Quantitative Analysis for Polymer Degradation in the Extrusion Process

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Abstract

Polymer degradation in the extrusion process decreases quality and it is necessary to prevent polymer degradation. In the extrusion process, polymer degradation is caused by oxidation [1]. It depends on the processing temperature and the amount of dissolved oxygen in the molten polymer. Therefore, a quantitative analysis of these factors is required.

The purpose of this paper is to clarify the behavior of polymer degradation in the extrusion process focusing mainly on a quantitative analysis for dissolved gases in the extruded molten polymer. An online measuring apparatus to analyze dissolved gases in the extruded molten polymer was developed and dissolved nitrogen (index of entrained air) was analyzed with a full-flight screw and a barrier screw. Furthermore, the observation of cross sectional views in the screw channel obtained from the cooling experiment under the operating conditions was carried out for a full-flight screw and a barrier screw. Consequently, it is clarified that the use of a barrier screw is suitable for oxygen reduction in the extruded molten polymer, which is a factor in causing polymer degradation.

1. Experimental

A measuring apparatus which analyzes dissolved gases in the molten polymer is shown in Fig.1. This measuring system was composed of three pieces of equipment for the introduction of the extruded molten polymer, collection of dissolved gases in the molten polymer and analysis of dissolved gases. At the sampling point for the extruded molten polymer, the flow channel was changed to the vacuum chamber by switching the valve and the extruded molten polymer was introduced into the vacuum chamber which was controlled at the same temperature of the extruded molten polymer. Then the molten polymer was introduced into the vacuum chamber which was decompressed. After desorbing dissolved gases under the decompression, dissolved gases were introduced into a gas chromatography with helium gas which was a carrier gas. Thus, dissolved gases in the extruded molten polymer were quantitatively analyzed.

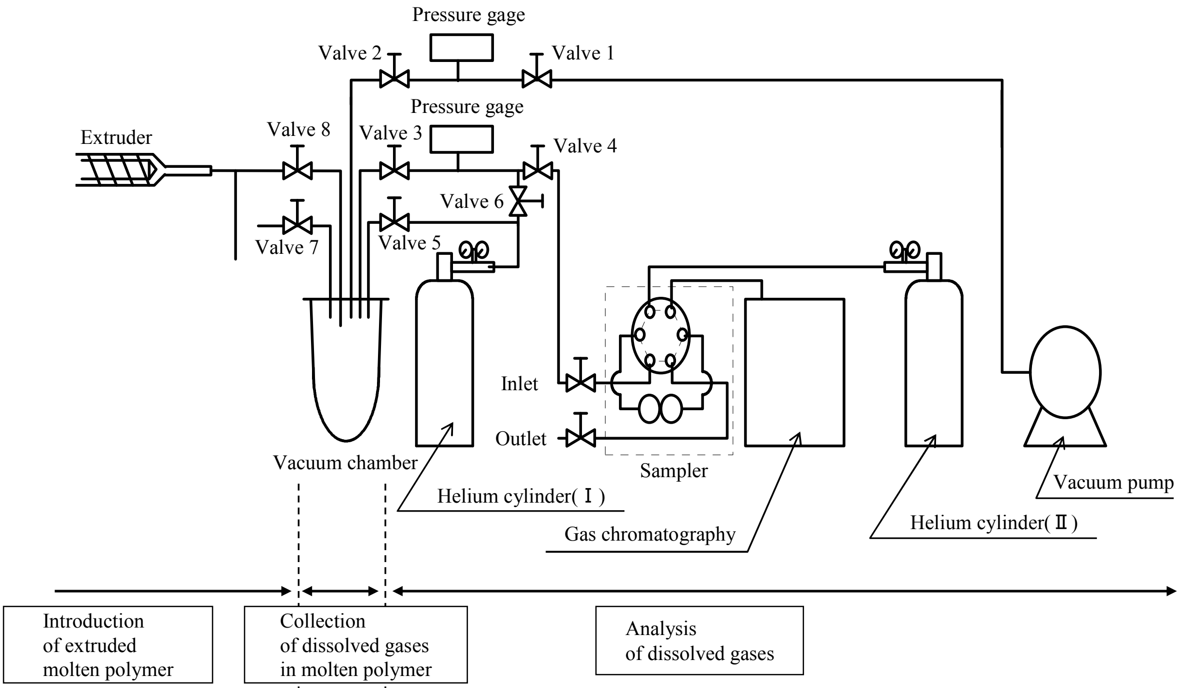

Figure 1: Apparatus for measuring dissolved gases in molten polymer

2. Results and Discussion

Fig.2 shows the relationships between the extrusion pressure and the volume ratio of dissolved gas (N_2, O_2) to the molten polymer, the ratio of analyzed data N_2/O_2 and the extruded temperature with a full-flight screw. The ratio of analyzed data N_2/O_2 were higher than the ratio of N_2/O_2 (=4) in air atmosphere and it is estimated that dissolved oxygen of entrained air in plasticizing process is consumed by oxidation. Furthermore, the ratio of analyzed data N_2/O_2 became increasing in the high extrusion pressure range. This result indicates that oxidation is relatively proceeding in the high extrusion pressure range corresponding to the increasing of the extruded temperature.

Fig.3 shows the relationship between the extrusion pressure and the volume ratio of dissolved nitrogen N_2 to the molten polymer which were extruded with a full-flight screw and a barrier screw. As for the evaluation of the screw, the quantity of dissolved nitrogen was used for the index to indicate the quantity of entrained air, because the quantity of dissolved oxygen was influenced by the oxidation consumption. The quantity of dissolved nitrogen with a full-flight screw is greater than that with a barrier screw. This indicates that the amount of entrained air increases when a full-flight screw is used.

Fig.4 shows the cross sectional views in the screw channel obtained from the cooling experiment under the operating conditions with a full-flight screw and a barrier screw. The break up phenomenon (collapse of solid bed) occurred in a full-flight screw. Thus, it is estimated that air in the collapsed solid bed was entrained. As for a barrier screw, the solid polymer was separated from the molten polymer by a sub-flight and the break up phenomenon was suppressed. These results ensure the results in Fig.3.

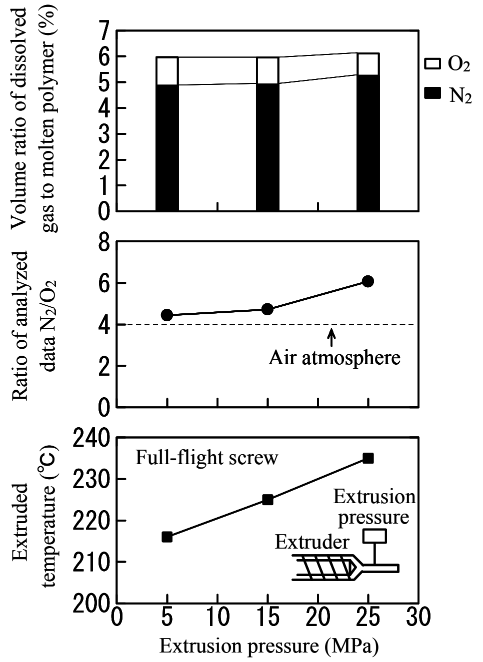

Figure 2: Relationships between extrusion pressure and volume ratio of dissolved gas to molten polymer / ratio of analyzed data N_2/O_2 / extruded temperature

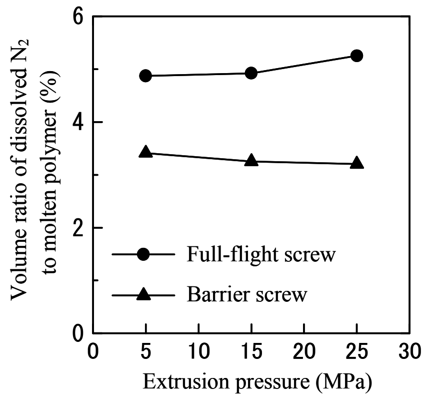

Figure 3: Relationship between extrusion pressure and volume ratio of dissolved nitrogen N_2 to molten polymer with full-flight screw and barrier screw

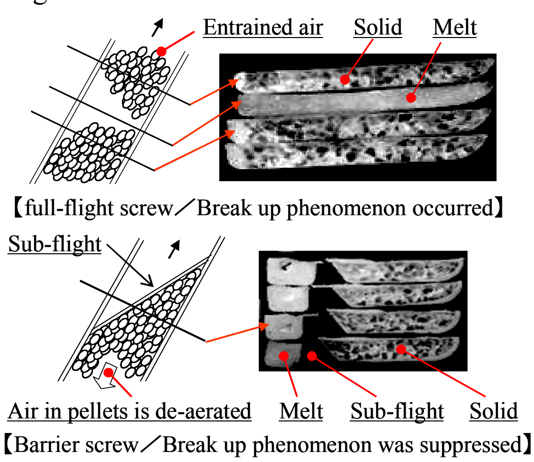

Figure 4: Cross sectional views in screw channel with full-flight screw and barrier screw

3. Conclusions

With the analysis of dissolved gases in the extruded molten polymer and the observation in the screw channel, it is clarified that the use of a barrier screw is suitable for oxygen reduction in the extruded molten polymer.

4. References

1. M. Celina and G. A. George, *Heterogeneous and Homogeneous Kinetic Analyses of the Thermal Oxidation of Polypropylene*, Polym. Deg. Stab., 50, pp.89-99 (1995)