UNIVERSITI TEKNOLOGI MARA

MODELLING AND PROFIT MAXIMIZATION OF LOW-DENSITY POLYETHYLENE IN INDUSTRIAL HIGH PRESSURE TUBULAR REACTOR

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ABSTRACT

Highly exothermic nature of low-density polyethylene (LDPE) polymerization process and expensive cost of heating-cooling equipment in tubular reactor have led to low ethylene conversion and high production costs. Both problems are taken into account when optimizing the LDPE production to obtain the highest profit without violating the thermal safety regulations. However, the monomer conversion (X_M) which is typically correlated with profitability would make this a complex operation. Thus, an optimization study has been conducted to maximize profit of the LDPE production under safety and product quality constraints in this work. Prior to the optimization study, kinetic rate parameters selection was carried out. A mathematical model of LDPE production in tubular reaction has been well - developed and validated using the given industrial data. Several mass and energy balances were also involved in this study. Only the first zone of the LDPE tubular reactor was taken into account for this study. Based on the sensitivity studies, monomer flow rate (F_M), solvent flow rate (F_S), initiator flow rate (F_I) reactor inlet temperature (T_{in}), inlet pressure (P_{in}) and reactor jacket temperature (T_J) were selected as the optimized input parameters. These parameters have shown significant results towards the performance and quality of LDPE which is known as melt-flow index (MFI). This optimization study employs a *dynopt* coded programming, which is based on the orthogonal collocation (OC) and quadratic programming (SQP) approaches in order to overcome the non-linear programming (NLP) issues. In different constraints case studies, the unconstraint optimization has obtained the highest X_M than the base case and other constraints. Six control variables were also involved in this work. The maximum temperature (T_{max}) and melt-flow index (MFI) constraints were considered and successfully satisfied in all cases. The monomer conversion and profit obtained in the case study was the highest at 13.55% and RM98.51 million/year. Overall, the complex relationship between the process parameters for the LDPE tubular reactor was successfully resolved using the optimization method. Lastly, the findings on this study will redound to the benefits towards industrial aspect under profitability and growth.

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The thesis is dedicated to my backbone, Dr Mohd Supion bin Haji Dimin and

including my friends for their support. This piece of victory is dedicated to my whole family and I would also like to express my gratitude to my late grandmother, Allahyarham Khatijah @ Mek Bt Omar for being with me throughout the whole journey of me completing my master's degree till her death.

Pursuing my postgraduate studies was considered as a lonely journey and overwhelming for me to complete it within a year due to being a caregiver at the moment. Choosing a different path from most of my peers while going through a rough patch in life have led me to having constant anxious thoughts and loss of motivation. The feeling of being trapped in a bubble and involved in a repetitive cycle made me burnout and wished a lot of things could be different.

As time passes, hatred inside me have grown significantly and were indeed causing more harm towards my mental and physical health state instead of the total opposite due to feelings of inadequacy and emptiness. Furthermore, the amount of times I felt wanting to disappear in thin air and never look back at all the pains that I've endured and including the one that I'm currently enduring, by choice as a compromise. I believed that's the moment I want to be found the most whenever I felt like disappearing which allows them to see the softness that I've within, that I too need help and also that I'm not always a strong independent woman.

Acknowledging my feelings from running away from all the pain and problems were understood because I'll never be healed in a matter of time if I keep on telling myself if it doesn't bother and hurt me in some ways. I once believed that the more I run from it, the more it would be less painful but I was wrong. Without people realizing, I love the most when people point light at me whenever I'm surrounded by darkness.

Throughout the whole journey, a total stranger that Allah made me crossed paths was my biggest supporter during my darkest days and giving the reassurance that I seek out. The amount of gratitude I've for this person as my active listener and became the reason for me to start viewing life in a good perspective were indeed blessings from Him.

Lastly, I constantly tried to humble myself while embracing obstacles by believing that there must be wisdom behind every trials that I've faced with patience because Allah's help is close to those who are patient. My determination and perseverance are two crucial qualities that have brought me to this success despite all the countless mental breakdowns, endless tears, pain, grief and loneliness. Alhamdulillah.

مَنْ جَدَّ وَجَدَ

"Whoever strives shall succeed"

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Low-density polyethylene is classified as one of the major compounds of the first grade commercialized thermoplastic polymer. This branched type of polymer is well-known for its processing and excellent end-use properties which are primarily ascertained by its molecular weight distribution (MWD), long chain branching distribution (LCBD) and short chain branching distribution (SCBD). The process in the manufacturing of LDPE has been established in the early 1970s (Häfele et al., 2005). The packaging industry's increasing need for LDPE is anticipated to fuel the market's expansion. Both non-food and food packaging are using LDPE more and more. Good tensile strength and flexibility are two characteristics of LDPE that make packaging simple. Bread bags, fruit and vegetable bags, coffee can lid, and other food packaging products are frequently made from LDPE and utilized in grocery stores. Additionally, it is utilized in non-food packaging materials as rack and counter bags, bubble wrap, envelopes, and shipping sacks.

Global demand is being driven by the expanding usage of LDPE in the production of films, sheets, and extruded coatings for packaging. Sales are anticipated to soar throughout the projected period as more and more end-use sectors adopt LDPE. Applications such as films, sheets, and coatings are driving the demand for LDPE. Moreover, demand for LDPE used as a packaging material is accelerated by the rise in packaging. With a compound annual growth rate (CAGR) of 9.6%, the size of the worldwide low-density polyethylene (LDPE) market will increase from $46.65 billion in 2022 to $51.11 billion in 2023 (Clara, 2023). A market assessment demonstrates that the projected growth in LDPE production and consumption rates provide justification for the material's steady improvement over the previous 40 years. Figure 1.1 shows that the sales of low-density polyethylene have increased at a 4.4% of compound annual growth rate (CAGR) between 2014 and 2021 due to strong demand across all application areas. Besides, 68% of films and sheets were favoured by consumers through the split of application in the year 2022.