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Optimal Design of PID Controller for a CSTR System Using Human Dynamic Opinion Algorithm

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Abstract-*This paper presents a comparative analysis of continuously stirred tank reactor (CSTR) control based on optimal tuning of PID control based on Human Dynamic opinion algorithm. In Human Dynamic opinion control parameters of PID controller is tuned by using the concept of different human opinions get optimized operating point for minimum error. The results show the adjustment of PID parameters converting into the optimal operating point and the good control response can be obtained by the Human dynamic opinion technique.*

Introduction

The continuous stirred-tank reactor (CSTR), also known as vat- or back mix reactor is a common ideal reactor type in chemical engineering. A particular CSTR with a single steady-state as a function of jacket temperature may have multiple steady-state behavior if the jacket inlet temperature is considered the manipulated. A chemical reactor contains two types of chemical reactions: exothermic and endothermic reactions, which is mainly used for heating and cooling of one or more than one chemical in reactor[1]. But for isothermal condition, temperature is constant throughout the process i.e. heat will neither evolve nor absorb in chemical reactor. The main task of chemical engineers is to ensure that the reaction will give relevant output with good efficiency, i.e. maximum profit and minimum cost. A continuously stirred tank reactor (CSTR) with concentration control transfer system is an interesting dynamic phenomenon. Because of the immense use of CSTR in process control industries, control engineers are taking much interest in intelligent control mechanism to get desired result.

PID controller is a generic control loop feedback mechanism widely used in industrial control systems[2]. It calculates an error value as the difference between measured process variable and a desired set point. The PID controller calculation involves three separate parameters proportional integral and derivative values[3]. The proportional value determines the reaction of the current error, the integral value determines the reaction based on the sum of recent errors, and derivative value determines the reaction based on the rate at which the error has been changing the weighted sum of these three actions is used to adjust the process via the final control element. Controller tuning is used to determine the controller parameters, which helps to get optimum output and minimize the error of the system. It is difficult to determine the optimal value of PID controller parameters through conventional tuning method [4].The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). The proportional, integral, and derivative terms are summed to calculate the output of the PID controller. Defining u(t) as the controller output, the final form of the PID algorithm is:

$$U(\mathrm{t}) = \mathrm{MV}(\mathrm{t}) = k_p e(\mathrm{t}) + \mathrm{k}_i \int e(\mathrm{t})dt + k_d \frac{de(\mathrm{t})}{dt} \quad (1)$$

Computational Fluid Dynamics Model

The equations which describe the processes of momentum, heat and mass transfer are discretized and solved iteratively for each control volume. As a result, an approximation of the value of each variable at specific points throughout the domain can be obtained. The turbulence equations were also solved in conjunction with the continuity equation, the Navier–Stokes equation, and the energy equation. According to Meroney and Colorado (2009), the standard k-e model is the most adopted turbulence closure because of its simplicity, low computational requirement and good convergence for complex turbulent flows. We assume that the mixture of substrate and activated sludge in the reactor is homogeneous and incompressible, and that the various components of the mixture shared the same mean velocity, pressure and temperature fields[5].

The following general form is used to model interphase drag forces. M_α describes the interfacial forces acting on phase α due to the presence of phase β

$$M_\alpha = c_{\alpha\beta}^{(d)}(U_\beta - U_\alpha) \qquad (2)$$

where coefficient $c_{\alpha\beta}^{(d)}$ was computed applying the dimensionless drag coefficient

$$C_D = \frac{D}{\frac{1}{2}\rho_\alpha (U_\alpha - U_\beta)^2 A} \qquad (3)$$

$$c_{\alpha\beta}^{(d)} = \frac{C_D}{8} A_{\alpha\beta}\rho_\alpha |U_\beta - U_\alpha| \qquad (4)$$

Human Dynamic Opinion Algorithm

Human interactions give rise to the formation of different kinds of opinions in a society. The study of formations and dynamics of opinions has been one of the most important areas in social physics. The opinion dynamics and associated social structure leads to decision making or so called opinion consensus. Opinion formation is a process of collective intelligence evolving from the integrative tendencies of social influence with the disintegrative effects of individualization, and therefore could be exploited for developing search strategies. The algorithm is governed by four basic rudiments namely social structure, opinion space, social influence and updating rule. Social structure is an important aspect of social dynamics which governs the interaction between two individuals, among individuals, the frequency of interactions and the way of interactions. Many different social structures e.g. small world[6-7], random graphs[8-9], cellular automata model[10] etc. have been proposed and simulated in social physics. The second basic rudiment of the proposed algorithm is Opinion space. In social physics terms, as already described, the individual's opinion may be of two kinds: discrete or continuous. Discrete opinions may take values such as {0,1} or {1,1}, whereas, continuous opinions could be any real. Social influence is the combined effect of these influences, due to which, individuals act in accordance to the beliefs and expectations of others. This forms the third rudiment of the algorithm. Updating rule which governs its dynamics in general. The social interaction models invariably encompass the idea of change of opinions of an individual. Various strategies/rules have been adopted to update the opinions, as stated in the literature[11].

The social influence $w_{ij}(t)$ of individual j on individual i is given by-

$$w_{ij}(t) = \frac{SR_j(t)}{d_{ij}(t)} \qquad (5)$$

where $d_{ij}(t)$ is the Euclidean distance between individuals i and j.

The update rule can be given by-

$$\Delta o_i = \frac{\sum_{j=1}^{N}(o_j(t) - o_i(t))w_{ij}(t)}{\sum_{j=1}^{N} w_{ij}(t)} + \xi_i(t), j \neq i \qquad (6)$$

Where, $o_j(t)$ is the opinion of neighbors of individual i, N is the no. of neighbors, $w_{ij}(t)$ represents the social influence and $\xi_i(t)$ is a normally distributed random noise with mean zero and standard deviation $\sigma_i(t)$.

$$\sigma_i(t) = S\sum_{j=1}^{N} e^{-f_{ij}(t)} \qquad (7)$$

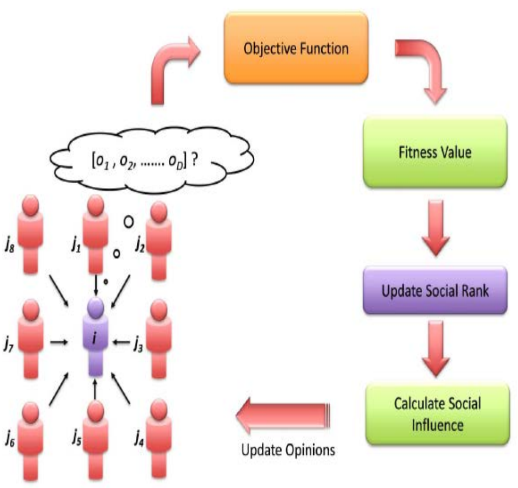

Fig.1-Human Dynamic Opinion Algorithm

4. Experiments and Results

PID TYPE	Kp	Ti	Td
P	0.6KCr	-	-
PI	0.45KCr	Pcr/1.4	-
PID	0.7KCr	Pcr/2.2	Pcr/8

Table 1-The parameters values for PID in Z-N method

Table 2-Values of PID controller parameters for different

Algorithms	Kp	Ki	Kd
Z-N	0.2	0.94	0.23
Human dynamic optimizatio n	1.2	1.3	0.100

algorithms used

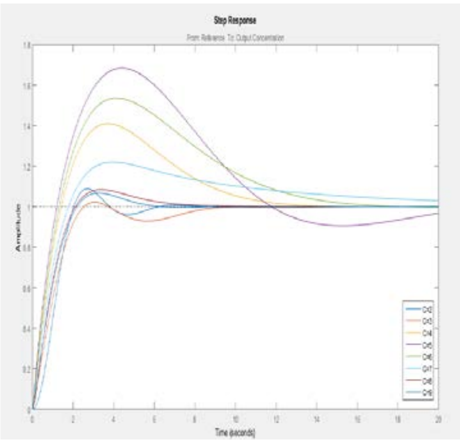

Fig.2-Different Concentration values specified depending on the error value

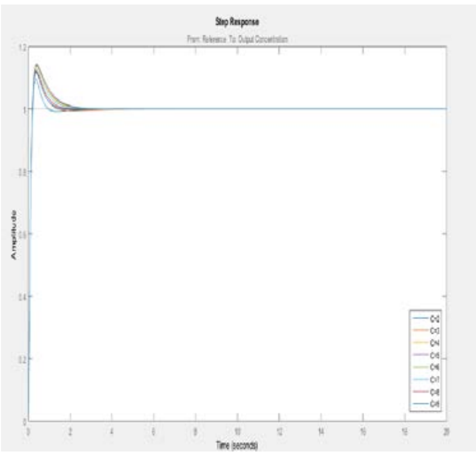

Fig.3-Output response of Concentration control of CSTR using HU-Dependent PID controller

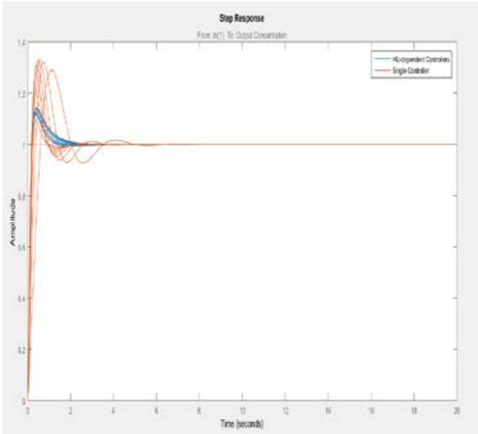

Fig.4-Comparison of output concentration control of CSTR between HU-dependent PID controller and conventional PID controller

5. Conclusion

This paper present a controller design mechanism to regulate the product concentration of an isothermal CSTR when there is a sudden change in the inflow concentration and flow rate. The controller needs to be tuned to maintain the output concentration. The conventional controller design is done by Ziegler-Nichols method, in the resent human dynamic optimization

6. References

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