Synopsis
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Chapter 1: Introduction
The introductory chapter provides a description of the extrusion film casting (EFC) process and its industrial application. The commercial importance and relevance of this process is also discussed through global demand and production numbers for the films made by this process. The chapter discusses the key defects of the EFC process namely, necking and edge-beading, and instabilities such as draw resonance that limit the productivity of the process and also affect final film properties. Next, the chapter provides background on the various polyethylenes (PE’s) that are widely used in EFC and their macromolecular attributes. Finally, the role of macromolecular architecture on the EFC process through polymer dynamics and rheology is brought forward. At the end of the chapter, the objectives and scope of the present work are stated.

Chapter 2: Literature Review
This chapter provides a comprehensive literature review of all relevant prior art in the EFC process. The experimental and numerical modeling efforts of various researchers for investigating the key defects associated with the EFC process such as necking and edge-beading are reviewed here. Next, the key concepts of polymer dynamics are brought forward to explain the reptation and tube theories. Literature on the molecular constitutive models such as the Rolie-Poly (RP-S) and the eXtended Pom-Pom (XPP) is discussed. Finally, a few papers discussing the role of macromolecular architecture on the necking phenomenon are reviewed.

Chapter 3: Materials & Characterization
In this chapter, the detailed characterization of selected PE materials used in EFC processing is presented. The PE materials are all equivalent melt flow index (MFI) materials with either linear or long chain branched (LCB)
architecture. In particular molecular level characterization by high-
temperature gel permeation chromatography (HT-GPC) and high-
temperature nuclear magnetic resonance (HT-NMR) is discussed. HT-GPC
gives the average molecular weights (MW), molecular weight distribution
(MWD) and distribution of long chain branching, if any, in the PE materials.
HT-NMR provides information on the extent of long-chain branching (LCB)
present, if any, in the PE materials. The polymers were also characterized by
differential scanning calorimetry (DSC), which provides information on
melting and crystallization temperature of the polymers. Next, detailed
rheological characterization of the given PE materials is presented. In
particular, rheological data from tests such as steady-shear, step-shear, small
amplitude oscillatory shear (SAOS), creep, capillary, and uniaxial extension, is
presented. From the rheological data, the relaxation spectra, the flow-
activation energy (FAE), the zero-shear viscosity (ZSV), etc. for the given PE
materials are obtained. Finally, the rheological data is modeled with the
appropriate “molecular” constitutive equations such as the RP-S and XPP, and
key model parameters are obtained.

**Chapter 4: Experimental Studies on Extrusion Film Casting (EFC)**

In this chapter, the details of the lab-scale EFC experimental set-up are
outlined. The experimentally probed ranges of the key parameters such as
draw ratio (DR), take-up length (TUL), extrusion temperature, screw speed,
and the chill-roll temperature are given. Details of the measurement
techniques to obtain the film necking, thickness, and temperature profiles are
presented. The technique to determine the centerline surface velocity in the
molten extruded films is also described. Data analysis techniques used in this
research include Matlab® based particle-tracking velocimetry (PTV) for
centerline velocity profile and image analysis for edge-detection for necking
profile. Infrared thermographic image analysis to obtain surface temperature
of molten extruded films is also presented. Additionally, the width and
thickness variation of the solidified PE films with DR and TUL is presented.
Chapter 5: CFD Modeling Studies on Extrusion Film Casting (EFC)

This chapter describes the CFD modeling studies performed on the EFC process. The EFC process is analyzed using the one-dimensional (1-D) flow model of Silagy et al.¹ in conjunction with the RP-S and XPP constitutive equations, under isothermal as well as non-isothermal processing conditions. Governing equations, constitutive equations, and the relevant boundary conditions are written in the form of coupled ordinary differential equations. The coupling of temperature in the flow model is introduced by considering a temperature dependence on viscosity and relaxation time represented by Arrhenius law. CFD simulations are performed using Matlab® software with a built-in optimizer toolbox. It is possible through the use of the CFD toolbox to choose virtual polymers (with given macromolecular architecture) and perform EFC simulations to carefully elucidate the role of LCB and MWD on the necking and other related phenomena in EFC process.

Chapter 6: Results & Discussions

In this chapter, the results from the CFD simulations of the EFC process are compared with the experimental results. In particular, semi-quantitative comparisons are made between experimental data and simulation results for necking, thickness, centerline velocity, and temperature profiles. Experimental data is compared with CFD simulations run under isothermal and non-isothermal conditions. Additionally, CFD simulation results for a few hypothetically constructed polymers with controlled macromolecular architecture are also presented to elucidate the role of LCB, MWD, and the non-isothermal conditions on necking and other important parameters in the EFC process.

Chapter 7: Conclusions and Future Work

This chapter summarizes the important conclusions of this research and suggests recommendations for future work in this area.