

References

- [1] K. Prashantha, J. Soulestin, M. F. Lacrampe, E. Lafranche, P. Krawczak, G. Dupin, and M. Claes, “Taguchi analysis of shrinkage and warpage of injection-moulded polypropylene/multiwall carbon nanotubes nanocomposites,” *Express Polym. Lett.*, vol. 3, no. 10, pp. 630–638, 2009.
- [2] P. Shrinkage, “Controlling Mold and Post-Mold Shrinkage and Warpage,” pp. 107–130, 2013.
- [3] B. S. Reddy, J. S. Kumar, V. K. Reddy, and G. Padmanabhan, “Application of soft computing for the prediction of warpage of plastic injection molded parts,” *J. Eng. Sci. Technol. Rev.*, vol. 2, no. 1, pp. 56–62, 2009.
- [4] G. Menges, W. Michaeli, and P. Mohren, Georg Menges , Walter Michaeli , Paul Mohren "How to Make Injection Molds."
- [5] A. Kramschuster, R. Cavitt, D. Ermer, Z. Chen, and L. S. Turng, “Quantitative study of shrinkage and warpage behavior for microcellular and conventional injection molding,” *Polym. Eng. Sci.*, vol. 45, no. 10, pp. 1408–1418, 2005.
- [6] K. Cho and I. Jeon, Numerical analysis of the warpage problem in TSOP,” *Microelectron. Reliab.*, vol. 44, no. 4, pp. 621–626, 2004.
- [7] P. S. F. F. Alves, “Shrinkage and warpage behaviour on injection moulding parts,” 2008.
- [8] E. Bociaga, T. Jaruga, K. Lubczyńska, and A. Gnatowski, “Warpage of injection moulded parts as the result of mould temperature difference,” *Arch. Mater. Sci. Eng.*, vol. 44, no. 1, pp. 28–34, 2010.
- [9] Z. Shayfull, M. F. Ghazali, M. Azaman, S. M. Nasir, and N. A. Faris, “Effect of Differences Core and Cavity Temperature on Injection Molded Part and Reducing the Warpage by Taguchi Method,” *Int. J. Eng. Technol. IJET-IJENS*, vol. 10, no. 6, pp. 133–140, 2010.

- [10] S. Kamaruddin, Z. A. Khan, and S. H. Foong, "Quality characteristic improvement of an injection moulding product made from blends plastic by optimizing the injection moulding parameters using Taguchi method," *Int. J. Plast. Technol.*, vol. 14, no. 2, pp. 152–166, 2010.
- [11] P. K. K. Kennedy, "*Practical and Scientific Aspects of Injection Molding Simulation.*" 2008.
- [12] M. Hayaty and M. H. Beheshty, "Shrinkage, Cure Characterization and Processing of Unsaturated Polyester Resin Containing PVAc Low-profile Additive," *Iran. Polym. J.*, vol. 13, no. 5, pp. 389–396, 2004.
- [13] S. Asproiu and E. Străjescu, "Influence of mold properties on the quality of molded parts," *UPB Sci. Bull. Ser. D Mech. Eng.*, vol. 69, no. 3, pp. 39–46, 2007.
- [14] K. S. R. Wilkinson, E.A. Poppe, Karl Leidig, "Engineering Polymers : the 'Top Ten' Injection Molding Problems," *W.D.Sol.Tech Rep.*, pp. 1–4.
- [15] S. Mohamed, M. Yusoff, W. a N. Harun, W. a N. Hamid, and E. Ramly, "A Plastic Injection Molding Process," *Design*, vol. 41, pp. 1–16, 2007.
- [16] C. T. Wong, S. Shamsuddin, I. N, and A. M. S. Hamouda, "Design and Simulation of Plastic Injection Moulding Process," *Pertanika J. Sci. Techno!. Suppl.*, vol. 12, no. 2, pp. 85–99, 2004.
- [17] Y. Q. Lu, P. L. Liu, X. M. Ding, and Y. S. Chung, "Mould Conceptual Design Method and System," pp. 323–329.
- [18] A. J. Pontes, "Shrinkage and Ejection forces in injection molded products," p. 234, 2002.
- [19] D. Stan, A. Tulcan, L. Tulcan, and T. Iclanzan, "Influence Factors on the Dimensional Accuracy of the Plastic Parts," no. 1, pp. 119–124, 2008.

- [20] M. H. E. Van Der Beek, G. W. M. Peters, and H. E. H. Meijer, “Characterization of polymers for improved shrinkage prediction in micromolding .,” no. C, pp. 1–4.
- [21] V. Speranza, U. Vietri, and R. Pantani, “Monitoring of injection moulding of thermoplastics: Adopting pressure transducers to estimate the solidification history and the shrinkage of moulded parts,” *Stroj. Vestnik/Journal Mech. Eng.*, vol. 59, no. 11, pp. 677–682, 2013.
- [22] A. Peng, Y. Chang, A. Yang, and V. Yang, “3D Fiber Orientation and Warpage Analysis of Injection-Molded Throttle Valve,” *Polymer (Guildf.)*., no. 7.
- [23] R. Bonart, “Thermoplastic elastomers,” *Polymer (Guildf.)*., vol. 20, no. 11, pp. 1389–1403, 1979.
- [24] J. Wang, “PVT Properties of Polymers for Injection Molding,” *Some Crit. Issues in Inject. Molding 2012 of Moratuwa, Sri Lanka*.
- [25] C. Schauer, “Inherent problems in early IM,” 2007.
 www.ipt.mrt.ac.lk
- [26] “Gate Location Optimization In Injection Molding Based On Feasible Space” Ming Zhai , NERC for APPT , Zhengzhou University , Zhengzhou , China Haiwen Wang , School of Art and Information Engineering , Dalian Polytechnic University , China Abstract Opt,” pp. 1–5.
- [27] Moldflow Corporation, “Moldflow Design Guide,” pp. 1–346, 2006.
- [28] B. J. Hasenauer, D. Küper, J. E. Laumeyer, and I. Welsh, “Correct gate location,” pp. 15–18.
- [29] Prof T. Gutowski, “Injection Molding.” 2002.
- [30] J. Shen, “Design and Molding Simulation of a Plastic Part,” 2010.
- [31] H. S. Park and X. P. Dang, “Design and Simulation-Based Optimization of Cooling Channels for Plastic Injection Mold,” *New Technol. Innov. Res.*, pp. 19–45, 2012.

- [32] V. Maag and K.-H. Küfer, “Optimal Cooling in Injection Molding and Die Casting,” no. June, pp. 1–5, 2008.
- [33] Lars-Erik Rännar, *On Optimization of Injection Molding Cooling*, no. April. 2008.
- [34] O. A. Mohamed, S. H. Masood, and A. Saifullah, “A Simulation Study of Conformal Cooling Channels in Plastic Injection Molding,” *Int. J. Eng. Res.*, vol. 2, no. 5, pp. 344–348, 2013.
- [35] C. Özak and Y. H. Çelik, “Calculating Molding Parameters in Plastic Injection Molds with ANN and Developing Software,” *Mater. Manuf. Process.*, vol. 27, no. January 2015, pp. 160–168, 2012.
- [36] A. G. Smith, L. C. Wrobel, B. A. Mccalla, P. S. Allan, and P. R. Hornsby, “Optimisation of Continuous and Pulsed Cooling in Injection Moulding Processes.”
- [37] J. Meckley and R. Edwards, “A Study on the Design and Effectiveness of Conformal Cooling Channels in Rapid Tooling Inserts.” *Technol. Interface Journal/Fall, Vol. 10, No. 1, 2009*
- [38] Y. Wang, K. M. Yu, C. C. L. Wang, and Y. Zhang, “Automatic design of conformal cooling circuits for rapid tooling,” *CAD Comput. Aided Des.*, vol. 43, no. 8, pp. 1001–1010, 2011.
- [39] R. Hill, “Dynamic Temperature Control in Injection Molding with New Conformal Heating / Cooling System,” pp. 5–11, 2010.
- [40] E. Sachs, E. Wylonis, S. Allen, M. Cima, and H. Gu, “Production of Injection Molding Tooling With Conformal Cooling Channels Using the Three Dimensional Printing Process,” *Polym. Eng. Sci.*, vol. 40, no. 5, pp. 1232–1247, 2000.
- [41] M. M. Bunch and P. Delp, “Prediction of Shrinkage in Plastic Injected Parts Due to Cooling Introduction to the Project.”
- [42] T. Kimerling, “Injection Molding Cooling Time Reduction and Thermal Stress Analysis,” pp. 1–5, 2002.

- [43] D. Lee, W. A. Chen, T. W. Huang, and S. J. Liu, “Factors influencing the warpage in in-mold decoration injection molded composites,” *Int. Polym. Process.*, vol. 28, no. 2, pp. 221–227, 2013.
- [44] S. Teklehaimanot and D. Thesis, “Simulation and Design of a plastic injection Mold,” pp. 1–53, 2011.
- [45] R. A. Malloy, *Plastic Part Design for Injection Molding*. 2010.
- [46] N. Mehat, S. Kamaruddin, and A. Othman, “Reducing the Shrinkage in Plastic Injection Moulded Gear via Grey-Based-Taguchi Optimization Method,” *Proc. World Congr. Eng. 2012 Vol III*, vol. III, pp. 1–4, 2012.
- [47] S. Kuriakose, S. K. George, and P. V. Mathew, “Study of Moulding Defects in Automobile Relay Cover,” vol. 2, no. 6, pp. 134–138, 2012.
- [48] H. P. Kale and U. V Hambire, “Review on Optimization of Injection Molding Process Parameter for Reducing Shrinkage of High Density Polyethylene (HDPE) material,” vol. 4, no. 4, pp. 2847–2850, 2015.
- [49] D. G. Ahn, University of Moratuwa, Sri Lanka, ‘Optimal injection molding conditions considering the core shift for a plastic battery case with thin and deep walls,’ *J. Mech. Sci. Technol.*, vol. 24, no. 1, pp. 145–148, 2010.
- [50] A.L. Gershon, L.J. Gyger, Jr., H.A. Bruck and S.K. Gupta, “Thermoplastic Polymer Shrinkage in Emerging Molding Processes,” *J. Chem. Inf. Model.*, vol. 53, no. 9, pp. 1689–1699, 2013.
- [51] Z. Kamal, “Trouble Shooting In Plastic Injection Molding Machines,” *Public Health*, p. 125, 2007.
- [52] V. Shah, “Scientific Approach to Injection Molding What is Scientific Approach to Injection Molding ?,” 2004.

Appendix A – Mould Assembly Drawing



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Appendix B – Modified Mould Assembly Drawing



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Appendix C – Product Drawing



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Appendix D – Properties of Polycarbonate

Rheological properties	Value	Unit
Melt volume-flow rate, MVR	19	cm ³ /10min
Temperature	300	°C
Moulding shrinkage, parallel	0.7	%
Moulding shrinkage, normal	0.7	%
Ejection temperature	130	°C
Mechanical properties		
Tensile Modulus	2400	MPa
Yield stress	66	MPa
Yield strain	6	%
Nominal strain at break	>50	%
Tensile creep modulus, 1h	2200	MPa
Tensile creep modulus, 1000h	1900	MPa
Test specimen production		
Injection Moulding, melt temperature	280	°C
Injection Moulding, mould temperature	80	°C
Injection Moulding, injection velocity	200	mm/s
Injection moulding		
Drying Temperature	120	°C
Drying Time	3-4	Hrs
Maximum moisture content	0.02	%
Vent Depth	0.025-0.075	mm