An Improved Particle Swarm Optimization Based on Hormone Modulation Mechanism

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Abstract. The manufacture of polyacrylonitrile carbon fiber (PCF) contains a group of workshop technologies with very complexity. A pivotal technology is the coagulation of the PCN in production of fiber which has a great many arguments connecting with one another. In this paper, an PID neural network regulate strategy with improved particle swarm optimization (PIDNNHPSO) on account of the endocrine hormone regulate theory of human body is presented, and used to the coagulation tank of PCF manufacture. Three crucial arguments including liquid high, temperature, concentration of water are extracted. Experimental consequences reveal that the PIDNNHPSO can promptly response to the alternating quantity of regulate arguments, perfectly cut down the coupling effect and make reposeful adjustment without fluctuation, which has a exceed property than traditional regulate programmes.

1. Introduction
The manufacture of polyacrylonitrile carbon fiber (PCF) contains a group of workshop technologies with very complexity [1], such as aggregation, spin extension, coagulation, laundrying, extending, preoxidation, acieration and postprocessing, etc. The goal for exploiting so technologyes is to invent remarkable carbon fibers with typical power and coefficient of elasticity. Whereas, these technologies with varying operating places are cheek by jowl linked, and the equipment used for every technology have miscellaneous kee-jerk and regulate distinctions [2]. The distinction of the untreated materials (primarily the PCN) also miscellaneous inwardly in these technologies and so unable to be served as jarless during the entirety of manufacture, and the bonding or lag occurring in each craft link also have brought complex problem to the exploitation of brilliant regulate programs.

The solidification technology of the PCN as untreated fiber in the sink is one of the pivotal technologies during the entirety of manufacture of fibers. The PCN peptizer is above all squeezed out of the spray head at a fixed speed, shaped small flow and then immersed in a sink that involves the solidification liquor of a fixed percentage. The PCN flow there swop equipment with the solidification tank liquor, and some equipment of the solidification tank liquor also permeate into the flow which is named inchange proliferation [3]. In the meantime, the flow begin to curdle and shape the pulsable fibers that can be drived to the next technology. The performance of the finished fiber primarily resolved by the arguments of the solidification tank, and influence the crucial quality of the PCF [4]. These arguments incorporating water temperature, solute percentage, and solution height of tank have great relevances which unable to be regulated dividually and approvingly.

For the regulate of the solidification tank, a orthodox method is to set up separate alone regulate single equipment with traditional PID theory regulators for the arguments. The occlusive cycle regulate unit can hence be assured to apiece different technology a few times change numerous arguments to be regulated in the solidification tank. In the second place exercise is the stack-up regulate system for certain crucial arguments which are chosen from the full arguments while keeping others neglected. Actually, ring opening plan can be implemented for each argument by fabricating the values of arguments stable with the help of assistant devices, e.g., a hotting devices to regulate the temperature by hand. For the PCF manufacture, all the regulate tactics here in above do not take the mutuality and conjunction among arguments into attention, which cannot assure the fixed steadiness of the solidification tank. Therefore, the PCN forerunner fibers manufactured by such technology can not ensure a good performance. In another context such question is that some programmes or means disposing of equipment decoupling have been devised but not implemented to the PCN manufacture.
technology yet because of its extraordinary traits and sophisticated cut down connections among arguments.

For the manufacture technology, it is crucial to remove the coupling impacts for a many input many output regulate equipment to ensure the product quality. Cutting down connections regulate, a key approach in regulate project, is one of the most final and available methods to settle this problem. The significance of the cut down connections regulate is to cut down or remove the coupling impacts among miscellaneous loops with offsets based on the mathematical simulate or the technology mechanism. The traditional cut down connections regulate approaches contain matrix cut down connections, disintegrate connections, offset cut down connections, and pole distribution disintegrate connections. Since the precocious 1990s, numerous intelligent cut down connections regulate skills have been grown such as fuzzy cut down connections, two-layer neural networks cut down connections control approach, GA-based cut down connections, adaptive system cut down connections, and essential cut down connections. However, masses of the current approaches would be a touch sophisticated, or fail in content the cut down connections results since the multitude of them rely on precise computational patterns that are sometimes unrealistic for industrial regulate.

In this paper, an PID neural network regulate strategy via improved particle swarm optimization (PIDNNHPSO) and its optimize methods are presented on account of the endocrine hormone control mechanism of biology, and used to the coagulation bath of PCF manufacture. Experimental consequences reveale that the PIDNNHPSO can promptly response to the alternating quantity of regulate arguments, perfectly cut down the coupling effect and make reposeful adjustion without fluctuation, which has a exceed property than traditional regulate programmes.

2. Modeling of the solidification tank in PCF manufacture

The solidification technology in entirety PCF manufacture line is made up of two tanks, a tank solvend percentage tank and a solidification slot. The major materials in the solidification tank are methyl-sulfoxide (DMSO) and the rest is mostly water. The solidification tank is chiefly completed in the solvend percentage tank by blending three variety of liquids (including solvend percentage liquid) originating in three independent gaps on the preparation tank, and then mixed into the solidification tank for official use. Through above two preparation steps technology, the wave in the mixed solution can be removed, which is good to the smooth and steady of the solidification. The form of the preliminary tank is ought to be a normal cube. The solidification tank is provided with a drain port, from which liquids can be drain when the cubage of the solidification solution is a high demand, and the drain solution can be reused for solidification again. Fig. 1 shows the diagrammatic drawing of the solidification tank and the ports on it. There are numerous parameters to be regulated in the solidification tank of the PCF manufacture, for example liquid height, temperature, and concentration of tank play the main character. However, these principal parameters often produce results together, that is joining with each other. It is the principal problem for the formation of regulate system for the solidification tank. Simultaneously, other subordination parameters may also affect the whole situation of the tank. To predigest the issue discussed, three main arguments of the solidification tank fore-mentioned are chosen as the prime goals, and then its computational pattern is designed in Fig. 1[5].
Figure 1. Coagulation technology of spinning solution during wet spinning\textsuperscript{[5]}

3. PID regulate principle

PID regulate has listed below features: mechanism is brief, lessen the difficulty of accomplishing, is a simple regulation can meet the most of actual needs; regulation can be applied to all kinds of different targets, the algorithm has stabilized structure and robustness, in most cases, its regulate quality is not sensitive to the structure and arguments perturbations of regulate object\textsuperscript{[4]}. However, the main limitation of PID regulation is decided by the regulate object, generally needs to know beforehand the computational pattern of the regulate object to design. Nevertheless, in practical industrial regulation, owing to that the regulate object has non-linear, time variability and other features, so it is hard to design accurate computational pattern or the representative arguments are hard to obtain online, making it restricts the adhibiliton.

For now, the theory approach of intelligent regulate has not been found, but the neural network regulate, fuzzy regulate, expert systems regulate, genetic algorithms optimize have become approved intelligent regulate approach, and has achieved resoundingly in most applications. Hence the neural network adhilitation in automatic regulate is the meet of automatic regulation field. PID neural network regulate is the incorporation of neural network and automatic regulate PID, and becomes one of the leading edge subjects in intelligent regulate field.

With the unremitting appearance new regulate thoughts and methods in the regulate field, artificial neural network as a late-model of information obtain, representation and holding, are causing technology regulate mind. Neural network has powers to simulate any nonlinear function relationship and more easily learning means, therefore it can be used to be a novel approach of complex industrial process modeling.

Since intellectual technology accessed in regulate field, using digital technology to replace simulated technology to compose intellectual regulate system, not only can employ software to achieve PID regulate algorithm, and can employ the intellectual function to make PID regulate more flexible. Digital PID regulate in the manufacture process is the many commonly used regulate means, widely used in intellectual computer, machinery, chemical process and other industries. In the intellectual regulate system, the PID regulate is broadly applied in different fields, the regulate mechanism as shown in figure 2.

\begin{equation}
\frac{du}{dt} = K_p e(t) + T_i \int_0^t e(\tau) d\tau + T_d \frac{de(t)}{dt},
\end{equation}

\begin{equation}
et(t) = r(t) - y(t),\end{equation}

Among them, r(t) is the given value, y(t) is the actual output argument, e(t) = r(t) − y(t), PID regulate law is: $u(t) = K_p e(t) + \frac{1}{T_i} \int_0^t e(\tau) d\tau + T_d \frac{de(t)}{dt}$, $K_p$ is scale coefficient, $T_i$ is integral time arguments, and $T_d$ is differential time arguments.
4. Basic Particle Swarm Optimizer

PSO was proposed more than ten years ago. As the particle fly randomly in D-dimension search space, the position and velocity of ith particle is represented as \( X_i = (x_{i1}, x_{i2}, x_{i3}, \ldots x_{id}) \) and \( V_i = (v_{i1}, v_{i2}, v_{i3}, \ldots v_{id}) \), independently. In a D dimension search space the pbest of the ith particle is represented as \( P_i = (p_{i1}, p_{i2}, p_{i3}, \ldots p_{id}) \) and the gbest of the whole swarm is represented as \( G = (p_1, p_2, p_3, \ldots p_d) \). The PSO algorithm updates the velocity and position of each particle by following Eqs. (1) and (2), respectively.

\[
V_{i,d}^{t+1} = V_{i,d}^t + c_1 rand_1 (p_{best} - X_{i,d}^t) + c_2 rand_2 (g_{best} - X_{i,d}^t)
\]

(1)

\[
X_{i,d}^{t+1} = X_{i,d}^t + V_{i,d}^{t+1}
\]

(2)

where \( c1=2 \) and \( c2=2 \) are independently learning arguments. \( rand1 \) and \( rand2 \) are independently random arguments. \( V_{ti,d} \) and \( X_{ti,d} \) are independently the velocity arguments.

5. Hormone mechanism

The general law \( F(G) \) for hormone gland to excrete hormone was given by Farhy: the change rule of hormone has characteristics with non-negative and monotone, the rising function \( F_{up}(G) \) and decreasing function \( F_{down}(G) \) for hormone modulation comply with Hill function, as shown in Eq.(3) and Eq.(4).

\[
F_{up}(G) = \frac{G^n}{T^n + G^n}
\]

(3)

\[
F_{down}(G) = \frac{T^n}{T^n + G^n}
\]

(4)

Where, \( G \) is independent variable; \( T \) is threshold and \( T>0 \); \( n \) is Hill coefficient and \( n \geq 1 \).

One kind of Hill curve is shown in Fig.3.

![Hill curve of hormone modulation](image)

**Figure 3. Hill curve of hormone modulation**

If hormone \( x \) is regulated by hormone \( y \), then the excreting speed \( S_x \) of hormone \( x \) is determined by the concentration of hormone \( y \), as shown in Eq.(5).

\[
S_x = \alpha F(C_y) + S_{x0}
\]

(5)

Where, \( S_{x0} \) presents initial excreting speed of hormone \( x \), and \( \alpha \) is a constant.

An inspiration is obtained from hormone modulation mechanism, and then an adaptive down regulation and an adaptive up regulation are designed, therefore an HPSO is proposed.

The relation between the liquid-high, temperature and concentration of the coagulation tank and the volume of solution components coming from each entrance port can be written as

\[
y_1(k) = 0.1619 \times y_1(k-1) + 1 \times u_1(k - 1) + 1 \times u_2(k - 1) + 1 \times u_3(k - 1) \quad \text{(liquid high)}
\]

(6)

\[
y_2(k) = 0.1619 \times y_2(k-1) + 15 \times u_1(k - 1) + 50 \times u_2(k - 1) - 5 \times u_3(k - 1) \quad \text{(temperature)}
\]

(7)
\[ y_3(k) = 0.1619 \times y_3(k - 1) + 5 \times u_1(k - 1) - 0.949 \times u_2(k - 1) - 0.8245 \times u_3(k - 1) \quad \text{（concentration）} \quad (8) \]

Fig. 4 shows the performance of PID neural network regulate based on improved particle swarm optimization(set-point value : value liquid level is 1m, temperature is 18℃, concentration is 70%).

Figure 4. PID neural network regulate performance

6. References

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