15 Continuous Process Visualization: Visual Observation, On-Line Monitoring, Model-Fluid Extrusion and Simulation

Chi-Kai Shih and Mark D. Wetzel

Significant advances in the fundamental understanding of the polymer extrusion and compounding processes have been made over the past 20 years. Major contributions to these advances arose through experimental investigations employing process visualization, including on-line monitoring, off-line sample analysis and process emulation. Experiments were carried out using combinations of laboratory extruders using model fluids, simple mixers using commercial polymer feed materials, and laboratory or plant-scale extruders using commercial polymer feed materials. Sophisticated monitoring tools were used in these investigations and selected examples will be described.

The dynamics of melting, mixing and reactions during twin screw extrusion were visualized by on-line monitoring using a dynamic perturbation technique to yield melting or mixing time and energy intensity profiles. Residence time distribution (RTD) was measured using specialized probes to detect tracer concentration. A simple throughput and screw speed measurement technique (Q and N mapping) was introduced to characterize the specific energy performance of twin screw extrusion processes during steady state operation. These investigations resulted in new insights on the sequence of events taking place in the melting, mixing and pumping regions of a twin screw compounder. Mixing in the melting zone, mixing after melting, mixing involving phase inversion, back mixing and unstable flow during single and twin screw extrusion were examined in connection with available compounding principles and illustrated with practical examples. The phenomenon of phase inversion was examined in greater detail with respect to morphological development and applicability of the simple Taylor dispersion theory. Some well known difficult extrusion processes involved in systems of polymer/polymer blend, polymer/plasticizer, polymer/filler and reactive polymer blends are described, and possible remedies are discussed.

Novel visualization and on-line monitoring techniques have been developed to capture process instabilities and fundamental principles of the underlying dynamic, physical processes. Examples using high-speed video cameras and data acquisition systems illustrate how these methods may be employed on laboratory or commercial-scale polymer processing equipment to make significant advances in fundamental understandings, to diagnose and control unstable behavior that may occur in melting, mixing, reaction and shaping or forming operations.

15.1 Introduction

To reveal the dynamic transformations of materials flowing inside a metal extruder barrel, investigators have employed many experimental techniques. In addition to dispersive and distributive mixing, the complex extrusion or compounding process may involve phase