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QUANTITATIVE ANALYSIS OF RELATIONSHIP BETWEEN EXTRUSION BLOW MOLDING PROCESS PARAMETERS AND DEFORMATION PROPERTIES

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ABSTRACT

Influence of design of extrusion blow molding (EBM) in terms of extrusion direction set-up and draw ratio as well as process conditions (mold temperature) on storage modulus of high density polyethylene EBM containers was analyzed with dynamic mechanical analysis. All three parameters - mold temperature, flow direction and draw ratio - are statistically significant and lead to relative and absolute evaluation of storage modulus. Furthermore, flow induced changes in crystallinity was analyzed by differential scanning calorimetry. Obtained data on deformation properties can be employed for more sophisticated finite element simulations with the aim to reach more sustainable extrusion blow molding production.

Keywords: extrusion blow molding, flow direction, mold temperature, draw ratio, DMA, DSC.

INTRODUCTION

Although, extrusion blow molding (EBM) is successfully performed for more than 50 years, still very less is known about the process-structure-property relationship for this kind of processing. Mechanical properties of EBM parts strongly depend on its processing parameters such as extrusion temperature, mold temperature and draw ratio.

Choi *et al*. (1989) studied the development of orientation during blow molding of PE bottles and found out that the level of orientation was relatively low with a tendency towards biaxiality. They also concluded that the molecular orientation increased with increasing inflation pressure and decreasing extrusion temperature. Furthermore, the crystallization during processing indicated an increase of molecular orientation and an increase towards biaxiality due to the oriented crystal nucleation and growth.

Grommes (2016) focused on the effect of different processing parameters on the Young's modulus in order to prove the anisotropic property of extrusion blow molded HDPE containers and to provide a process-dependent Young's modulus for modelling purposes. They found a significant improvement of the simulation reliability. Still, further investigation is needed. As the processing-structure-properties relationship for extrusion blow molding is better understood, this information can be implemented in finite element analysis (FEA) to improve the actual product and make the process more sustainable.

RESULTS AND CONCLUSIONS

The effects of the machine direction, the mold temperature and the draw ratio on the storage modulus in extrusion blow molding were investigated, Figure 1. There are significant evidences (p-value $< \alpha$) for the effect of the machine direction on the storage modulus up to a test temperature of 40 °C. The effect of the mold temperature (5 °C and 50 °C) is significant over the total range of the test temperature and the effect of draw ratio (2.0 and 3.4) is found to be significant over a test temperature range of -40 °C to 10 °C and 60 °C to 90 °C. Additionally, the influence of the mold temperature on the crystallinity was found to be statistically significant.

The effects of the investigated parameters can now be implemented by using a process dependent material data card in a finite element analysis to achieve more realistic simulation results. By means of these improved simulations, a specific material description for more efficient and economical HDPE containers becomes feasible.

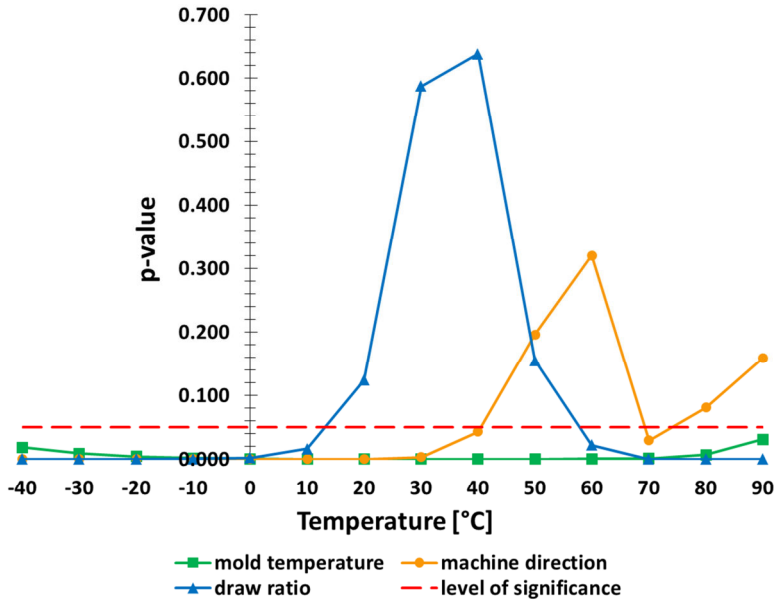

Fig. 1 - Statistical p-values of the process parameters interconnected over the entire test temperature. The dashed horizontal line represents the significance level limit.

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