ADAPTABLE ALGORITHMS FOR PERFORMANCE OPTIMIZATION OF DYNAMIC BATCH MANUFACTURING PROCESSES

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ABSTRACT

This study aims to explore the potential of implementing a multi-objective dynamic optimizer to acquire regular optimization on nonlinear characteristic of batch manufacturing process. The idea is proposed in an effort of accessing the functionality and practicability of the dynamic optimizer for the purpose of precision optimization. As such, yield productivity of maximizing the desired product while minimizing the undesired by-product could be improved. Traditionally, a fixed temperature profile has been identified and assumed as 'nominal optimized' for manufacturers to follow. Whether the process is fully optimized under inconsistent internal heat liberation, external environmental variations, model mismatches and process uncertainties remains as a challenging topic. In practice, the commercial batch process plant are often utilized to handle numerous production with different varieties of specific products and thus it is rarely being classified as dynamically optimized. This thesis investigates different approaches of integrating hybrid adaptable intelligent algorithms to accommodate the concept of precision optimization via simulated models of industry-scale and pilot-scale. The dynamic changes causing the need of dynamic modelling for a better dynamic optimization will be catered via a specifically formulated fitness function. With nowadays high end computation ability, revolutionary changes of implementing precision measurement is expectable and applicable to obtain expensive products. Central to precision manufacturing is artificial intelligence as this thesis presents the performance characteristics of tuning-based, rule-based, learning-based and evolutionary-based algorithms. Performance analyses are presented to validate how significant of the dynamic optimization based on the product molarity surpasses the existing conventional prescribed temperature approach. Various algorithms are designed, formulated and computed in MATLAB and then embedded to a real-time programmable microcontroller. The results indicate that the proposed algorithm is able to improve the percentage of yield by at least 10-15% under physical properties variation which could be a vital tool in the future era of precision manufacturing industries.

ABSTRAK

ALGORITMA KECERDASAN ADAPTIF UNTUK OPTIMASI PRESTASI BAGI DYNAMIK PROSES PEMBUATAN BERKELOMPOK

Kajian ini bertujuan untuk meneroka potensi pelaksanaan pengoptimasi dinamik pelbagai objektif untuk memperolehi pengoptimuman kerap ke atas ciri-ciri proses tidak linear dalam pembuatan kimia secara kelompok. Idea ini dicadangkan sebagai usaha mengakses kebolehgunaan pengoptimasi dinamik bagi tujuan pengoptimuman tepat. Dengan itu, kecekapan untuk memperolehi maksimum hasil produk diingini dengan minimum produk sampingan tidak diingini boleh ditambahbaikan. Sexara tradisinya, profil suhu sasaran telah dikenalpasti dan diambil sebagai pendekatan 'pengoptimuman nominal' untuk dipatuhi. Samada proses dioptimumkan sepenuhnya di bawah pembebasan tenaga haba tidak konsisten, perubahan persekitaran luaran, ketidakpadanan model dan ketidaktentuan proses kekal sebagai satu topik yang mencabar. Dalam praktikal, loji proses kelompok komersial sering digunakan untuk mengendalikan pelbagai jenis produk di mana ia jarang diklasifikasikan sebagai proses dinamik yang telah dioptimumkan. Tesis ini mengkaji pendekatan yang berbeza mengintegrasikan hibrid algoritma pintar penyesuaian diri untuk menampung konsep pengoptimuman ketepatan melalui simulasi model bagi reaktor kelompok pelbagai skala. Perubahan dinamik memerlukan pemodelan dinamik untuk pengoptimuman dinamik lebih baik boleh diperolehi melalui rumusan fungsi kecergasan secara khusus. Dengan keupayaan pemprosesan yang cekap pada masa kini, revolusi untuk pengukuran tepat dapat dijangka dan digunakan bagi penghasilan produk mahal. Keutamaan dalam pengeluaran tepat adalah kecerdasan buatan di mana tesis ini menyiasat ciri-ciri prestasi penentuan, peraturan asas, pembelajaran dan evolusi algoritma. Analisis prestasi dibentangkan bagi pengesahan kepentingan pengoptimuman dinamik berdasarkan kepekatan produk melebihi cara konvensional mematuhi profil tetap. Algoritma direka, dirumus dan dikira melalui MATLAB serta terbenam pada pengawal dalam talian secara praktikal. Keputusan menunjukkan algoritma yang dicadang mampu meningkatkan peratusan hasil 10-15% melalui variasi fizikal akan menjadi alat penting bagi industri pembuatan ketepatan dalam era masa depan.

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LIST OF ABBREVIATIONS

DM_{TC}	Dual-Mode temperature controller
DP_{ME}	Dynamic Programming as a model estimator
EA_{OC}	Evolutionary algorithm optimized controller
EA_{OC-MO}	Evolutionary algorithm optimized controller and molarity optimizer
EA_{TO-MO}	Evolutionary algorithm multi-mode optimizer
FL_{TC}	Fuzzy Logic temperature controller
$FLPID_{TC}$	Fuzzy Logic PID temperature controller
GA_{MO}	Genetic Algorithm molarity optimizer
GA_{TC}	Genetic Algorithm temperature controller
PID	Proportional-Integral-Derivative
SA_{MO}	Swarm Algorithm molarity optimizer
SA_{TC}	Swarm Algorithm temperature controller

LIST OF SYMBOLS

α_{AB}	Estimated reaction-rate coefficient
α_{AC}	Estimated reaction-rate coefficient
α_j	Estimated model coefficient
α_r	Estimated model coefficient
a_k	Arbitrary constants of model output
A_s	Conducting surface area of reactor substances
β_{AB}	Estimated reaction-rate coefficient
β_{AC}	Estimated reaction-rate coefficient
β_j	Estimated model coefficient
β_r	Estimated model coefficient
b_k	Arbitrary constants of model output
c	Molar concentration of substance
c_i	Molar concentration of substance in ith inlet stream
c_j	Molar concentration of substance in jth outlet stream
ce	Change in error
C_A	Molar heat-capacity of substance A
C_B	Molar heat-capacity of substance B
C_C	Molar heat-capacity of substance C
C_D	Molar heat-capacity of substance D
C_f	Heat capacity of fluid
C_i	Molar heat-capacity of substance i
C_s	Total molar heat-capacity of reactor substances
d_l	Process disturbance
ϵ_n	Error of variation between model and measured outputs
e	Error

E_{cj}	Sum of heat energy transferred from fluid to jacket
E_i	Activation energy of reaction i
E_j	Sum of heat energy stored in jacket
E_{jr}	Sum of heat energy transferred from jacket to reactor
E_r	Sum of heat energy stored in reactor
E_{rj}	Sum of energy transferred from reactor to jacket
E_R	Sum of heat energy released due to reaction
f_{C}	Fitness function of control system
f_{MO}	Fitness function of molarity optimizer
f_{O}	Fitness function of optimization system
f_{TC}	Fitness function of temperature controller
f_{TO}	Fitness function of temperature optimizer
F_c	Manipulated fluid flow rate
F_i	Volumetric flow rate of the ith inlet stream
F_j	Volumetric flow rate of the jth outlet stream
h_i	Specific enthalpy of the material in the ith inlet stream
h_j	Specific enthalpy of the material in the jth outlet stream
h_s	Conducting height of reactor substances
ΔH_{AB}	Enthalpy change of Reactions AB
ΔH_{AC}	Enthalpy change of Reactions AC
k	Reaction-rate constant
k_B	Boltzmann constant
k_i	Reaction rate constant of reaction i
k'_{AB}	Rate constant of Reactions AB
k'_{AC}	Rate constant of Reactions AC
k'_i	Frequency factor of reaction i
K	Kinetic energy of the reactor system
K_d	Derivative parameter

K_i	Integral parameter
K_p	Proportional parameter
m_k	Process input
$\widetilde{m}_{n-k}$	Previous measured input
M_A	Number of moles to substance A
M_B	Number of moles to substance B
M_C	Number of moles to substance C
M_D	Number of moles to substance D
M_i	Number of moles to substance i
M_s	Total moles for reactor substances
M'_A	Molar mass of substance A
M'_B	Molar mass of substance B
M'_C	Molar mass of substance C
M'_D	Molar mass of substance D
M'_i	Molar mass of substance i
${M_e}^2$	Squared modelling error
$\int {M_e}^2\, dt$	Integral squared modelling error
ρ	Density of the material in the reactor system
ρ_f	Fluid density
ρ_i	Density of the material in the ith inlet steam
ρ_j	Density of the material in the jth outlet stream
ρ_s	Overall density of the reactor substances
P	Potential energy of the reactor system
P_i	Process parameters
Q_{cj}	Heat transferred from the fluid to jacket
Q_j	Heat exchanged in the jacket
Q_{jr}	Heat transferred from jacket to reactor
Q_r	Heat exchanged in the batch reactor