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Multi - response optimization of injection molding process parameters using moldex 3D

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ABSTRACT

The research is an approach to multi - response optimization of injection molding process parameters. In this author uses Moldex 3D to analyse the injection molding process. The experiments are plotted using L9 orthogonal array, which is generated with the help of DOE module in Moldex3D software. The process parameters melt temperature, packing time, Max. packing pressure are optimized by multiple response consideration of max cooling time and warpage. With the help of Moldex 3D software, the desirability function analysis optimal values of process parameters are obtained. The analysis shows optimized process parameters combination of melt temperature, packing time and max- packing pressure which are 250°C, 6s, and 140 Mpa respectively. The confirm run results show that by this injection molding machine performance can be improved. However, the future work should be needed to analyze multi cavity molding for the part which is more appliable before we can make the real run.

Keywords: *Injection molding, Moldex 3D, multi - response optimization*

1. INTRODUCTION

There are numerous approach had been developed which present the solution related to optimization of process parameter. Ahmad et.al focused on the warpage minimization. They selected the ABS material and process parameters melt temperature, mould temperature, packing pressure, packing time for study. By considering Taguchi method, L18 orthogonal array experiments were planned. They found that as melt temperature, mould temperature increased warpage increased and packing pressure and packing time increased warpage is minimized[1].

Akbarzadeh et.al considered the effect of warpage and shrinkage with the help of Taguchi and ANOVA approach and select polypropylene (PP) and polystyrene (PS) material. The input parameters were melt temperature, injection pressure, packing pressure and packing time. They found that melt temperature and packing pressure were effective process parameter amongst the melt temperature, packing pressure and packing time[2].

Ghazali et.al studied effects of parameters involved in producing Nylon PA66 side arms that lead to this warpage. For this they considered melt temperature, filling time, packing pressure and packing time as process parameters. Simulation was also done with the help of Mold flow software. They found melt temperature and packing time were most significant parameters[3].

Villarreal et.al considered simple rectangular plaque for cycle time and warpage as response factor. They consider melt temperature and packing pressure as the two process factor. After optimization of process parameter they saw that melt temperature contribute a lot in cycle time and warpage minimization[4].

Chi-Wei Su et.al were carrying out research to optimize process parameters and adaptive quality monitoring injection molding process for materials with different viscosity. In this study, the viscosity index, peak pressure, and clamping force peak are characterized as quality monitoring parameters, which guide process adjustments and enhance the stability of the control system. Based on the results of preliminary experiments, the appropriate V/P switchover point and clamping force were determined by analyzing the peak pressure and clamping force for materials with varying viscosities. The viscosity index and peak pressure were found to be strongly correlated with the weight of the injection molded parts for different materials. These characteristics, along with the

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clamping force peak, were defined as quality monitoring parameters for guiding adjustments and increasing process stability in the presented control system. By combining nozzle pressure curve-based adaptive process control with clamping force peak monitoring, the weight variation of injection molded parts was reduced. The coefficient of variation of product weight for materials with low to high viscosities was decreased to 0.031%, 0.020%, and 0.024%, respectively, as demonstrated by the experiments[5].

Gurjeet Singh et.al studied the multi - response optimization of injection moulding process parameters to reduce cycle time and warpage. The injection molding process parameters, including injection pressure, melt temperature, packing time, and packing pressure, were optimized using a multi-response approach considering cycle time and warpage. After conducting a desirability function analysis and using composite desirability values, the optimal values for the process parameters were determined. The experimental results demonstrate that this injection molding machine performance can be improved, as evidenced by the successful production of injection molded products using virgin polypropylene through this approach. Because the error of experiments were found approximately of 15%, the model is fit for the cycle time and warpage[6].

There were a number of researchers work on factors that have high possibility influencing on cycle time and warpage. This study investigates three factors: melt temperature, packing time, and max packing pressure which are considered to have better responses of max cooling time and warpage.

2. DESIGN OF EXPERIMENTS

2.1. Base run

a. Model information

In this study, the author chose a plastic folk as a part to analysis the injection molding process. The model's thickness is in range from 0.15 mm to 3.865 mm.

Figure 1. Model information

After choosing gate location, material and analyzing the cooling system more suitable for the project, a base run for DOE was made. This run would have information as follow:

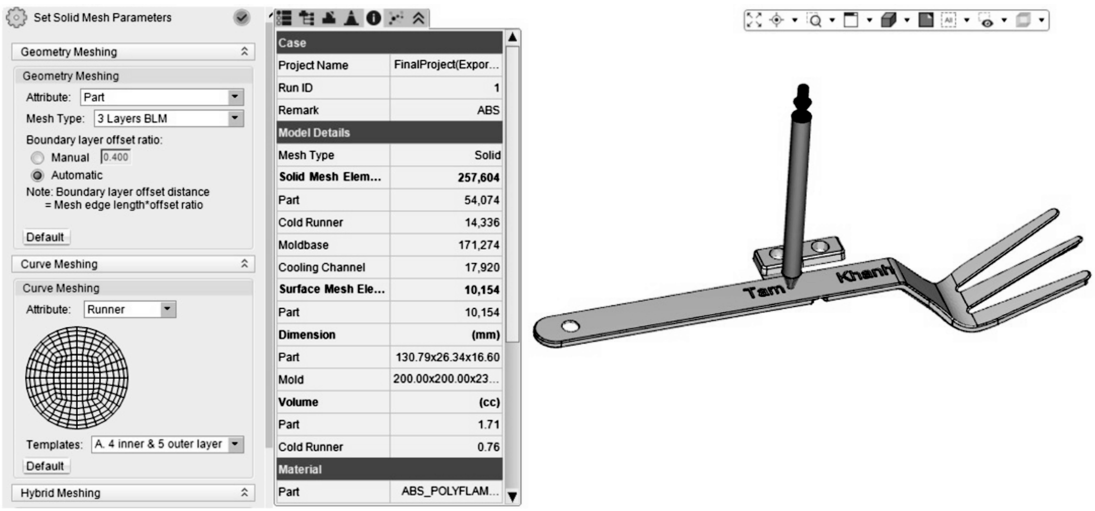


Figure 2. Model details and mesh parameters

b. Material information

From the material bank of Moldex 3D, we can easily take necessary information such as, viscosity, PVT charts, and mechanical properties of material. The material we chose is ABS POLYFLAM RABS 90950 UV5.

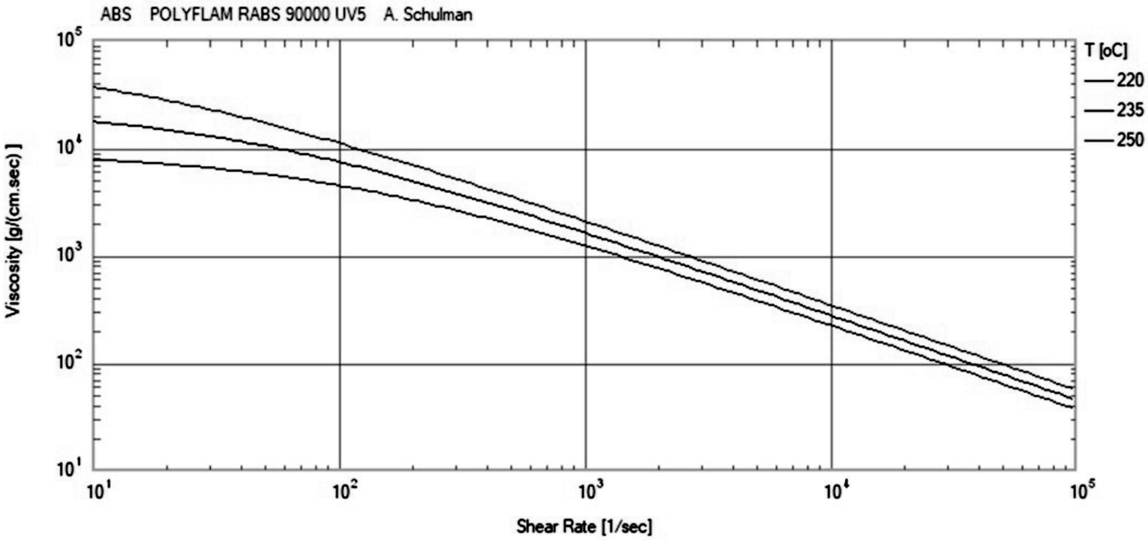


Figure 3. Viscosity feature of material

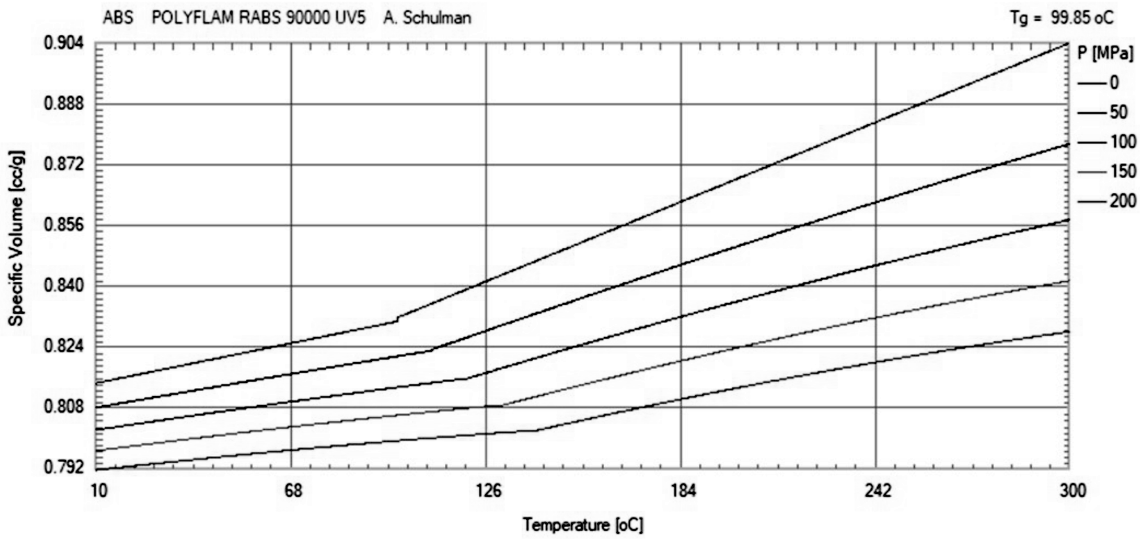


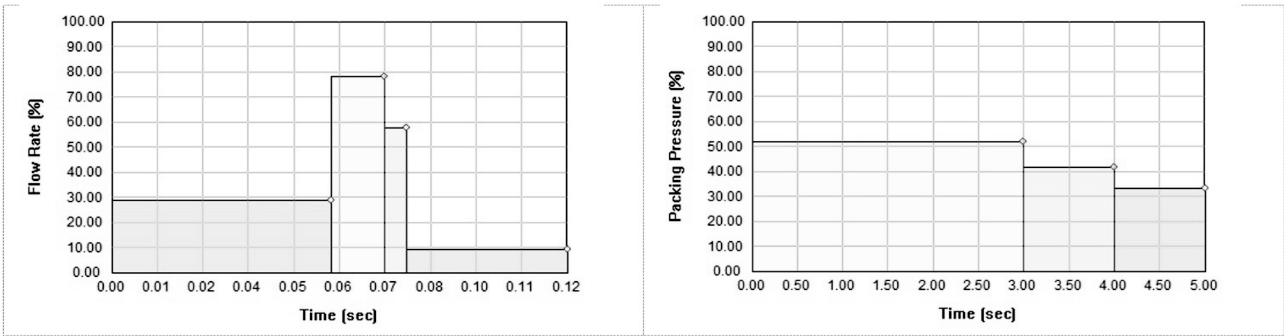
Figure 4. PVT chart of material

Polymer	ABS
Grade Name	POLYFLAM RABS 90000 UV5
Producer	A. Schulman
Comment	MVR(220,10)= 30 cm3/10min,D=1.2 g/cc
Moldex3D Bank Version	2021.1.3(Modified)
Process condition	
Melt temperature (minimum)	220 oC
Melt temperature (normal)	235 oC
Melt temperature (maximum)	250 oC
Mold temperature (minimum)	40 oC
Mold temperature (normal)	50 oC
Mold temperature (maximum)	60 oC
Ejection temperature	99.85 oC
Freeze temperature	119.85 oC

Figure 5. Thermal properties of material

c. Process conditions

For setting process parameters, I chose the machine mode 1 in Moldex 3D, with all the set up as below:



a) Flow rate profile *b) Packing pressure profile*

Figure 6. Flow rate profile and packing pressure profile of the run

For the flow rate set up, typically, a higher injection rate is preferable as it allows a larger volume of plastic material to flow through the mold in a shorter duration, preventing incomplete filling caused by melt flowability loss due to excessive cooling at low injection speeds in thinner sections. However, a high injection rate may result in thermal decomposition of plastic with poor heat stability due to excessive shear heating, often resulting in aesthetic defects like yellowing, brown-black stripes, and other appearance-related issues[7]. As shown in Figure 6 for the part, at the beginning, the melt front has a smaller initial cross section, corresponding to a flow rate of 30%. As the cross section gradually expands, the flow rate transitions to a faster 79% in the second stage. In the latter half of the injection process, the cross section begins to decrease, resulting in a lower flow rate of 59%, which further decreases to 10% before the mold cavity is completely filled.

2.2. DOE setting up

By applying the Taguchi method, the orthogonal array has been highly utilized in engineering analysis and consists of a design of experiments with the objective of acquiring data in a controlled way, to take information about the behavior of a given process. The effects of several process parameters can be determined effectively by carrying out matrix experiments based on the Taguchis orthogonal design [8]. In this project, the process parameters ranges recommended from Moldex3D software. L9 orthogonal array for three parameters and three levels were selected. After we have the result from base run, we choose the control factors and quality factors for DOE set up. For the melt temperature, there were three levels of 220°C, 235°C and 250°C respectively. While the packing time was set with 4.75s, 5.3s and 6s, the max. Packing pressure was input of 140MPa, 150Mpa and 160Mpa respectively.

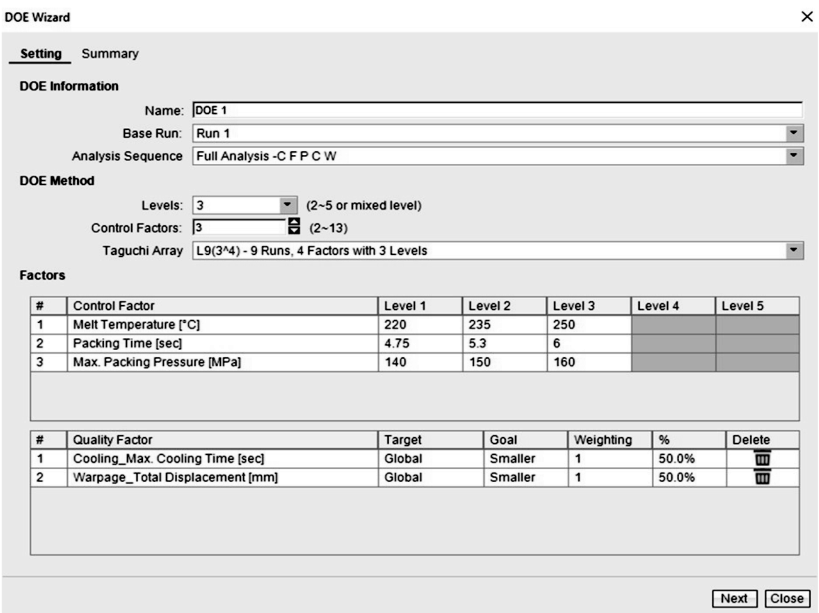


Figure 7. DOE set up

3. RESULT AND DISCUSSION

3.1. Experiment results

After having the matrix experiment design, Moldex 3D would run 9 processes applying each set of parameters, then it shown the results of these runs (shown in Figure 8).

DOE Wizard

Setting **Summary**

DOE Table

Control Factor	Melt Temperature [°C]	Packing Time [sec]	Max. Packing Pressure [MPa]	Quality Factor	Cooling_Max. Cooling Time [sec]	Warpage_Total Displacement [mm]
Level	3	3	3	Target	Global	Global
Min	220	4.75	140	Goal	Smaller	Smaller
Max	250	6	160	Weighting	1	1
1. Run 3	220	4.75	140	1. Run 3	4.04823	0.419851
2. Run 4	220	5.3	150	2. Run 4	3.47051	0.454029
3. Run 5	220	6	160	3. Run 5	2.73831	0.493978
4. Run 6	235	4.75	150	4. Run 6	4.39574	0.314759
5. Run 7	235	5.3	160	5. Run 7	3.78884	0.358704
6. Run 8	235	6	140	6. Run 8	3.2401	0.295546
7. Run 9	250	4.75	160	7. Run 9	4.69423	0.316491
8. Run 10	250	5.3	140	8. Run 10	4.15409	0.232856
9. Run 11	250	6	150	9. Run 11	3.50332	0.269387
Run 12*	250	6	140	Run 12*	3.47496	0.237206
Prediction						
Setting	250	6	140	Predicted Value	3.47496	0.237206

Figure 8. Experiment results

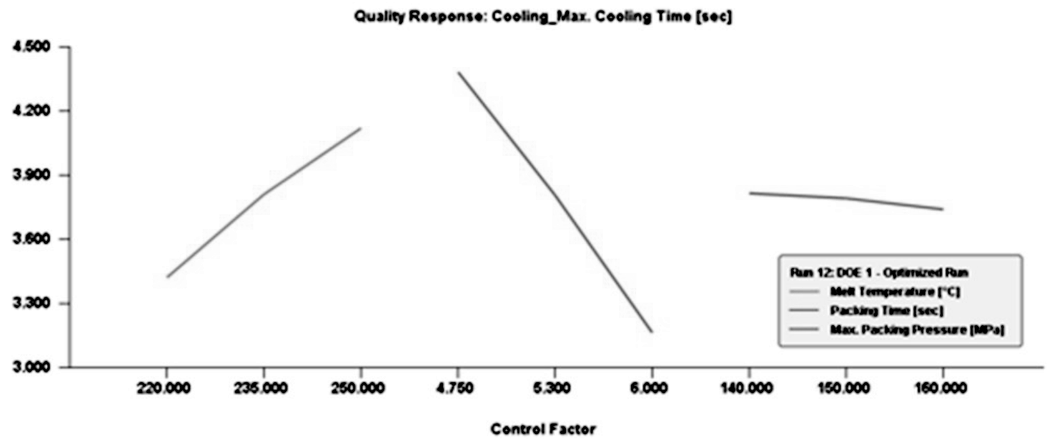


Figure 9. Quality response: cooling_Max cooling time

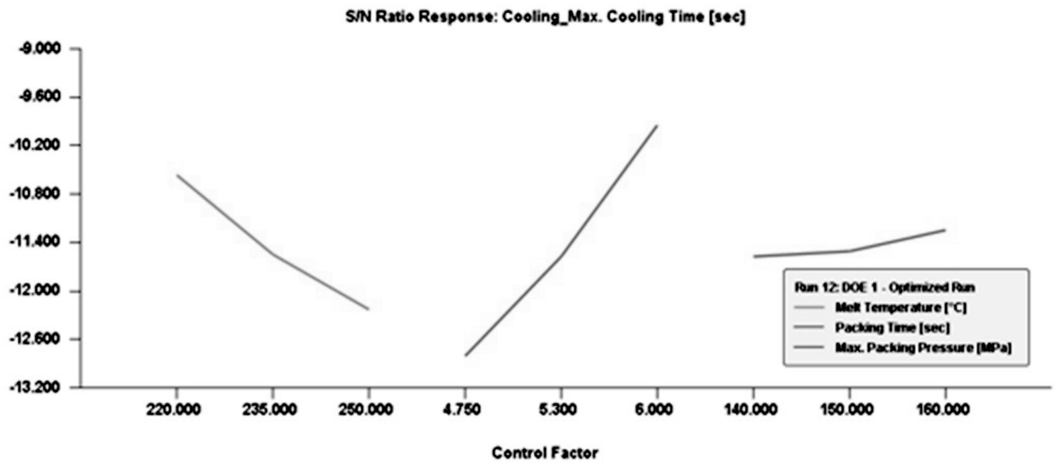


Figure 10. S/N ratio response: cooling_Max cooling time

As shown in Figure 9 and Figure 10, melt temperature and packing time have most influence on the max cooling time, while max packing pressure has less affection on it.

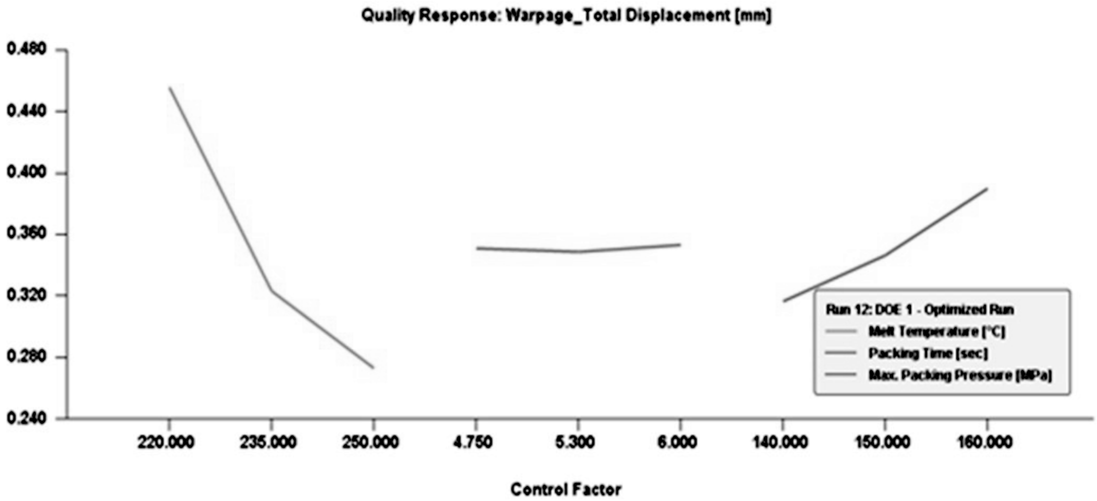


Figure 11. Quality response: cooling_total displacement

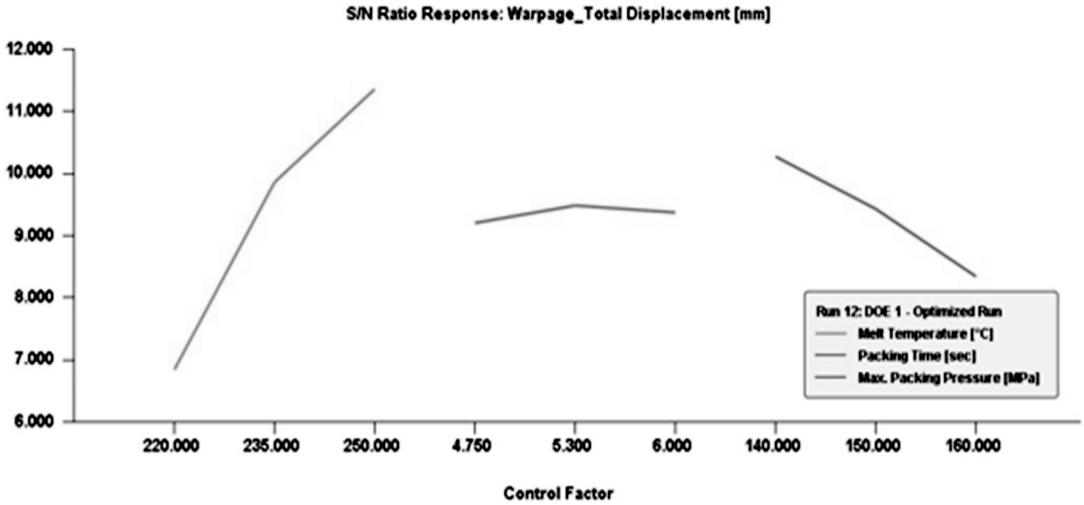


Figure 12. S/N ratio response: cooling_total displacement

As shown in Figure 11 and Figure 12, melt temperature and max packing pressure time have the most influence on total displacement, while packing time has less affection on it.

3.2. The confirming run results.

After obtaining the optimized parameters, Moldex 3D would carry out a confirm run which used those set of parameters. They are 250°C, 6s and 140 Mpa for melt temperature, packing time and max. packing pressure respectively.

Figure 13. Cooling _max cooling time

The max cooling time is optimized of 3.475s compared to 4.201s in the base run.

Figure 14. Warpage _ total displacement

The total displacement is quite low, just 0.237mm. It is improved compared to the base run of 1.08mm.

4. CONCLUSION

Based on the analysis results, the product meets the requirements; however, to apply to the reality, we should use the multi- cavity for this kind of product. The DOE results show that melt temperature and packing time have more impact on the cooling time while warpage is affected more by melt temp and packing pressure. The best level of melt temp, packing time and Max packing pressure for the smallest cooling time and warpage are 250°C, 6s and 140 Mpa respectively.

REFERENCES

[1] A. H. Ahmad, Leman, Z., Azmir, M. A., Muhamad, K. F., Harun, W. S. W., Juliawati, A., & Alias, "ABS In Modelling & Simulation," *AMS'09*, Third Asia International Conference on pp. 470-474, 2009.

[2] A. Tootoonchi, "A.International Journal of Modeling and Optimization," 2011.

[3] M. F. Ghazali, Shayfull, Z., Shuaib, N. A., Nasir, S. M., & Salleh, "Int J of Basic & Appl Sci," *IJBAS-IJENS*, no. 11(01), 2011.

[4] M. G. Villarreal, Mulyana, R., Castro, J. M., & Cabrera-Ríos, "In Simulation Conference," *IEEE*, no. WSC 2008. Winter (2008) -1995-2003, 2008.

[5] C.-W. Su et al., "Optimization process parameters and adaptive quality monitoring injection molding process for materials with different viscosity," *Polymer Testing*, vol. 109, p. 107526, 2022/05/01/ 2022.

[6] G. Singh, M. K. Pradhan, and A. Verma, "Multi Response optimization of injection moulding Process parameters to reduce cycle time and warpage," *Materials Today: Proceedings*, vol. 5, no. 2, Part 2, pp. 8398-8405, 2018/01/01/ 2018.

[7] M. L. Wang, R. Y. Chang, and C. H. Hsu, *Molding Simulation: Theory and Practice*. Carl Hanser Verlag GmbH & Company KG, 2018.

[8] R. K. Roy and R. Rāẏa, *A Primer on the Taguchi Method*. Van Nostrand Reinhold, 1990.

Tối ưu hóa đa mục tiêu các thông số trong quá trình ép phun khuôn ép nhựa dùng moldex 3D

Lê Văn Cảnh

TÓM TẮT

Nghiên cứu là một cách tiếp cận phương pháp tối ưu hóa đa mục tiêu các thông số trong quá trình ép phun khuôn ép nhựa. Trong nghiên cứu này, tác giả sử dụng phần mềm Moldex 3D để phân tích quá trình ép phun. Các thí nghiệm được thiết kế và thực hiện dựa trên mô hình Taguchi trực giao L9, được khởi tạo nhờ *modun DOE trong phần mềm Moldex 3D. Các thông số của quá trình như nhiệt độ nóng chảy, thời gian giữ áp, áp suất giữ tối đa được tối ưu hóa dựa trên nhiều mục tiêu đầu ra bao gồm thời gian làm nguội tối đa và độ cong vênh. Với sự hỗ trợ của phần mềm Moldex 3D, giá trị tối ưu của các thông số ép phun được xác định thông qua việc phân tích hàm mong muốn. Phân tích cho thấy các thông số tối ưu gồm có nhiệt độ nóng chảy, thời gian giữ áp và áp suất giữ tối đa lần lượt là 250°C, 6 giây, và 140Mpa. Kết quả thực nghiệm xác nhận cũng cho thấy rằng quá trình ép phun được cải thiện. Tuy nhiên, công việc cần nghiên cứu trong tương lai là cần thiết có sự phân tích quá trình ép phun đa lòng khuôn cho sản phẩm mà có tính áp dụng cao hơn trước khi đưa quá trình vào thực tế.*

***Từ khóa**: Ép phun khuôn nhựa, Moldex 3D, tối ưu hóa đa mục tiêu*

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