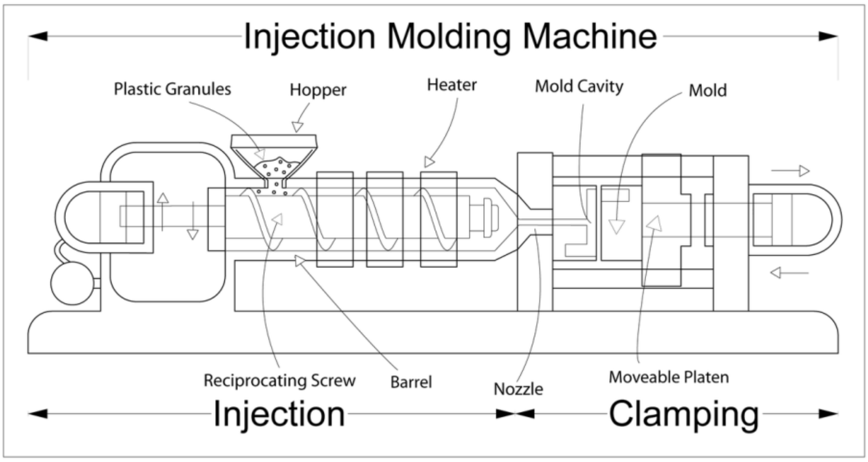

Fig. 1. Injection screw

The injection moulding screw is a basic component of an injection moulding machine that melts and injects plastic material into the mould cavity. It is divided into three distinct zones, each of which has a specific purpose in ensuring optimal plastic processing. These zones are known as the feed zone, the transition zone and the metering zone.

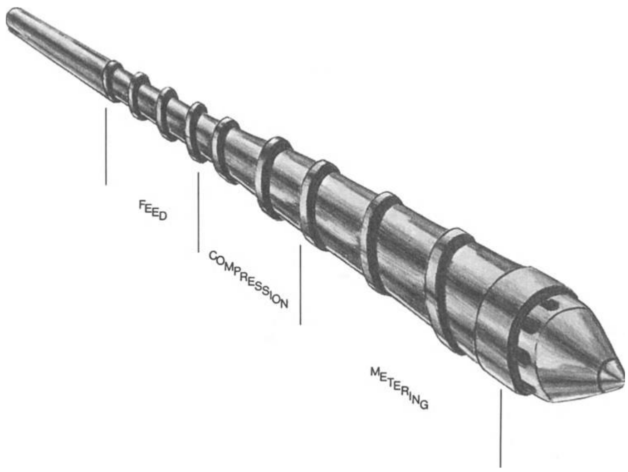

Fig.2 Injection screw. [2]

- **Feed zone**

The feed zone is located near the back of the screw and is responsible for picking up and transporting the solid plastic granules to the heated cylinder. The plastic granules are gradually compressed and transported forward in this zone. The main objective of the feed zone is to maintain a consistent and continuous flow of material, preventing bridging or uneven feeding.

- **Compression zone**

As the next area after the feeding area, this is where the plastic granules begin to melt and become molten material. The temperature gradually rises in this zone until the melting point of the plastic is reached. The screw design is optimised to generate the shear and pressure required for efficient melting. In the transition zone, the molten plastic transforms from a solid to a viscous, molten state.

- **Metering zone**

This area is the final section of the screw, closest to the die. Its function is to precisely control and measure the amount of molten plastic to be injected into the mould cavity. The depth and compression of the screw gradually decreases in this zone, allowing precise volume control. The screw rotates at a constant speed, ensuring that the molten plastic is injected into the mould in a constant and controlled manner.

The three-zone configuration of the injection screw allows optimal processing of the plastic and ensures that the molten plastic is delivered evenly and consistently during the injection process. Temperature, screw speed and other parameters in each zone can be adjusted to suit different plastic types, viscosities and injection requirements.

This zone will be the starting point in solving the dosing problem. Injection size in the mould injection process refers to the volume of molten plastic injected into the mould cavity during each cycle. It plays a crucial role in determining the quality and characteristics of the final product. Injection size is usually measured in grams and depends on a number of factors, including the size and complexity of the part as well as the type of material used and the capabilities of the injection moulding machine.

The proposed software solution consists of three main components: the database, the sensors and the algorithm. The database stores the ideal values of various parameters such as mould temperature, injection pressure and melt temperature. The sensor measures the real-time values of these parameters during the injection process. The algorithm compares the real-time values with the ideal values and calculates the mass of plastic to be injected to achieve the desired quality of the injected part.

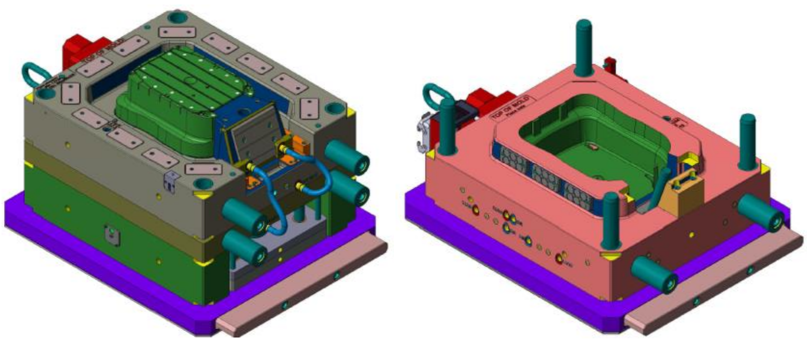

Fig.3. Movable part and fixed part of the injection mould.

It will be implemented using the Python programming language. The user interface is designed using the Tkinter library, which provides a simple and easy-to-understand user interface. Sensor data is acquired using the PySerial library, which allows communication with the sensor via a serial port. The algorithm is implemented using the NumPy and SciPy libraries, which provide very useful mathematical and statistical functions.

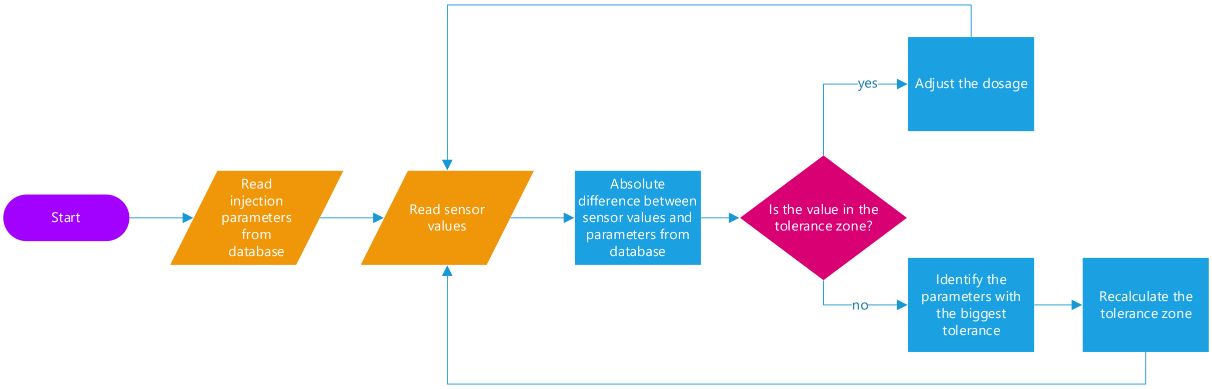

Fig. 2 Recursive algorithm diagram for dose calculation.

3. Contents

To determine the quantity of material, the mathematical model will start from the volume of the product. In this case, the volume of the product is specified. The calculation of the cavity volume in the mould will also be taken into account. The mould cavity volume is the space inside the mould that will be filled with plastic to create the product. It is usually larger than the part volume to account for factors such as shrinkage. The injection mould cavity volume (V_c) can be calculated by multiplying the part volume by a factor, usually between 1.2 and 1.5.

$$V_c = V_p \cdot F_c \tag{1}$$

The next important element is the fill factor which takes into account the additional volume required to compensate for the shrinkage of the material during the cooling and solidification stages. This is usually expressed as a percentage. To calculate the fill factor (U_F), the formula is used:

$$U_F = 1 + (\frac{P_c}{100}) \tag{2}$$

In that way, we obtain an initial formula for the dosage :

$$D_i = V_c \cdot U_F \tag{3}$$

Subsequently, the injection pressure (P_{inj}) and volume (V_{inj}) as well as the dosing rate (D_v) are integrated into the equation:

$$D = D_i \cdot \left(\frac{V_{inj}}{P_{inj} \cdot D_v}\right) = V_c \cdot U_F \cdot \left(\frac{V_{inj}}{P_{inj} \cdot D_v}\right)$$

(4)

In order to confirm the principle, values for the parameters in the formula will be entered according to the test injections performed.

Table 1. Testing values obtained from the injection test process.

Nr.	Parameter	Value	Unit
1.	Product volume	933.352	[cm^3]
2.	Cavity factor	1.2	-
3.	Shrinkage	0.75	[%]
4.	Compensatory injection volume	459.39	[cm^3]
5.	Injection pressure	1450	[bar]
6.	Dosage speed	0.55	[mm/s]
7.	Product mass	1120 ± 5%	[g]

Applying the formula based on the parameter values, we obtain :

$$D_{test} = 933.352 \cdot 1.2 \cdot (1 + 0.75) \cdot \left(\frac{459.39}{1450 \cdot 0.55}\right) = 1129.05 \quad [g]$$

(5)

After applying the formula with the real parameters obtained from the test injection, we can see that the mathematical model is correct and falls within the error margin of the product mass value.

$$1064 \leq 1129.05 \geq 1175 \; [g]$$

(6)

4. Conclusion

This project presents a software solution that optimises the injection process, allowing real-time adjustment of the plastic supply to meet desired specifications. The algorithm compares actual sensor values with ideal parameters and then adjusts this plastic dosage to ensure that the finished product meets the desired quality standards.

One of the main advantages of the software is the user-friendly interface, which allows the user to enter ideal values for each parameter and monitor the injection moulding process in real time. The interface displays sensor values and ideal values as well as a graph of the injection parameters in real time. This feature allows the user to monitor the performance of the injection process.

This computer system reduces the amount of wasted material and improves product quality by optimising the process. The software solution ensures that plastic material input is adjusted to meet desired specifications, preventing the production of defective parts and reducing material waste.

5. Bibliography

[1]. Constantin Gheorghe OPRAN (2014), "*Tehnologii de injecție în matrițe"*, Bren, București, ISBN 978-606-610-085-4.
[2]. Dominick V. Rosato, Donald V. Rosato, Marlene G. Rosato (2000), *"Injection molding handbook"*, Norwell, Massachusetts, ISBN 0-7923-8619-1.
[3]. Suhas Kulkarni (2017), "Robust Process and Scientific Molding", Hanser, Germania, ISBN 978-1-56990-586-9.
[4]. John P. Beaumont (2004), *„Runner and Gating Design Handbook"*, Hanser, Germania, ISBN 3-446-22672-9.
[5]. Rosato, D.V. & Rosato, M.G. (2000), „*Plastics Processing Data Handbook"* Springer,US, doi: 10.1007/978-1-4757-3169-9.
[6]. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot (2007), *„Transport Phenomena"*, US, ISBN : 978-0-4470-11539-8.
[7]. Peter Unger (2006), „Gastrow Injection Molds", Germania, ISBN-10 :1-56990-402-2, ISBN-13: 978-3-446-40592-9.

5. Notations

- V_c : Cavity volume [cm^3]
- V_p : Product cavity[cm^3]
- F_c : Cavity factor
- U_F: Fill factor
- D_i : Initial dosage [g]
- D : Dosage [g]
- V_{inj} : Injection volume [cm^3]
- P_{inj} : Injection pressure [bar]
- D_v : Dosing speed [mm/s]