Tailored Material Properties
Using Single Layer Extrusion
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Introduction

Medical tubing is a critical step for manufacturing of high pressure and stent delivery balloons. Strict dimensions within tight tolerances are required for regulatory reasons. These tubes are manufactured by a continuous process called extrusion. A commonly known problem is that, depending on extrusion parameters, tubes with similar dimensions present different mechanical properties. Due to the important stretching the tubes will undergo during balloon forming, their quality are of first importance for the ability to form high-strength balloons.

Objectives

The aim of this project is to assess the influence of extrusion parameters on dimensions and morphology of polymer medical tubes in order to understand their different mechanical properties.

Experimental

Tubes manufactured with different extrusion parameters are characterized by:

- Tensile test
- Differential Scanning Calorimetry
- Polarized Light Microscopy
- Fourier Transformed Infrared Spectroscopy
- Wide Angle X-ray Scattering

Correlation between the morphology and the mechanical properties are observed.

Results

Design of Experiment

Design of experiment is used to measure the effect of several input parameters of a defined system onto the output properties. The input is typically processing parameters and the output may be physical properties. The main goal of a DoE is to assess the contribution of a specific parameter compare to others on several measured outputs. As a result, it creates a mathematical model that can, in the experimental space, predict the inputs in order to get a product with desired features.

Input parameters:

- Melt pressure
- Drawing speed
- Air gap
- Melt temperature

Output properties:

- Elongation at break
- Outer diameter
- Wall thickness

Mathematical models are created to predict the output properties as:

\[ X_i = K + K_aA + K_bB + K_cC + \ldots + K_{ab}AB + K_{ac}AC + K_{bc}BC + \ldots + K_{a2}A^2 + K_{b2}B^2 + K_{c2}C^2 + \ldots \]

Where:

- \( X_i \) is the dependent response variable
- \( K \) is a constant
- \( K_a \) is the factor for the independent variable A
- \( K_{ab} \) is the factor for the interaction of variable A and B
- \( K_{a2} \) is the square factor for the independent variable A

Conclusion

Several extrusion parameters are studied such as the polymer melt pressure, melt temperature, drawing speed, gap between water bath and extruder head as well as the dimensions of die and mandrel. Their impact on the tube dimensions is reported according to the change in outer diameter and wall thickness. An improved method to mechanically test the tube in tension is proposed. Mathematical models to describe the contribution of each parameter on the elongation at break and dimensions are developed. An optimization using these models is performed in order to maximize the elongation at break for specific tubes’ dimensions. The morphology of polymer tubes is quantified and correlated with the different extrusion parameters.