A literature review on injection moulding process based on runner system and process variables

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A literature review on injection moulding process based on runner system and process variables

P D Kale[1], P D Darade[2] and A R Sahu[1]

[1]G H Raisoni College of Engineering and Management, Pune, India
[2]Sinhgad Institute of Technology and Science, Narhe, Pune, India

Email: prachidkale@gmail.com

Abstract. Injection moulding is the fabrication process which is the most widely used for polymeric. This paper describes Injection moulding process in detail along with its process parameters and their effects on the moulding component. Runner system is playing a significant role in the quality of the moulded part. Every injection moulding method works when a plastic substance flows from the sprue of the runner system, through a gate into the mould cavity. Runner system is of two types, Hot runner and cold runner system, both having some advantages and disadvantages of each. Research has been carried out which concludes about the effectiveness of hot runner over the cold runner. It has been observed that although hot runner gives better quality of the product, many of the industries use cold runner due to the high cost and complexity of the design. The paper deals with the illustration of mould defects related to the process parameters and the need for its Optimization. This paper focuses on the effectiveness of hot runner systems and scrap reduction of the process by replacing the cold runner system with the hot runner
Keywords: Injection moulding, Process parameters, Runner system, Mould defects.

1. Introduction
Injection moulding is the most traditional plastic parts manufacturing procedure. Using injection moulding, a large range of items are made, varying in scale, complexity and implementation. Hot runner is better than cold runner but is seldom utilised due to high cost and difficulty. Every substance needs a complicated set of parameters such as injection temperature, injection pressure, flow rate, mould temperature, ejection temperature, cooling rate and cycle time. Improper set of parameters leads to many flow lines, burn marks, warping, vacuum voids / air pockets, sink openings, weld lines, jetting. Few defects, including discoloration, plastic use and delamination storage. Quick shots and flash triggers faulty construction or fix. These criteria include process optimization and defect-removal collection. The impact of these criteria on moulding process and recommendations to generate defect-free components needs more study.

2. Literature review
Mr. P. Vinod, Mr. K. Vijaykumar [7] have designed multi-cavity injection mould with HRS and CRS. By comparing both designs, they researched the impact of runner systems, mould cooling and venting. Moulding analysis is carried out using ANSYS.
G. Rajendra Prasad, Dr S. Chakradhar Goud [8] Studied dynamic characteristics like hot runner nozzle strain using analysis in FEA.
N. Divya, Dr. S. N. Malleswara Rao, Dr. V. S. Parameswara Rao, [9] concluded in their paper as the hot

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runner system accommodates the molten plastic. The runner method determines mould component consistency and productivity. They performed structural and thermal analysis of the mould 's original and updated designs concluding that the modified design produces the best performance.
Rashi A. Yadav, S. V. Joshi, N. K. Kamble [5], Recent studies to design and determine injection moulding method parameters. In parameter environment for injection moulding, several test works were performed focused on various approaches. In the plastic injection moulding (PIM) industry, optimum process parameter settings are critically affected by performance, consistency, and cost of output.
A. Demirer, Y. Soydan [3], Unlike the conventional runner approach, hot runner machine effects on injection moulding method and injection product properties were studied. They used data from method parameters experiments. Injection pressure and temperature change a broad variety. For the hot runner process, injection pressure was marginally lower for higher weight samples. If the temperature of the process increases, shrinkage and warpage increased, reducing with increased injection pressure and happening at a low level where the sample weight was high.
Gurjeet Singh, Ajay Verma [10] Studied primary moulding conditions from design creation to product manufacturing. They studied different factors based on processing parameters. It is concluded that efficiency declines when channelizing efforts to improve quality. Parameters must be optimised to ensure good quality and efficiency. Authors analysed different responses to injection moulding process quality based on output parameters and methods.
Mehdi Moayyedian, Kazem Abhary [11], the injection moulding method implemented a new gate geometry. It was observed that current edge gates corners create turbulence of molten plastic leading to internal and external defects. New geometry was introduced to reduce injected parts' internal and external flaws. The study's goal was to make the final piece easier geometry, which eliminates the last part 's apparent blemish after de-gating.
V.Chandra Sekhar, N. Jaya Krishana [12] Suggested design for two circular flat plate 1 mm wide. Contribution of this research was to change the existing edge gate geometry by eliminating rectangular edge gate corners to minimise scrap occurrence of injected bits. Smooth plastic flow through cavities often prevents internal and exterior defects. The result reveals no shot-filling cavities. No weld lines, meld lines or sink marks were identified with new edge gate design. The experiment ends with an added portion of the initial edge gate step, less noticeable than the current edge gate.
Harold Godwin [13], Mold Making Technology — Competition and price pressure in the injection moulding industry affected many manufacturers of OEMs, moulders, and moulds. The required operating costs were due to increased resin, electricity, human capital, resulting in profit pressure. The decision to use a hot runner was noticeable for medium and large moulded component volumes.
Sal Benenati,[14], Hot runner systems are so popular injection moulds. Hot runner suppliers must adjust part designs to satisfy more strict output and material demands, sometimes adding complexity to products. Some techniques , for example, use moving motors to control valve gates, some need specific heaters, and some require unique mould tolerances to function properly. Standard convection, low shear velocity, and high viscosity-dependent effects were studied.
Lee and Lin et al. [15] Built a multi-cavity mould runner and gating system. Use Finite Element Theory (FEM) network. Optimal runner unit parameter used to minimise injection mould warp, FEM, Taguchi phase and adductive framework. Processes during mould filling, enhancing moulding condition. Model injection mould simulation at steady flow rate. Finite differences method offers strong consent for methodological solutions.
Different gate sizes and locations using flow simulation have been detected for defects reduction such as weld lines and air traps, air traps and warpage can be managed by varying process parameters [17]. Part flow-reducer studied using Autodesk Mould Flow tools. The mould flow analysis is used to predict the

piece's deformation and change the design accordingly. [18]. The plastic toy building block section is analysed; cycle time is successful for four cavities as filling and cooling time for four cavities does not improve in single cavity configuration. The outcome indicates that both parameters influence product consistency, Plastic Flow Simulation analyses the flow of molten plastic to optimise part and mould designs, reducing possible part defects [19]. Simulation research was undertaken for optimum gate location. Comparing two gate positions was achieved. Comparative analysis found the optimal gate location. Several product flaws decrease due to improper eating. [20]. Comparative analysis of the use of different gate types and runner system for the same job, resulting in a satisfactory reduction of moulding defects and increased pressure in the component, which is also within limits [21].

Vikas B J and Chandra Kumar R [22] Optimizing scrap processing period. Manual gui plays a key role in producing plastic components without compromising product consistency. This paper explains gate position and size effect by repetitive analyses. Plastic flow advisor programme prevents fill, scrap and automated degassing. Simulation analyses method parameters including fill time, shrinkage, weld lines, pressure decrease, and air traps in successive tests. Experimental verification for current improved gate location in the injection moulding method. Reduced shrinkage and ventilation, minimising defeats.

Simulation software has greatly impacted the injection moulding industry [23]. Cheaper simulation simulations are an alternative to traditional factory-floor experiments. Study on developing plastic injection moulding method has now expanded a tonne. Sadeghi's [24] Built a neural network model to predict consistency or soundness of injected plastic parts based on major process variables and differing material grade. The system shortened preparation period, improving process requirements or operational parameters. Lee and Kim [25] Used a revised, complicated warpage reduction method by optimising various surface thicknesses, further growing the warpage by reaching optimal processing conditions. Ozcelik and Erzurumlu [26] Comparison acrylic warpage moulding for ANOVA. Neural, genetic algorithm. Sahputra [27]. The results of the injection moulding system and simulation analysis of MPI software were contrasted with those of a limited manufacturing process MPI was found to measure the optimum pressure required to correctly fill the mould cavity and graphically track weld lines. MPI offered further simulation analysis.

3. Moulding machine

The various components of the in-line injection screw moulding system are shown in the following figure.

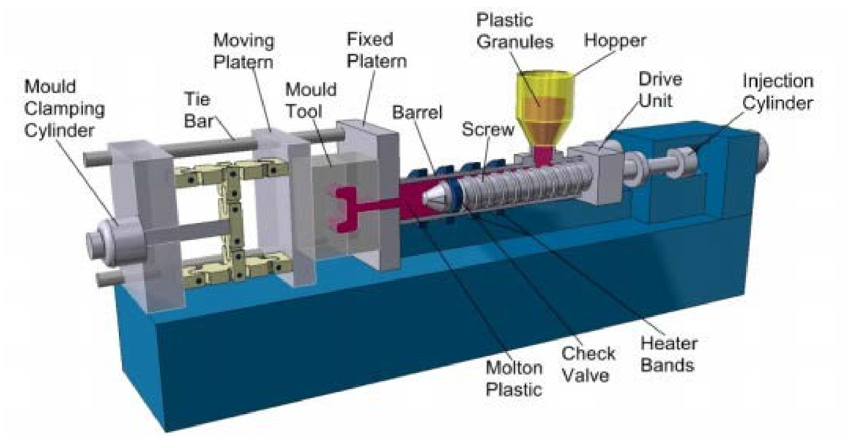

Figure: 1: Major parts of Injection moulding machine [1]

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Clamping device, plasticizing device, and drive unit are a standard injection moulding machine 's key units; as seen in Fig.1. Mold-containing clamping system. For locking, clamping and moulding. Its key components are shifting and fixed frames, tie bars, opening, closing and clamping mechanisms.
Heats plastic and injects it into the mould. The drive unit involves plasticizing and clamping. Ultimate clamping force also classifies moulding devices of the system. The force that forces the two moulds together to avoid mould opening due to plastic melting in the mould. The clamping intensity of standard injection moulding machines varies from 200-100,000 kN.

4. The runner system [2]

Sprue, racer, gate and cavity are main mould sections. The sprue is the channel, cut from the nozzle to the runner in the stationary plate. The plastic melt enters the mould, running through a runner system, into the mould cavities through the gates. The runner's gate connects. The gate cross-section is usually small, so the runner can be quickly extracted from the piece and leaves no broad gate mark on the part. The runner device is part of the injection moulding machine since it plays an essential function in moulding.
The injection moulding method will use two different moulding systems — cold runner moulds and hot runner moulds. Each injection moulding system operates as sprue plastic content flows through the mould cavity.

4.1Cold Runner Molds[1]

This process holds runners at the same temperature as moulds. Cold runner system consisting of two or three surfaces. The two-platform system is simple. It needs an ejection device to remove both the runner and the component. Three-plate device requires the area to be ejected separately. The three-plate moulds make construction flexible. In a cold runner method, each moulding cycle moulds a new runner and the runner is ejected along with the moulded pieces. Runner plastic can also be reprocessed and re-developed. The aim of runner device design is to make plastic hit all gates simultaneously. An significant problem in multi-cavity moulds is the amount of cavities in a rectangular runner. Circular runner can use any number of cavities. In the cold runner method, the runner dimension must be larger than part. Ensure the fluid fills the piece properly and the mould is not underfilled.

4.1.1 Advantages:

- It is accessible to maintain and inexpensive
- Due to less heat sensitivity, it is suitable for more types of polymers.
- Colour changes can be made quickly.

4.1.2 Disadvantages:

- It is a Longer process compare to the hot runner system.
- Robotics or a person to remove runners is needed.
- If the runners cannot be melted down properly and recycled, then it Creates waste.

4.2 Hot Runner Molds [1]

Hot runner moulds are two surfaces. These plates are heated by multi-system. There are two types of hot runners, insulated internally. Externally heated moulds are suitable for heat-sensitive materials, whereas internal heated moulds are ideally flow-stable. Runners can be heated by including coils. We can use heating rods and heating pipes as well. Throughout the runner process, the material remains molten until it enters the mould cavity.

4.2.1 Advantages:

- Cycle time is Faster.
- Waste is less
- laminated because of no runners

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- Adapts bigger components and greater manufacturing rates
- Quality of the components is better with the right consistency
- Less friction to force the liquid mixture into the mould cavity

4.2.2 Disadvantages:

- Higher cost to produce moulds and maintain equipment
- Colour changes cannot be made quickly.
- It is not suitable for some thermally sensitive material.

5. Process Variables [3]

Process variables are divided into five major types including speed, pressure, time , temperature, and stroke. These relationships cannot be readily separated. They boost hydraulic back pressure, adjust linear retraction speed. It allows improve screw recovery time, melt temperature, and homogeneity. Mould fill time varies, injection strength, mould temperature, ejection temperature and product measurements may be changed as melt temperature rises. It concludes as the pressure variable shift impacts three other variables and affects the consistency of mould components.
Changes in process parameters influence the reliability of the moulding process, which can lead to faulty parts. To rectify this disruption, process variables must be monitored. The incorrect hopper throat temperature has been found to cause short mouldings. It misleads the moulder to alter other variables including holding pressure, shot length, mould filling speed, etc.
The following are common process variables to track and manage throughout each step.

5.1 process variables related to velocity

1. Opening and closing velocities
2. Injection velocity
3. Screw velocity
4. Retraction of components

5.2 Pressure related process variables

1. Pressure at the Injection
2. pressure needed for holding
3. back pressure value for hydraulic

5.3 Time-related process variables

1. Time of Injection
2. Time for Holding pressure
3. Lead time
4. Time for Cooling
5. Time for total Cycle

5.4Temperature related process variables

1. Melting temperature
2. Mould Inside temperature
3. temperature of Barrel
4. Temperature of Cooling water

6.**Summary**

Injection moulding is the most common production process of plastic pieces. Using injection moulding, a broad variety of products are produced, varying greatly in size, sophistication and implementation. Hot runner is stronger than cold runner, but is seldom used due to its high cost and complexity nature. Each material requires a complicated collection of parameters such as injection temperature, injection speed, flow rate, mould temperature, ejection temperature, refrigeration rate and cycle time. Improper collection of flow patterns, burn marks, warping, vacuum voids / air pockets, sink gaps, weld lines, jetting. Few faults, including discoloration, plastic storage and delamination. Fast shots and flash cause bad design or repair. These parameters include process optimization and selection to remove defects. The effect of these requirements on the moulding method and guidelines to manufacture defect-free components need further research.

References

[1] N.Divya, Dr.Ch.V.S.Parameswara Rao,Dr. S.S.N.MalleswaraRao, (March 2017) " Multiintegral Analysis Of Injection Mould With Hot Runners For Gate", International Journal of Scientific and Research Publications, Volume 7, Issue 3, ISSN 2250-3153
[2] A. Demirer, Y. Soydan, et al. (2007) "An experimental investigation of the effects of hot runner system on injection moulding process in comparison with conventional runner system", Science Direct, Materials and Design 28 ,1467–1476
[3] PK Bharti, M. I. Khan, 2010, "Recent Methods For Optimization Of Plastic Injection Molding Process –A Retrospective And Literature Review", International Journal of Engineering Science and Technology, Vol. 2(9), 4540-4554
[4] Rashi A.Yadav, S.V.Joshi, N.K.Kamble, (December-2012), "Recent Methods for Optimization of Plastic Injection Molding Process - A Literature Review", International Journal of Scientific & Engineering Research Volume 3, Issue 12, ISSN 2229-5518
[5] Ivan W.M. Chana,∗, Martyn Pinfold a, C.K. Kwongb, W.H. Szeto, (2014) "Automation and optimization of Family Mould Cavity and Runner Layout Design (FMCRLD) using genetic algorithms and mould layout design grammars", Elsevier, Computer-Aided Design 47 118–133
[6] Mr P. Vinod, Mr K. Vijaykumar, May -2017 Multi-cavity hot runner injection mould tool polymer", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395 -0056, Volume: 04 Issue: 05,
[7] G. Rajendra Prasad, Dr S. Chakradhar Goud, Multiintegral May -2017, "Analysis Of Injection Mould With Hot Runners For Gate", International Journal Of Engineering Sciences & Research Technology, ISSN: 2277-9655,
[8] N. Divya, Dr Ch. V. S. Parameswara Rao, Dr S. S. N. Malleswara Rao, March 2017, "Multiintegral Analysis Of Injection Mould With Hot Runners For Gate", International Journal Of Engineering Sciences & Research Technology, Volume 7, Issue 3, ISSN 2250-3153
[9] Gurjeet Singh, Ajay Verma, (2015) , "A Brief Review on injection moulding manufacturing process", 5th International Conference of Materials Processing and Characterization (ICMPC 2016), ScienceDirect Materials Today: Proceedings00
[10] Mehdi Moayyedian, Kazem Abhary, Romeo Marian, February 2015, 2nd International Materials, Industrial, and Manufacturing Engineering Conference, MIMEC2015, 4-6, Bali Indonesia,
[11] V.Chandra Sekhar, N. Jaya Krishana, Hot Runner Mould Design and Plastic Flow Analysis for CAP, International Journal & Magazine of Engineering, Technology, Management and Research, ISSN No: 2348-4845
[12] Peter Unger, 2006 ―Hot Runner Technology, Hanser Gardener Publication,.
[13] D.Frenkler, H. Zawistowski, ― Hot Runners in Injection Moulds, Rapra publishers, Shawbury 1998, p.267.
[14] Spina R., (2004), Injection moulding of automotive components: comparison between hot runner systems for a case study.J. Mat. Process. Tech. 155-156 1497-1504.
[15] Tang SH, Kong YM, Sapuan SM, Samin R and Sulaiman S. (2006) ,Design and thermal analysis of plastic injection mould.J. Mat. Process. Tech. 171(2) 259-267.

IOP Conf. Series: Materials Science and Engineering 1017 (2021) 012031 doi:10.1088/1757-899X/1017/1/012031

[16] Vikas. B. J and Chandra Kumar. R, 2013 "Influence of Feeding System in Injection Moulding for Lower Washer of Bearing," International Journal of Research in Engineering and Technology, pp. 396-399.
[17] V. V. Andhalkar and Dr S. R. Dulange, 2017 "Injection Molding Methods Design, Optimization, Simulation of Plastic Flow Reducer Part by Mold Flow Analysis," International Research Journal of Engineering and Technology, vol. 4, no. 6, pp. 1742-1746.
[18] M. Salunke, R. Kate, V. Lomate and G. Sopal, 2015 "Injection Moulding Design Methods Optimization", Simulation of Plastic Toy Building Block by Mold Flow Analysis, International Journal of Mechanical Engineering and Technology, vol. 6, no. 6, pp. 33-42.
[19] S. R. Pattnaik, D. B. Karunakar and P. K. Jha, 2012 "Application of Computer Simulation for Finding Optimum Gate Location in Plastic Injection Moulding Process," International Journal of Advanced Engineering Research and Studies, vol. 1, no. 2, pp. 159-161,.
[20] K. R. Yathish Kumar and P. Nagaraja. R, 2014 "Significance of Mold Filling Analysis for Finding Optimal Gate Location in Injection Molding Process for Bobbin.," International Journal of Scientific and Research Publications, vol. 4, no. 4, pp. 1-8.
[21] Vikas B J, Chandra Kumar R, Influence Of Feeding System In Injection Moulding For
[22] Lower Washer Of A Bearing", International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308
[23] Manzione, L.T. Applications of Computer-Aided Engineering in Injection Moulding. Hanser, New York,1987.
[24] Sadeghi, B.H.M., 2000, A BP-neural network predictor model for the plastic injection moulding process. Journal of Materials Processing Technology, , 103, 411-416.
[25] Lee, B.H., Kim, 1995,B.H. Optimization of part wall thickness to reduce warpage of injection-moulded parts based on the modified complicated method. Polymer-Plastic Technology and Engineering, 34, 793–811.
[26] Ozcelik, B., Erzurumlu, T., 2006, Comparison of the warpage optimization in the plastic injection moulding using ANOVA, neural network model and genetic algorithm. Journal of Materials Processing Technology, 171,437–445.
[27] Sahputra, I.H., 2-4 Dec. 2007, Comparison of two flow analysis software for injection moulding tool design. Proceedings of the International Conference on Industrial Engineering and Engineering Management , Singapore.
[28] Chen, Wu-Lin, Chin-Yin Huang, and Ching-Ya Huang, (2013), "Finding an efficient frontier of process parameters for plastic injection moulding." Journal of Industrial Engineering International 9, no. 1 1-11.
[29] Stanek, Michal, David Manas, Miroslav Manas, and Jakub Javorik, 2011,"Simulation of the injection moulding process." In Proc. 13th WSEAS International Conference on Automatic Control, Modelling & Simulation, pp. 231-234.
[30] Islam, Aminul, Hans Nørgaard Hansen, N. M. Esteves, and T. T. Rasmussen. (2013), "Effects of holding pressure and process temperatures on the mechanical properties of moulded metallic parts." ANTEC 2013
[31] A. RiazAhamed, A.K. ShaikDawood, R. Karthikeyan", December 2013, Designing and Optimizing the Parameters which affect the Molding Process using Design of Experiment". Volume 1, Issue 2, October- pp.116-122.
[32] Pareek, Rishi, and Jaiprakash Bhamniya, (2013), "Optimization of Injection Moulding Process using Taguchi and ANOVA." Journal of Scientific and Engineering Research 4, no. 1.

IOP Conf. Series: Materials Science and Engineering 1017 (2021) 012031 doi:10.1088/1757-899X/1017/1/012031

[33] Rahimi, Mohammad, Mohsen Esfahanian, and Mehran Moradi, (2014) "Effect of reprocessing on shrinkage and mechanical properties of ABS and investigating the proper blend of virgin and recycled ABS in injection moulding." Journal of Materials Processing Technology 214, no. 11 2359-2365.
[34] Müller, Egon, Rainer Schillig, Timo Stock, and Miriam Schmeiler. (2014) "Improvement of Injection Moulding Processes by Using Dual-Energy Signatures." Procedia CIRP 17 704-709.2
[35] Chen, Wu-Lin, Chin-Yin Huang, and Ching-Ya Huang. (2013) "Finding an efficient frontier of process parameters for plastic injection moulding." Journal of Industrial Engineering International 9, no. 1 1-11.
[36] Mehta, Nik Mizamzul, Shahrul Kamaruddin, and Abdul Rahim Othman, 2012, "Reducing the Shrinkage in Plastic Injection Moulded Gear via Grey-Based-Taguchi Optimization Method." In Proceedings of the World Congress on Engineering, vol. 3
[37] Fei, Ng Chin, Nik Mizamzul Mehat, and Shahrul Kamaruddin, 2013 "Practical applications of Taguchi method for optimization of processing parameters for plastic injection moulding: a retrospective review." ISRN Industrial Engineering 2013.
[38] Tang SH, Kong YM, Sapuan SM, Samin R and Sulaiman S. Design and thermal analysis of plastic injection mould.J. Mat. Process. Tech. 171(2) (2006) 259-267.
[39] Ozcelik, B., Erzurumlu, T. 2006, Comparison of the warpage optimization in the plastic injection moulding using ANOVA, neural network model and genetic algorithm. Journal of Materials Processing Technology, 171,437–445.
[40] Saman, A.M., Abdullah, A.H., 2009, MAM Computer simulation opportunity in plastic injection mould development for an automotive part. International Conference on computer technology and Development,13-15 Nov. Kota Kinabalu, Malaysia.