UNIVERSITI TEKNOLOGI MARA

MODELLING AND CONTROL OF DISTILLATION PLANT USING FRACTIONAL-ORDER PID CONTROLLER

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ABSTRACT

Over the recent years, there has been an explosive growth of interest in the usage of essential oil. Essential oils can be obtained through various type extraction techniques that ranging from conventional to modern techniques with the most common practice approach in extraction technology using steam distillation. Temperature is identified as the most influencing parameter in the quality of essential. Hence this study is focusing on the steam temperature control alone. The steam temperature exhibits nonlinear behaviour due to many factors. Previous studies have shown that fractional order control has the capability to handle the nonlinearity dynamic better than the conventional technique. Hence, the improvement of the control strategy is a necessary. This research presents the design of Fractional Order Proportional Integral Derivative (FOPID) with enhancement of low-pass filter and error filter for temperature regulation in a Small-Medium Industry Steam Distillation (SMISD) plant. There are several tests have been done to evaluate the performance of the developed controllers in the SMISD plant such as step test, set point change, and load disturbance test. The experiment was conducted in simulation and real-time environment. The results indicated that the system has a time constant of 796.86 s and dead time of 765.63 s. The Auto Regressive with eXogenous input (ARX) model that has been used to represent SMISD plant during the simulation study presented a good model fit with 99.24 %. The enhanced version of Model Predictive Controller (MPC) with anti-windup strategy has been introduced in this study which derived from Unconstrained MPC (UMPC) and Constrained MPC (CMPC). By integrating this strategy, it managed to stabilize the responses of UMPC controller towards step response and at the same time has a superior performance against the CMPC controller. The FOPID controller performance was successfully elevated by integrating error and low-pass filter. The error filter is responsible for eliminating persisting steady state error in fractional order controller while the low-pass filter is responsible for attenuating the effect of measurement of high frequencies noise. The improvement can be observed in simulation disturbance test where the FOPID with error and the low filter has better recover time of 12.32 % improvement compared with conventional FOPID. The performance FOPID and their variance also been benchmarked with conventional controllers (proportional controller) and advanced controllers (MPC controller) in simulation and real-time environment. The overall simulation experiments have shown the proposed FOPID-ZN*erlp* demonstrated the best performance under various test with a reduction in rise time, settling time, overshoot disturbance recovery time of 62.80 %, 87.50 %, 8.52 % and 70.30 % respectively. The real-time results have also shown agreement with reduction of 42.38 %, 65.20 %, 4.99 % and 62.92 % respectively.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

Over the recent years, there has been an increasing growth of interest in the usage of essential oil [1]. It becomes an important commodity that is traded around the world and the demands have fluctuated over the past few decades. The term of essential oils is referred to the complex mixture of low molecular weight volatile compounds [2] that were extracted from the plant. Essential oils are concentrated hydrophobic liquid consisting of bioactive compounds that are sensitive and thermolabile to the heat [3]. The plant used the essential oils as secondary metabolism for their own need apart for nutrition [4, 5]. Essential oils are commonly synthesized from plant parts such as flower [6], leaves [7, 8], root [9], and seeds [10]. Essential oils have been used in a diverse amount of applications and have a promising capability to contribute towards the expansion of economical opportunities for the industry such as food [11], fragrances [12], pesticides [13], and medicine [14]. The essential oils have characteristically strong, generally pleasant flavour and much more concentrated than the parent plants [15]. Generally, the essential oils have constituents of a terpene component, aromatic compounds, and mixture of sulphur and nitrogen compounds [16, 17].

Essential oils can be obtained through various type extraction techniques that ranging from conventional to modern techniques such as hydro distillation [18, 19], solvent extraction [20], supercritical fluid extraction (SFE) [21, 22], soxhlet extraction [23, 24], and steam distillation [25, 26]. Although it seems relatively easy to separate the essential oils, the chemical composition of essential oils depends on the type of extraction method used. Currently, the most common practice approach in extraction technology is by using steam distillation. It represents as 93% of the total market share and the rests of 7 % of the market share are represented by other extraction methods [27]. The domination of high market share is due to the chemical structure of steam that has high capacity latent heat which is cheaper and widely available [28]. In term of operation, it has the lowest operation cost compared to other available methods and high productivity and the end product (essential oils) are clear from additional substances