EFFECT OF INTERNAL MOLD PRESSURE AND MECHANICAL PROPERTIES OF LLDPE ON ONE-SHOT CHEMICAL FOAMING

J.Tateishi[1,2]*, N.Taniguchi[1], T.Nishiwaki[1], Sathish K. Sukumaran[2] and M.Sugimoto[2]

[1]*Institute of Sport Science, ASICS, Hyogo 651-2271, Japan*
[2]*Dept. of Polym. Sci. and Eng., Yamagata University, Yamagata 992-8510, Japan*
E-mail of corresponding author: junichiro.tateishi@asics.com.

ABSTRACT

Foaming behavior of linear low-density polyethylene (LLDPE) on one-shot chemical foaming process was investigated. In this study, specimen compounds contain different amount of chemical foaming agent and cross-linker. The experimental resulst showed that saturated internal mold pressure during foaming process increased with the chemical foaming agent content, and was independent of the cross-linker content. On the other hand, expansion ratio was dependent on both the contents of the chemical foaming agent and the cross-linker. As a result, the expansion ratio was linearly-correlated with a parameter calculated through internal mold pressure divided by storage modulus at expansion. It was suggested that the expansion ratio was influenced by the mechanical property of compounds as well as the internal mold pressure at expansion.

1. INTRODUCTION

One-shot chemical foaming process has been widely employed for manufacturing cross-linked polymer foams for industrial fields such as vehicle and shoe sole parts. In this foaming process, at first, polymer compounds including chemical foaming agent (CFA) and cross-linker are filled into the mold at a certain temperature. While suppressing expansion of compounds by the mold clamping pressure, the cross-linking reaction of the polymer and the decomposition reaction of the CFA proceed simultaneously. After decompression of the mold clamping pressure, compounds immediately expands. Then, the cross-linked polymer foam can be obtained. In the previous studies, the foaming behaviors on one-shot chemical foaming process have been investigated by considering molding condition and viscoelasticity of compounds[1,2]. The authors reported the thermal decomposition behavior of the CFA during one-shot chemical foaming process by constructing in-situ measuring system[3]. It was shown that the internal mold pressure made an influence on the expansion ratio of compounds. This study aims to discuss the effect of both the internal-mold pressure and the mechanical properties of compounds on the foaming behavior of linear low-density polyethylene (LLDPE).

2.EXPERIMENT

The specification of specimen is shown in Table 1. A commercial LLDPE (MFR = 3.8 g/10min) was used as a matrix polymer of specimen compounds. Dicmylperoxide (DCP), azodicarbonamide (ADCA), and zinc oxide (ZnO) were used as the cross-linker, CFA and the CFA activator, respectively. Specimen number in Table denotes CFA content - DCP content. A mold cavity geometry is 100 × 100 × 5 mm^3 with a taper angle of 45° at edges. A pressure sensor (KISTLER made 6194B) is attached at the center of the cavity. The molding temperature was 448 K and molding time was 1200 s. The expansion ratio (E_R) is calculated as follows;

$$E_R = \rho_0 / \rho_f \quad (1)$$

where ρ_0 and ρ_f are densities of the unfoamed and the foamed specimens, respectively. The

Table 1 The specification of specimens.

	2-0.8	6-0.8	10-0.8	2-1.2	6-1.2	10-1.2
LLDPE			100			
DCP		0.8			1.2	
ADCA	2	6	10	2	6	10
ZnO	1	3	5	1	3	5

unit:phr

time evolution of cross-linking behavior of the compounds without the chemical foaming agent was determined by a variation of the storage modulus. The viscoelasticity was measured by using rotational rheometer (Anton Paar, MCR301) with parallel plates at a constant temperature of 448 K.

3. RESULTS AND DISCUSSION

3.1 Internal mold pressure and E_R

The internal mold pressure at expansion (P_s) and E_R are plotted against ADCA content in Figure 1 (a) and (b), respectively. Figure 1(a) shows that P_s increases with ADCA content, and is independent of the cross-linker content. On the other hand, in Figure 1(b), E_R has a positive correlation with ADCA content, and its correlation is dependent on DCP content.

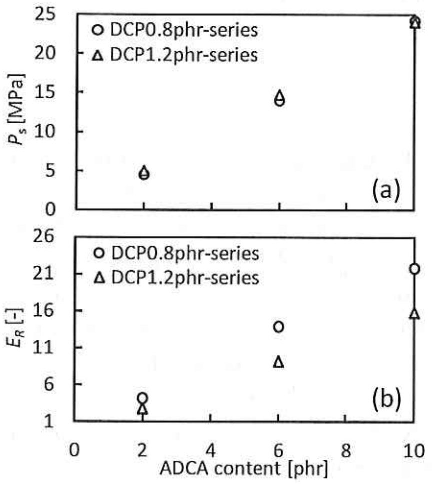

Figure 1 Relationships between ADCA content and (a) the internal mold pressure at expansion P_s, (b) the expansion ratio E_R.

3.2 Mechanical property at expansion and E_R of compounds

Figure 2 shows the time history of the storage modulus G' of LLDPEs with DCP of 0.8 and 1.2 phr. On both compounds, G' sharply increases until 300 s due to the cross-linking reaction of LLDPE, followed by equilibrium values. The difference of the equilibrium G' corresponds to the difference of the molecular weight between crosslinking points. In other words, it is confirmed that elastic modulus of the compound at expansion depends on DCP content. This is supported by the previous

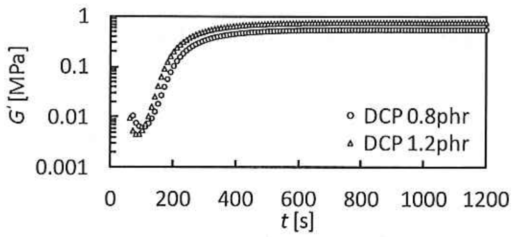

Figure 2 Storage modulus histories of LLDPEs containing DCP of 0.8 and 1.2 phr.

results[3], it should be noted that the mechanical property of compounds at expansion and P_s are important factors for describing E_R. Figure 3 shows the relationship between E_R and a parameter obtained through dividing P_s by G'_s, where G'_s is the storage modulus of compounds at $t = 1200$ s in Figure 2. It can be estimated that G'_s is equivalent to the elastic modulus of compounds at expansion. As a result, E_R has positive linear relation with P_s/G'_s. Namely, we should note that it has a constant relationship regardless of DCP contents. This result indicates that E_R is determined by the correlation between the mechanical property and the internal mold pressure at expansion.

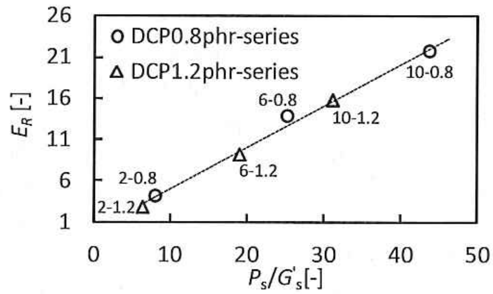

Figure 3 Relationship between E_R and P_s/G'_s.

4. CONCLUSION

In one-shot chemical foaming process of LLDPE, E_R was linearly-correlated with P_s/G'_s. It was suggested that E_R was influenced by the mechanical property of compound as well as the internal mold pressure at expansion. As a future work, we will conduct a verification experiment by using other polymer and investigate forming mechanism of cell structure.

REFERENCES

1. C. J. Benning et al, J. Cell. Plast., 3,62(1967)
2. R. Gendren et al, J. Cell. Plast., 39, 71(2003)