Evaluate the mechanical properties and appropriate formulations required for a mono-material dunnage bag

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Introduction

This study aims to develop a Level 1 mono-material dunnage bag for the company Cordstrap to facilitate recycling and reduce production steps, contributing to a sustainable circular economy for plastics and lowering the cost of possible production process automation.

The main focus was to investigate which mono-material, thickness, and sealing combination can withstand the customer's requirements. Key questions included determining the yield strength of the client's current dunnage bag system and a competitor bag, followed by the blown films produced during the project, the influence of sealing parameters in the seal strength, and the impact of air diffusion on pressure decrease in a dunnage bag.

Materials & Methods

A literature research was conducted to select the materials, and the necessary thicknesses to withstand the internal pressure of a dunnage bag was calculated using Barlow's formula. Blown films were produced and sealed under different conditions.

Tension tests were conducted according to ISO 527-1 to determine the yield strength of the blown films and the seal strength of the seals made under different parameters (dwell time, temperature, and pressure). Fick's law was used to estimate the diffusion of atmospheric air out of the dunnage bag, assessing its effect on pressure reduction under the test conditions for Level 1.

Results & Discussion

Blown film production followed Barlow formula estimated thicknesses. LDPE and HDPE films were successfully produced and homogeneous, while PP films were challenging to process, resulting in non-homogeneous films with wrinkles and thickness variations, see Figure 1.

Fick's law estimated air diffusion for dunnage bags made from the three materials with calculated thicknesses under Level 1 leak test conditions. The highest pressure reduction was to 2.46 psig, while the test accepts up to 1.5 psig, showing the reduction is not significant.

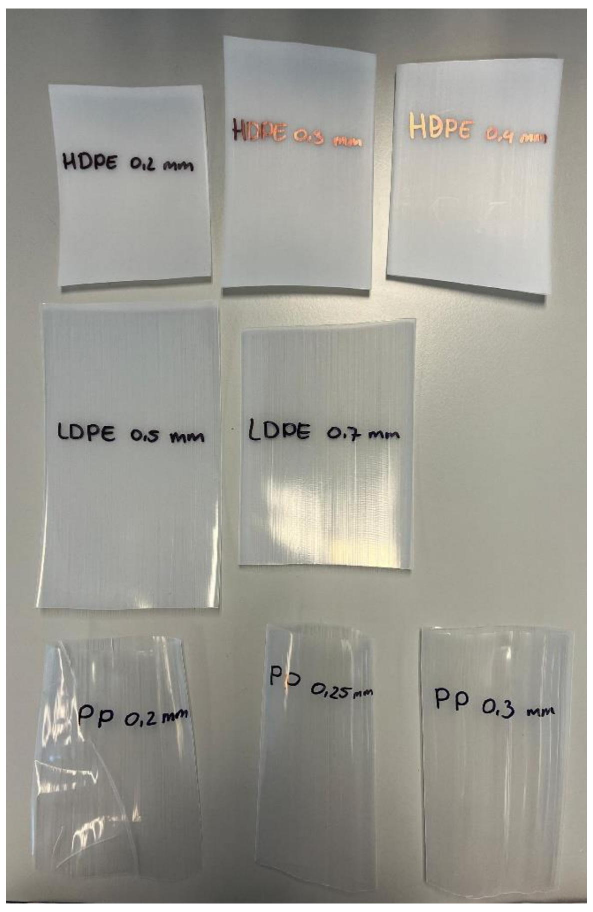

Figure 1: Produced blown films

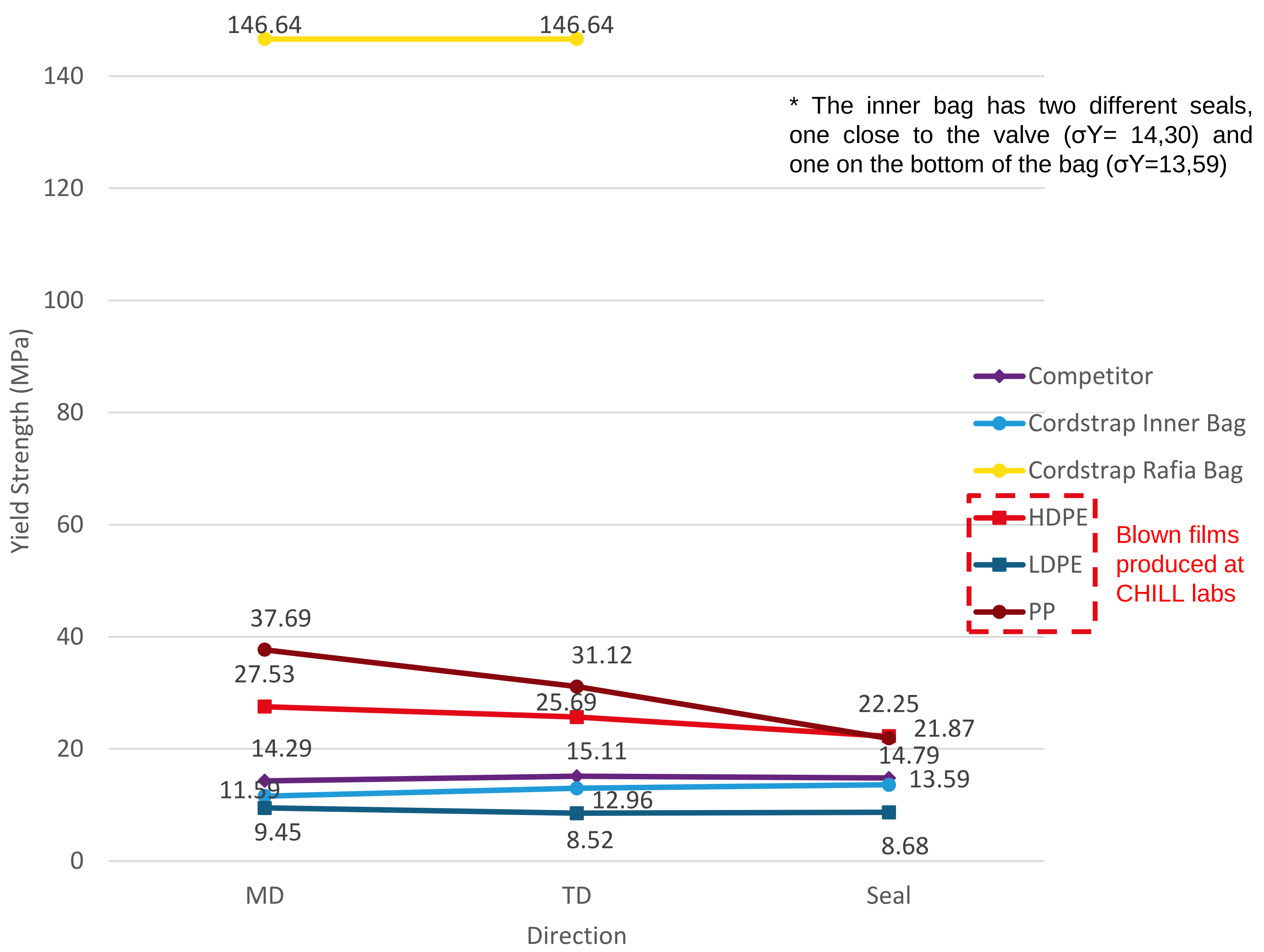

Figure 2: Yield strength results comparison between MD, TD, and seal for all the evaluated films

Figure 2 shows that the current raffia layer used by the client has high yield strength values, while the competitor's has low strength and fails the burst test. For the blown films produced, the required thicknesses calculated using the Barlow formula with experimental yield strength values are 0.270 mm for PP, 0.327 mm for HDPE, and 0.987 mm for LDPE. Sealing thicker films is challenging, and improvements in sealing parameters are necessary for HDPE and PP.

Conclusions and recommendations

- LDPE and HDPE blown films were successfully produced but PP films were non-homogeneous with wrinkles;
- Required thicknesses for Level 1 dunnage bag were estimated and their air diffusion in Level 1 dunnage bag leak test was insignificant;
- Yield and seal strength were measured, showing that the customer's dunnage bag with two layers is highly resistant;
- LDPE sealed properly, while HDPE and PP faced difficulties, with optimal conditions slightly below the melting point and adjusting pressure and dwell time. PP is the best material due to its strength, thinness, cost, and sealing, but needs improved processing for homogeneous films;
- Next steps involve optimizing the sealing process of thick films and the blown film process of PP.

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