A Development on Design of the Multi Cavity Injection Moulds with a Cold Runner System for Rubber Seal Manufacturing

Supasit Rodkwan[1,2,*] Chakkrit Muntasawe[1,2] and Suntorn Rodwilai[2,3]

[1]Department of Mechanical Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand 10900

[2]Center of Excellence in Rubber Mould, Research and Development Institute of Industrial Production Technology, Faculty of Engineering, Kasetsart University, Thailand 10900

[3]Industrial Production Technology Program, Faculty of Engineering, Kasetsart University, Thailand 10900

*Corresponding Author: E-mail: fengssr@ku.ac.th, Tel.: 662 942 7188, Fax.: 662 942 7189

Abstract

In general, rubber seals are manufactured using compression moulding which results in long period of cycle time, excessive flashes and nonuniform part thickness. In this research work, a design of the multi cavity injection moulding with a cold runner system for Nitrile Butadiene Rubber (NBR) seal production is proposed to replace the compressing moulding process.

The injection parameters including gate position, runner pattern and balancing, material flow rate, injection time, injection speed, injection pressure, injection temperature, shear rate, as well as viscosity were investigated. A numerical simulation was performed to predict the flow characteristics and then to design the cold runner system. In addition, the part injection experiment using the developed mould design was conducted for simulated result verification.

The results show that the cold runner system with equivalent distance and four pin gate type selection as well as the flow rates of 51, 58 and 66 cm^3/s and the injection speeds of 51, 54 and 57 % for the injection temperatures of 70, 80, and 90 °C, respectively, leads to the optimized operating condition of part injection process. Consequently, it can be seen that the multi cavity injection mould with a cold runner system was successfully developed to reduce product cycle time and to provide less waste materials leading to higher production cost.

***Keywords**:* Multi Cavity Injection, Mould, Cold Runner, Seal, Nitrile Butadiene Rubber.

1. Introduction

Rubber moulding is one of widely common processes to manufacture the rubber parts used in automotive, electrical, electronics, as well as pharmaceutical industries. Rubber moulding can be further classified into compression, transfer and injection moulding. In general, rubber seals used in spray bottles, as shown in Fig. 1, are manufactured using compression moulding which results in long period of cycle time, excessive flashes and nonuniform part thickness. In this research work, a design of the multi cavity injection moulding with a cold runner system for Nitrile Butadiene

Rubber (NBR) seal production is proposed to replace the compressing moulding process for precision rubber seal production. The use of cold runner can benefit in reduction of rubber waste materials in the runner system. Therefore, the objective of this work is to develop and to design the cold runner in system multi cavity injection moulding for precision rubber seal products. In addition, the application of Computer Aided Engineering (CAE) is introduced to predict and flow behavior in order to obtain a mould design in this work [1-5].

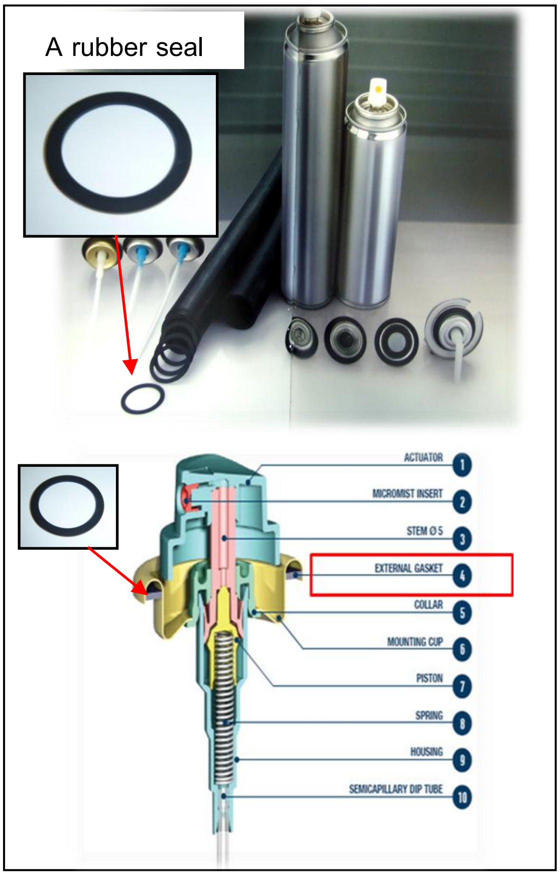


Fig. 1 A rubber seal used in a spray bottle

2. Methodology

The overall methodology for mould design and manufacturing for seals is illustrated in Fig. 2. The main tasks include gate and runner design, as well as injection conditions.

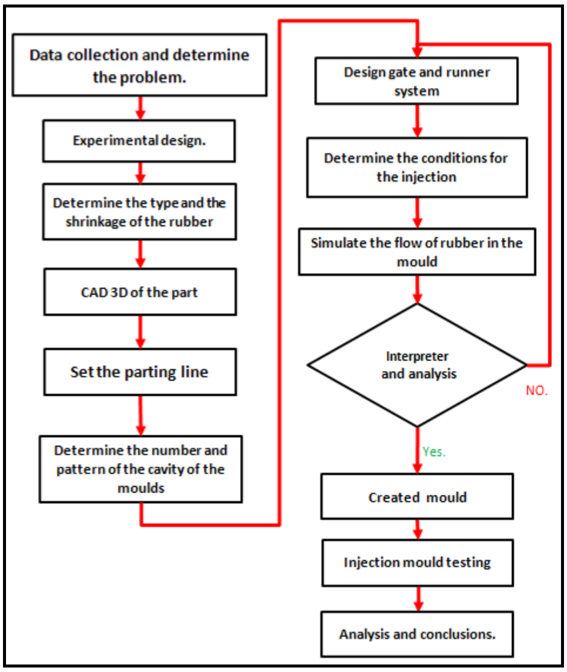


Fig. 2 Mould design and manufacturing flowchart

2.1 Gate and Runner Design

Various ball nose type runner patterns with different length and constant cross sectional area of 73.10 mm^2 were developed as shown in Fig. 3 and then were simulated using 3D-SIGMA [5] for the runner design using NBR material with 80 shore A hardness. In addition, pin point gate type was selected with the total cross sectional area of 19.63 mm^2 [1]. In simulation, cubic element type with a number of 1,000,000 – 10,000,000 elements is considered.

2.2 Injection Conditions

Injection variables such as temperatures and flow rate used in this research are listed in Table. 1. In addition, the governing continuity equation for incompressible flow can be described as Eq. (1):

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

Where *u, v, w* are velocities in *x, y, z,* axes respectively.

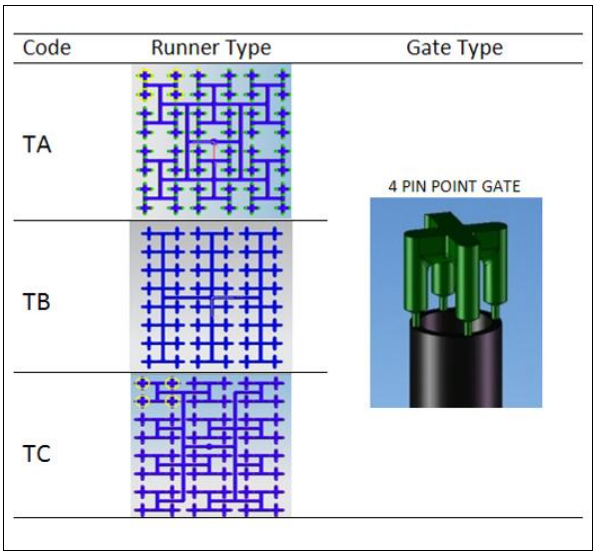


Fig. 3 Various runner used in this research

3. Results and Discussions

3.1 Gate and Runner Design

Element verification is shown in Fig. 4; as a result, the steady state of pressure was reached when the number of element is 4,000,000. Therefore, element number is chosen to be 6,000,000 in this work. Table. 2 shows the simulated results for three different runner design with various stage of injection from 30% to 100%. The characteristics of each runner type are listed in Table. 3. Although the TB runner provides less waste and less cavity volume; however, the non-runner system was used in this work, as a result the TA runner which was selected.

3.2 Injection Conditions

Fig. 5 shows various parameters affecting the injection process of rubber seals. In addition, relationship of the flow rate, the inlet injection pressure and the injection time is shown in Fig. 6. Using this obtained data, the velocity selection can be done as depicted in Table. 3.

Table 1. Injection variables used in an injection moulding process in this work

Parameters	Values
1.Temperature of rubber material in an injection cylinder	70, 80, 90 °C
2.Mould temperature (runner plate)	80 °C
3. Mould temperature (cavity plate)	180 °C
4.Flow rate	40, 50, 60, 70, 80 cm^3/s
5. Curing time	230 s
6.Material and hardness	NBR, 80 Shore A

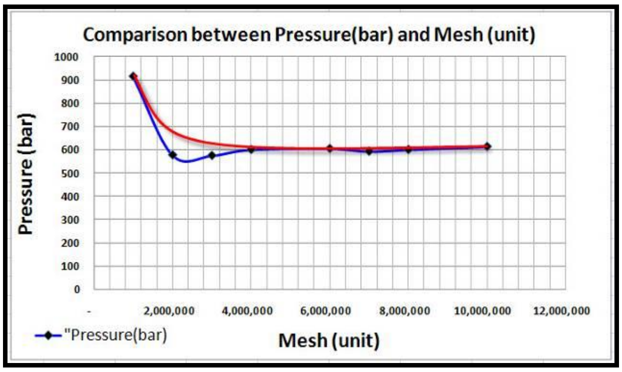
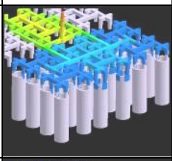
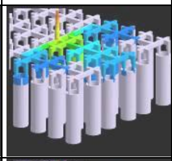
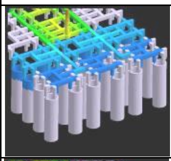
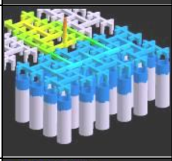
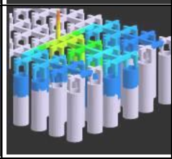
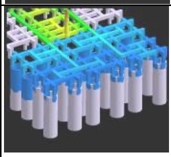
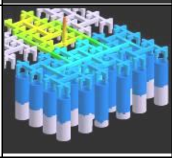
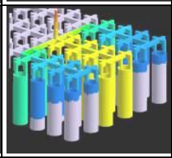
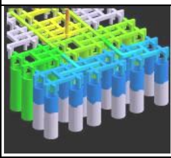
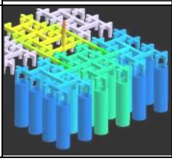
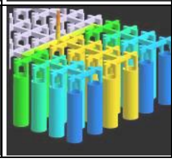
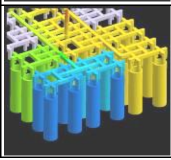


Fig. 4 Mesh verification

Empirical work was also performed using the injection machine with a hydraulic pressure of 160 bars as shown in Figs. 7 and 8.

Fig. 9 also shows the comparison between the numerical simulation and experimental data on the part in each injection stage. Acceptable discrepancy on injection time can be found in Table. 4.

Table. 2 Simulated results for three different runner design with various stage of injection

	TA	TB	TC
30%			
50%			
80%			
100%			

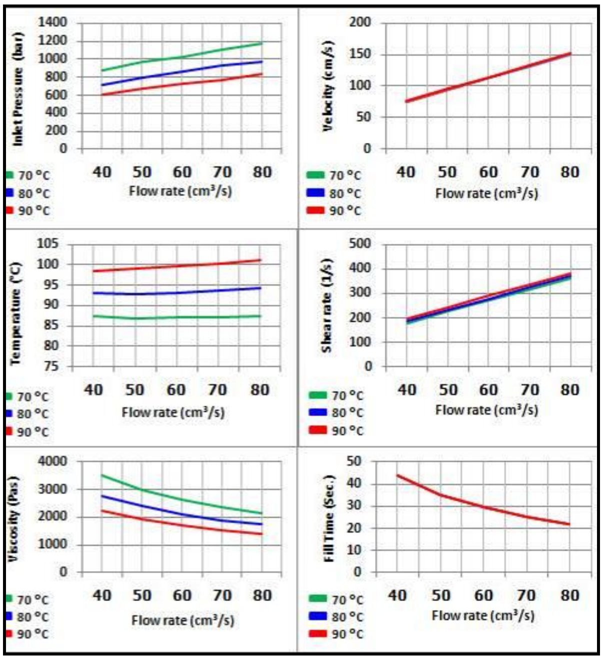


Fig. 5 Various parameters affecting the injection process of rubber seals

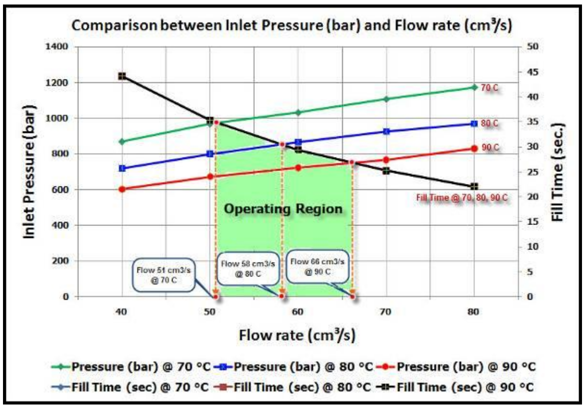


Fig. 6 Relationship of the flow rate, the inlet injection pressure and the injection time

Table. 3 Relationship between flow rate and injection speed on a specific injection temperature

Injection temperature (°C)	Flow rate (cm^3/s)	Injection speed (%)
70	51	51
80	58	54
90	66	57

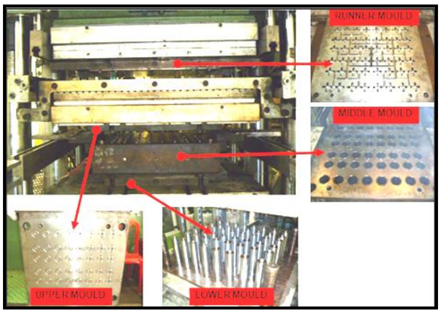


Fig. 7 Mould components

Fig. 8 Rubber parts from one cycle time

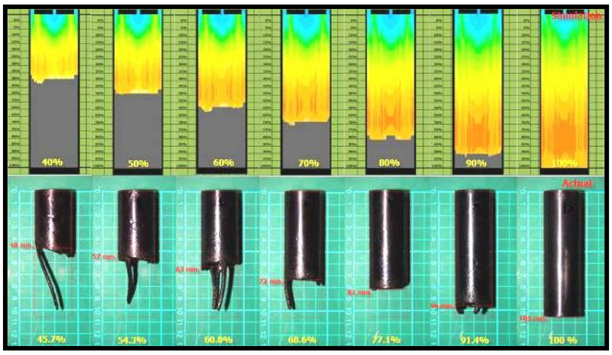


Fig. 9 Comparison between the numerical simulation and experimental data

Table. 4 Error comparison based on an injection

Injection speed (%)	Simulated injection time (s)	Actual injection time (s)	Discre pancy (%)	Average discrepancy (%)
51	35	34.4	1.74	2.22
54	31	30.5	1.64	
57	26.5	27.4	3.29	

It can be seen that the average discrepancy is within acceptable range considering product quality aspect.

4. Summary

In this research work, a design of the multi cavity injection moulding with a cold runner system for Nitrile Butadiene Rubber (NBR) seal is proposed to substitute the compressing moulding process for precision rubber seal production. The cold runner system with equivalent distance and four pin gate type selection as well as the flow rates of 51, 58 and 66 cm^3/s and the injection speeds of 51, 54 and 57 % for the injection temperatures of 70, 80, and 90 °C, respectively, leads to the operating condition of part injection process. Consequently, it can be seen that the multi cavity injection mould with a cold runner system was successfully developed to reduce product cycle time and to provide less waste materials leading to higher production cost.

5. Acknowledgments

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6. References

[1] Beaumont, J. P. (2008), *Runner and Gating Design Handbook: Tools for successful injection molding, 2nd Edition*, Hanser Gardner.

[2] Puttajak, S. (2002), *Rubber Physical and Rheology*, Songklanakarin University Press.

[3] Saedan, M. (1995), *Fundamental Rheology*, Songklanakarin University Press.

[4] Chutima, P. (2002), *Engineering Design of Experiment*, Chulalongkorn University Press.

[5] SIGMA Engineering GmbH (2004), *3D-SIGMA Manual, Version 4.5*, Aachen, Germany.