UNIVERSITI PUTRA MALAYSIA

CONTROL OF GRAIN DRYING PROCESS USING SELF-TUNING QUANTITATIVE FEEDBACK THEORY

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CONTROL OF GRAIN DRYING PROCESS USING SELF-TUNING QUANTITATIVE FEEDBACK THEORY

By

HASMAH MANSOR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To my beloved husband,

Muhammad Helmy

and my children,

Muhammad Fareezy Fahmy

Nur Farisya Alyssa

Nurisya Ezryn

Muhammad Rizq Aiman

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

CONTROL OF GRAIN DRYING PROCESS USING SELF-TUNING QUANTITATIVE FEEDBACK THEORY

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October 2011

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Faculty : Engineering

Grain drying process is very important in post-harvest technology. Drying is needed to reduce the moisture content of grains fresh from the fields to a safe level for storage. The challenges in grain drying system nowadays are to produce good quality of grains with minimal production cost and support for the green technology. There are not many automatic controllers applied to the commercial grain dryers and most existing grain dryer systems suffer unsatisfactory performance such as lack of accuracy, robustness, energy efficiency and grain quality. The main reason towards this problem is the inaccuracy of the grain dryer mathematical models which is derived based on assumptions and estimations used in designing the control system.

The performance of grain drying systems needs to be improved; therefore, this topic is proposed. A laboratory scale conveyor belt type grain dryer was specially fabricated for this study. System identification technique which utilised experimental input/output data was used to model the grain dryer plant. The obtained grain dryer process model in the form of low order transfer function was validated and the performance was compared with autoregressive with exogenous terms (ARX) model. Test result showed the process model has better modelling performance than ARX model.

The robust QFT-based controller was designed based on the obtained grain dryer process model. The controller design was done in two stages. In the first stage, the QFT-based controller was designed offline to meet the robust performance specifications and disturbance attenuation despite of uncertainty. Two ranges of uncertainty were considered; small range and wide range uncertainty. The performance of offline QFT-based controller was compared with PID controller tuned by Ziegler Nichols and Partical Swarm Optimisation (PSO). Tests results showed the superiority of QFT-based controller over PID controller tuned by both methods in terms of faster settling time, smaller percentage of overshoot and smaller control effort. However, the performance of QFT-based controller deteriorated when the parameters variation exceeded the defined uncertainty range. Therefore, in the second stage of design, online QFT-based self-tuning controller was proposed.

The QFT constraints were integrated into the self-tuning algorithm to ensure the robustness of the controller. Superiority of the online self-tuning controller was proven when the tests results showed that the online controller could adapt to larger uncertainty

range than offline controller. Better responses were produced by the online controller especially when larger parameters variation acts on the plant. The percentage of overshoot was reduced from 25% to 0.929%, and settling time from 96 to 36.5 samples.

The QFT based controller design by standard procedure successfully meets the pre-defined specifications. However, due to tighter specifications, online QFT-based self-tuning controller improves the transient response for larger uncertainty range and at the same time improves the QFT design method where the controller's design is done online.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KAWALAN UNTUK SISTEM PENGERING BIJIRIN MENGGUNAKAN TEKNIK TEORI SUAP BALIK KUANTITATIF PENALAAN- SENDIRI

Oleh

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Prosess pengeringan bijirin sangat penting di dalam teknologi selepas penuaian. Pengeringan diperlukan untuk mengurangkan kandungan lembapan di dalam bijirin yang baru dituai ke aras yang selamat untuk disimpan. Kini, cabaran yang dihadapi oleh sistem pengeringan bijirin adalah untuk menghasilkan bijirin yang berkualiti tinggi dengan kos produksi yang minima dan menyokong teknologi hijau. Terdapat tidak banyak aplikasi alat kawalan automatik pada alat pengering padi komersial dan kebanyakan sistem pengeringan bijirin yang sedia ada mengalami prestasi yang kurang memuaskan seperti kekurang dari segi ketepatan, ketegaran, kecekapan tenaga dan kualiti bijirin. Sebab utama masalah ini adalah ketidaktepatan model matematik alat

pengering bijirin yang diterbitkan berdasarkan andaian dan aggaran kemudian digunakan bagi mereka sistem kawalan.

Kecekapan dan produktiviti system pengeringan bijirin huruslah diperbaiki, oleh itu, tajuk ini dicadangkan. Pengering padi jenis tali sawat bersaiz kecil untuk kegunaan makmal telah direkacipta untuk penyelidikan ini. Identifikasi sistem telah digunakan untuk memodel alat pengering bijirin. Model proses alat pengering bijirin yang diperoleh dalam bentuk fungsi pindah aturan rendah telah disahkan dan prestasinya telah dibandingkan dengan model autoregresif dengan terma eksogenus atau "autoregressive with exogenous terms" (ARX). Keputusan ujian menunjukkan model proses mempunyai prestasi pemodelan yang lebih baik berbanding ARX model.

Alat kawalan tegar berteraskan teknik QFT telah direka berdasarkan model pengering bijirin yang telah diperolehi. Di peringkat pertama, alat kawalan berteraskan QFT direka secara luar talian untuk menepati spesifikasi prestasi tegar dan pengecilan gangguan walaupun terdapat ketidakpastian. Dua julat ketidakpastian telah diambil kira; ketidakpastian julat kecil dan ketidakpastian julat besar. Prestasi alat kawan berteraskan QFT luar talian telah dibandingkan bersama alat kawalan PID yang dilaraskan menggunakan Ziegler Nichols dan Particle Swarm Optimisation (PSO). Keputusan ujian menunjukkan kelebihan alat kawalan berteraskan QFT berbanding alat kawalan PID yang dilaraskan menggunakan kedua-dua cara dari segi masa enapan yang lebih cepat, peratusan terlajak yang lebih kecil dan usaha kawalan yang lebih kecil. Namun, prestasi alat kawalan berteraskan QFT merosot apabila variasi pembolehubah melebihi julat

ketidakpastian yang ditetapkan. Oleh itu, di dalam rekaan peringkat kedua, alat kawalan penalaan-sendiri berteraskan QFT dalam talian telah dicadangkan.

Kekangan QFT telah diintegrasikan ke dalam algoritme laras-sendiri untuk memastikan tahap ketegaran alat kawalan. Kelebihan alat kawalan penalaan-sendiri berteraskan QFT dalam talian telah dibuktikan apabila keputusan ujian menunjukkan alat kawalan ini boleh menyesuaikan diri kepada julat ketidakpastian yang lebih besar berbanding alat kawalan luar talian. Gerak-balas yang lebih baik telah dihasilkan oleh alat kawalan penalaan-sendiri berteraskan QFT dalam talian terutamanya apabila 50% variasi pembolehubah bertindak ke atas mesin. Peratusan terlajak system pengeringan padi telah dikurangkan dari 25% ke 0.929%, masa enapan dari 96 to 36.5 pensempelan.

Alat kawalan QFT yang direka menggunakan prosedur standard berjaya menepati spesifikasi yang diberikan. Namun, disebabkan oleh spesifikasi yang lebih ketat, alat kawalan penalaan-sendiri berteraskan QFT dalam talian memperbaiki gerak-balas fana untuk julat ketidakpastian yang lebih besar, dan dalam masa yang sama memperbaiki cara rekaan QFT di mana rekaan alat kawalan dibuat secara dalam talian.

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Wassalam…

I certify that a Thesis Examination Committee has met on 19 October 2011 to conduct the final examination of Hasmah Mansor on her thesis entitled "Control of Grain Drying Process Using Self-Tuning Quantitative Feedback Theory" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the relevant Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

HASMAH MANSOR

Date: 19 October 2011

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