Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Mutiscale Simulation of Polymer Injection Molding Fiiling Flow with Welding Line Formation

Yunpu Liu[1], Mengke Ren[1*], Zheng Li[1], Junfeng Gu[1,2], Shilun Ruan[1,2,3], Changyu Shen[1,4]
[1]State Key Laboratory of Structural Analysis, Optimization and CAE Software for Industrial Equipment, Dalian University of Technology, Dalian 116024, China
[2]Ningbo Institute of Dalian University of Technology, Ningbo, 315016, China
[3]Zhengzhou College of Dalian University of Technology, Zhengzhou, 450016, China
[4]National Engineering Research
Center for Advanced Polymer Processing Technology, Zhengzhou University, Zhengzhou, 450002, China
*rrmmkk@dlut.edu.cn

Abstract

This study proposes a novel multiscale simulation method integrating an improved smoothed particle hydrodynamics (SPH) method with the clustered fixed slip-link model (CFSM) to investigate the microstructure characteristics of welding and melding line defects in injection-molded polymer products. SPH enhanced with essential improvements was implemented to simulate the macroscopic filling flow in two ring-shaped cavities with different tail designs (with and without protrusion). The CFSM model was used to track the evolution of polymer chain microstructures, including entanglement density, chain orientation and re-entanglement ratio. The simulation results demonstrated that the cavity with tail protrusion reduced the welding line length and partially transformed the welding line into melding line due to flow enhanced shearing. Microscopic results demonstrated that welding line regions exhibited lower entanglement density compared to melding line, which showed higher chain orientation alignment and gradual structural transitions. The re-entanglement ratio after cessation of flow is higher in melding line, which signals higher mechanical performance compared with welding line. This is in line with realistic plastic product. These differences were attributed to shear-induced disentanglement and stretching effects near flow fronts, as well as chain relaxation after melt collision. The findings highlight that tail design can mitigate welding line defects by promoting better microstructural rearrangements, thus can improve mechanical performance as well. This multiscale framework bridges macroscopic flow behavior with microscopic polymer chain conformation, offering an insight for defect control of injection-molded products through mold design optimization.