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A Proposed Control Strategy for Processing Industries in Ghana

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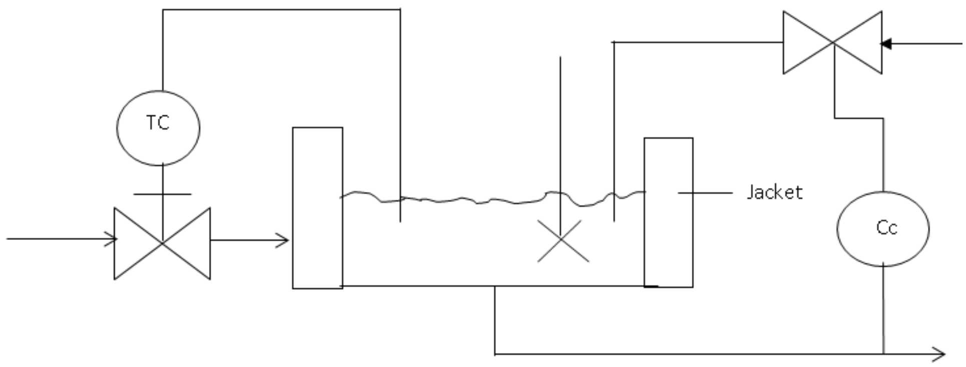
ABSTRACT
Industrial processes in Ghana are set of interrelated elements that act together to achieve desired values. These processes are nonlinear, mostly in liquid form in the continuous stirred tank reactor. Temperature and concentration are the common nonlinearities of these processes which pose serious control problems to these processes. According to experiments and theories, adaptive control mechanisms will solve the problems of these nonlinearities. Industrial practitioners must be encouraged to use adaptive control mechanisms and the gap between industry and academia must be close.
Keywords: Nonlinear, Temperature, Stirred-tank, Adaptive, Process.

INTRODUCTION

Most processing industries in Ghana are liquid or chemical processing which are defined as a set of interrelated elements that act together for performance to achieve desired values or set points. These elements are: machinery, tools, equipment, raw materials, labour, and management among others. Almost all these processes of manufacturing or processing industries in Ghana are non-linear. These industries are food, soap, beverages, hair creams, fruits, edible oil, industrial oil, fuel among others. Also these industries in Ghana use the continuous stirred tank reactor technology which has complex nonlinearities. The target process of the article is the continuous stirred tank reactor (CSTR) because it is use by all the types of industries mention above. The processes of the CSTR involve the effective mixing at conditional temperatures, concentration among others for the exact addition of chemicals and raw materials resulting to the complex nonlinearities they pose. Temperature and concentration pose the extremely difficult nonlinearities for the processes in the Ghanaian industries and are challenges to the implementation of modern control theories. Furthermore, while linear control processes and their systems have being successfully implemented and develop, these nonlinearities or nonlinear processes (CSTR) cause by temperature, flow, pressure, feed rate, concentration, dissolve oxygen used to cultivate cells in reactors, densities, wear and tear are making control of processes in this industries unsuccessful. Therefore, the objective of this research is to introduce strong control mechanisms (adaptive control law) that will make the proper changes on these processes to cancel these negative impacts that such nonlinearities have on the desired CSTR operations. Thus nonlinear controllers must be develop and analyzed to help Ghanaian industrialist as well as professionals solve nonlinearity problems at their industries. These nonlinearities also cause actuators to lose their authority under different operating conditions.

REVIEWED LITERATURE ON CSTR IN GHANAIAN INDUSTRIES

Diagram:-



TC = Temperature controller

Cc = Reaction composition controller

Description

The above diagram or sketch is a simplified form of CSTR use by almost all processing industries in Ghana. It shows the major features of the CSTR that liquid processing industries use in Ghana. This CSTR belongs to a class of nonlinear systems where both the steady state and dynamic behaviours are nonlinear. These process nonlinearities of this CSTR cause difficulties when controlling with conventional controllers with fixed parameters. One of the possible methods of solving these nonlinearities is by using adaptive control strategies based on appropriate choice of external linear model with recursive estimated parameters. The function of the jacket surrounding this CSTR is to remove accordingly heat generated by the CSTR. Thus energy passes through the CSTR walls and enters into the jacket to be transfer away. This jacket has feed, exist streams and assume to be perfectly mixed at lower temperatures. The control objective for the CSTR use in Ghanaian industries is to keep the temperature of the reaction mixture constant at desire values or range. Coolant temperature is a manipulated variable, whiles the operation of CSTR is disturbed by external factors. The CSTR use by Ghanaian industries is operated on by reactions that are exothermic. The stirrer is responsible for the effective mixing of the reaction mixture.

Principles of Operations
The CSTR use by most process industries in Ghana has two loops. From the diagram, one loop is for temperature control and the other loop is for reactant concentration control. There may be one loop, thus temperature controller (TC) and reaction composition controller (Cc). The reactant concentration may be manipulated by regulating the feed flow rate to this CSTR. Heat energy supply through coil results in the controlling of temperature of the reaction mass. Furthermore, the rate of reaction of these Ghanaian industries processes, CSTR can be manipulated by appropriate adjustments in temperature resulting to composition changes.

Mathematical Modeling
Balances within these CSTRs accounts for their appropriate mathematical modeling. The adaptive control law (Lyapunov adaptation law) finds a set of parameters that minimizes the difference (error) between the CSTR and the model outputs. The parameters of the nonlinear controller are appropriately adjusted until this error has reduced to zero.
The exothermic reaction scheme for these CSTRs is

$$A \xrightarrow{K_1} B \xrightarrow{K_2} C$$

This model of the CSTR is described by four nonlinear differentials given below as:

$$\frac{\partial C_A}{\partial t} = -\left[\frac{Q_r}{V_r} + K_1\right] C_A + \frac{Q_r}{V_r} C_{AF} \rightarrow (1)$$

$$\frac{\partial C_B}{\partial t} = -\left[\frac{Q_r}{V_r} + K_2\right] C_B + K_1 C_A + \frac{Q_r}{V_r} B_F \rightarrow (2)$$

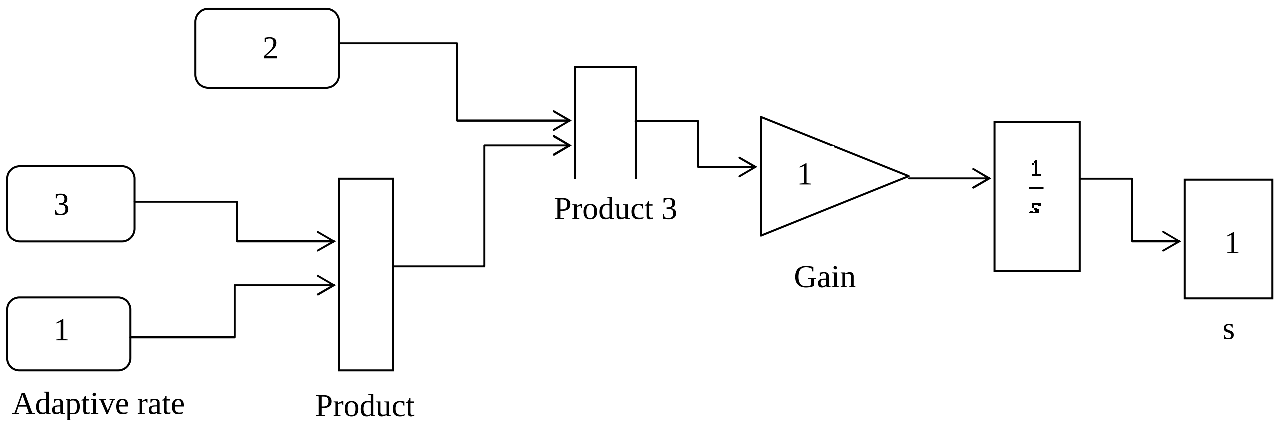
$$\frac{\partial T_r}{\partial t} = \frac{h_r}{(PC)r} + \frac{Q_r}{V_r}(T_d - T_r) + \frac{A_k U}{V_r (PC)r}(T_c - T_r) \rightarrow (3)$$

$$\frac{\partial T_c}{\partial t} = \frac{Q_c}{V_c}(T_{cf} - T_c) + \frac{A_k U}{V_c (PC)c}(T_r - T_c) \rightarrow (4)$$

Where
t = time
c = concentration
T = temperature
v = volumes
r = densities
C_p = specific heat capacities
Q = volume flow rates
A_k = heat exchange surface area
U = heat transfer coefficient
subscript r = reactant mixture

subscript c = coolant
subscript f = feed or inlet values
superscript s = steady state values

The Simulink buildup of the adaptation law (Lyapunov adaptation law) of the CSTR is given below as



The transfer function of the CSTR process is given as

$$G_p(s) = \frac{b_1 s + b_0}{s^2 + a_1 s + a_0}$$

Where
a = input parameter
b = output parameter

The transfer function of the model to match the CSTR process is given by

$$G_m(s) = \frac{\omega_n^2}{s^2 + 2\omega_n \varepsilon s + \omega_n^2}$$

Where
ε = damping ratio
ω_n = natural frequency

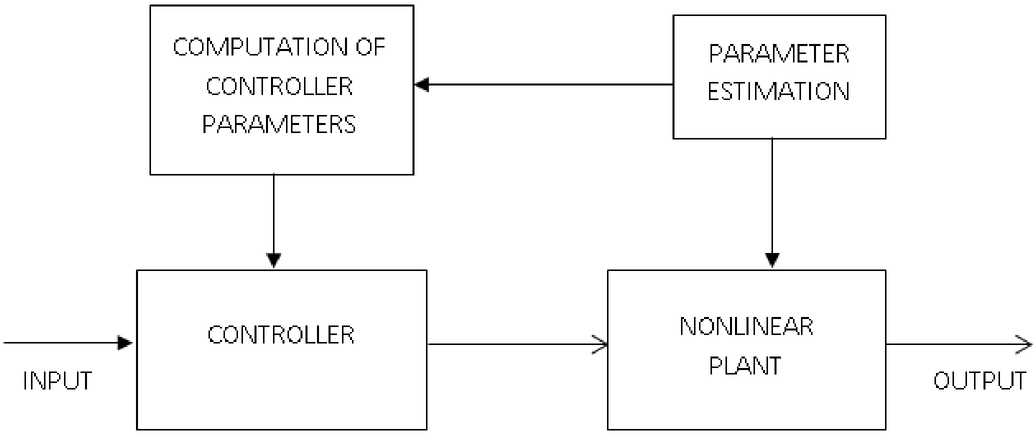
DISCUSSIONS
The reaction is exothermic; therefore the temperature can be manipulated by controlling the concentration. More penetration of concentration means the temperature inside the reactor will be higher. The control objective of the article is to maintain the CSTR processes in Ghana industries at the desire (set point) steady state operating points. The manipulating temperature is responsible for maintaining the CSTR temperature at the desired set point. As a result, there is the need to form a control action to alleviate the impact of nonlinearities and keeping values at their set points.

CONCLUSION
Research reveals that the PID controller must not be use but rather the adaptive controller due to the following reasons;

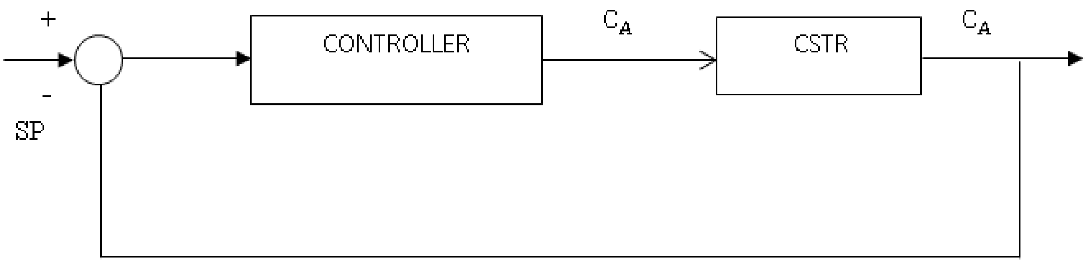
PID does not maintain stability.
PID provides higher response time.
PID does not keep temperature and concentration at desired values.
The peak overshoot is slow.

PID does not effectively suppress the influence of external disturbances.
Also, from theory, simulation result indicates that the adaptive controller were appropriate to use under the condition of nonlinear difficulties.

SUGGESTED ADAPTIVE CONTROL SCHEME



BLOCK DIAGRAM OF SUGGESTED CONTROL SYSTEM



RECOMMENDATIONS

Develop nonlinear controllers (adaptation law) to close the widening gap between the academia and industry.
The academia must make the applicability of nonlinear control (adaptation law) accessible to all industrial practitioners in Ghana.
Intensification of enough education.

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