Rheological Responses under Elongational Flow for Polyolefin Melts

Abstract

Various kinds of processing operations are known to be available in polymer industry. Among them, extrusion process is one of the most important operations for shaping a polymer melt into final products. Generally, the shape of a product is determined after passing through a die exit of an extrusion unit, in which elongational flow occurs. Therefore, rheological responses under elongational flow of a melt play a crucial role in polymer processing, because they decide the quality of products. One of the most important rheological responses is the viscosity. However, the data of elongational viscosity has been reported for only specific polymers with high molecular weight because of the difficulty in measurements. In industry, therefore, the drawdown force, defined as force required for uniaxial stretching of a polymer melt, is usually evaluated instead of the elongational viscosity because it has a close relation with elongational viscosity. Besides the elongational viscosity, the drawdown force contains the information on solidification process including crystallization because the drawdown force measurements are performed with non-isothermal condition. From the viewpoint of polymer processing, high level of the drawdown force is often required for good processability. Such situations lead to the confusion to understand the information on the drawdown force. In fact, the effect of the measurement conditions on the drawdown force has not been clarified yet.

Here, I study the measurement of the drawdown force and its enhancement. Firstly, the effect of extrusion condition and material parameters on the drawdown force was investigated. It was found that the drawdown force for polyolefins increases with the die length. This phenomenon is pronounced for the melt having high molecular weight at low extrusion temperature. The mechanism is attributed to the reduction of entanglement coupling density for the melt extruded from a long die, leading to rapid crystallization and thus, enhancement of the drawdown force. Moreover, the sensitivity of the drawdown force to the die length is found to depend on the difference between processing and crystallization temperatures. In addition, the drawdown force of polypropylene is enhanced by blending acrylate polymers having low viscosity, due to prompt solidification of the acrylate polymer dispersion which acts as rigid filler at the extrusion process.

Keywords: Capillary extrusion, Drawdown force, Polyolefin, Elongational flow, Cystallization