

Nonlinear Equations Solving Base on Immune Genetic Algorithm

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Abstract

A steam conversion of hydrocarbon mass balance of the nonlinear equations of the immune genetic algorithm method is researched in this paper. The nonlinear equations is transformed into nonlinear optimization problems; The transformation process and implementation are discussed, this method is used to quickly and easily obtain the effective solution of the production technology. The production process used to solve practical problems, optimize production and increase economic efficiency.

Keywords: immune genetic algorithm, nonlinear solver, hydrocarbon steam reforming, material balance

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1. Introduction

A collection of people called the hydrocarbon hydrocarbons, according to its phase in turn divided into gaseous hydrocarbons, liquid and solid hydrocarbons diameter. Hydrocarbons with water vapor under certain conditions, the chemical reaction to produce with CO, CO₂, CH₄, H₂ and other components of the conversion of gas, people used to refer to the reaction of hydrocarbon steam reforming reaction. Into gas is the basic raw materials, ammonia, synthetic hydroxyl, hydrogen is widely available and so on, so steam reforming of hydrocarbons in the fertilizer industry, petrochemical industry occupies a specific position.

For the steam reforming of gaseous hydrocarbons are natural gas, oil gas, refinery gas, coke oven gas, etc.; liquid hydrocarbons are naphtha, light distillate raffinate oil, to expand the sources of raw materials, recent research has begun conversion of heavy oil steam.

Thermodynamics of hydrocarbon steam reforming and materials, energy calculation for two purposes: First, hydrocarbon steam reforming reaction investigated the extent of the changes with the process conditions for the process conditions selected to provide the thermodynamic basis. Second, do the materials of the system, heat calculations, calculated consumption indicators; provide the basis for program ratings.

With the hydrocarbon steam reforming reaction characteristics and transfer characteristics of the process deepens the understanding, learn from related disciplines to develop mathematical modeling transformation process; and be tested in practice, derived structural parameters and operating parameters such as catalyst activity, water carbon ratio, working load, excess air ratio of the reactor state, operating flexibility, energy consumption, temperature distribution, concentration distribution trend. By hydrocarbon steam reforming process, with low energy consumption is running a long cycle of high cost significant advantages, as chemicals, fertilizers, industrial backbone.

2. Material Balance Equations of Nonlinear Binary

Hydrocarbon steam reforming reaction of the system, people are interested in the three reactions, namely carbon monoxide shift reaction, methane conversion reaction, methane decomposition reaction.

When conducting material balance, given two equilibrium temperature interval, an increase of two restriction equations, the equivalent of two key components of a given that the following holds:

$$K_{P_{ms}} = 0.974P^2 \left(3a + 4b - \frac{4-m}{2}\right)^3 \frac{10^{-10}}{n_T^2 (1-a-b)(R-a-2b)} \quad (1)$$

$$K_{P_{wgs}} = b \left(3a + 4b - \frac{4-m}{2}\right) \frac{1}{a(R-a-2b)} \quad (2)$$

$$n_T = 1 + R + 2(a+b) - \frac{4-m}{2} + D + E$$

n_T --to balance the system's total number of moles, mol.°

P --total pressure, Pa; balance of the system constant.

M --hydrocarbon in the hydrocarbon feedstock of hydrogen to carbon ratio, dimensionless.

R --raw hydrocarbon molar ratio of carbon in the water, dimensionless; gas constant, 8.3143KJ/(kmol.K)

D --hydrocarbon raw materials in nitrogen and carbon ratio of hydrocarbon

E --in the hydrocarbon feedstock hydrocarbon carbon ratio of argon

$K_{P_{ms}}$ --carbon monoxide shift reaction equilibrium constant

$K_{P_{mgs}}$ -- the conversion of methane equilibrium constants

General formula for the equilibrium constant expression:

$$\ln K_p = \frac{\Delta a_0}{R * T} + \frac{\Delta a_1 * \ln T}{R} + \frac{\Delta a_2 * T}{R} + \frac{\Delta a_3 * T^2}{2R} + \frac{\Delta a_4 * T^3}{3R} + J \quad (3)$$

T - temperature, K;

J - reaction is split business;

\ln - natural logarithm.

Polynomial coefficients in enthalpy and standard free enthalpy of the known conditions, obtained:

$$\begin{aligned} \ln K_{P_{ms}} &= -22632.811 - 47T^{-1} + 8.771694 \ln T \\ &\quad - 5.3148 \times 10^{-3} T + 5.138576 \times 10^{-7} T^2 \\ &\quad + 4.289387 \times 10^{-12} T^3 - 29.878849 \\ \ln K_{P_{wgs}} &= 5041.399446 T^{-1} - 0.158666 \ln T \\ &\quad + 1.807258 \times 10^{-3} T - 4.886386 \times 10^{-7} T^2 \\ &\quad + 5.99947 \times 10^{-11} T^3 - 4.991881 \end{aligned}$$

The various type (1), (2), only a , b are two unknowns, in the past and more with the style difference, generation method, to send on behalf of the method is very cumbersome. With the proliferation of computers, some with quasi-Newton method, but also trouble; Here we use genetic algorithm, to solve quickly and accurately and to avoid local minimum points.

We are in the hydrogen material balance, process optimization, energy saving devices, the nonlinear binary encounter equations (1), (2) of the solution. In the obtained a , b value, receive:

$$\begin{aligned} CH_4 (\text{mol}\%) &= \frac{100(1-a-b)}{n_T} \\ H_2O (\text{mol}\%) &= \frac{100(R-a-2b)}{n_T} \end{aligned}$$

$$H_2(\text{ mol\%}) = \frac{100(3a + 4b - 2 + \frac{m}{2})}{n_T}$$

$$CO(\text{ mol\%}) = \frac{100a}{n_T}$$

$$N_2(\text{ mol\%}) = \frac{100D}{n_T}$$

3. Immune Genetic Algorithm

Immune genetic algorithm (IGA) is based on biological immune mechanism in recent years, an improved genetic algorithm is proposed, is a new computational intelligence approach, which is the principle of life science and traditional genetic immune grate method combination. Biological diversity of the immune system has antibodies, self-regulation, and other characteristics of the immune memory function [3], immune genetic algorithm is introduced based on genetic algorithms the basic characteristics of biological immune system. Now research and application show that the immune genetic algorithm both the searching speed, global search ability and local search capabilities, optimal design is becoming one of the hot areas of research [4].

Immune genetic algorithm to solve the problem to be corresponding to the antigen, the solution of the problem corresponding to antibodies, antigens and antibodies by affinity feasible solution and optimal solution described in the approximation [5-6]. Firstly, to receive an antigen (corresponding to a specific problem), then randomly generated a set of initial antibodies (corresponding to the initial candidate solution); then calculate the fitness of each antibody (affinity), crossover and mutation of antibody; again Concentrations of population-based update strategy generates the next generation of antibody group, until a terminating condition, the algorithm ends.

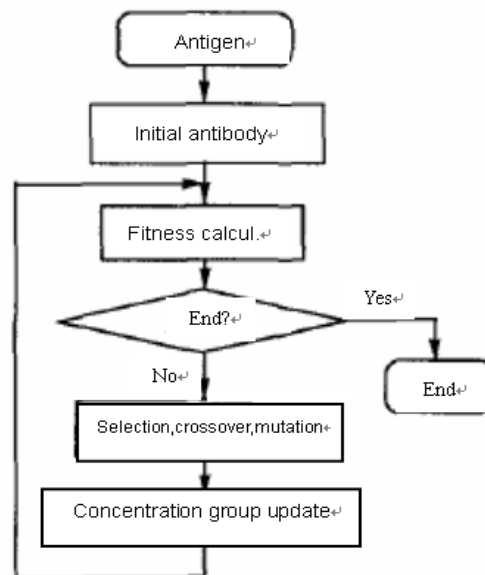


Figure 1. Immune genetic algorithm flow chart shown

The basic steps are as follows:

1) Algorithm initialization. Antigen input and parameter setting: enter the target function and constraints, as the antigen input; set population size Popsiz, select the probability Ps, crossover probability Pc, mutation method and other parameters.

2) The initial antibody. In the first iteration, the antibody used in the solution space is usually the method of random generation.

3) The affinity and concentration calculations. Calculate the fitness of antibody and antigen and antibody concentrations were calculated.

4) Termination of conditional. Determine whether the terminating condition is the highest fitness will be with the antigen antibody immune memory database join, and then terminate; otherwise continue.

5) The selection, crossover and mutation. According to the choice of setting the probability of Ps, the crossover probability Pc and mutation methods selected antibody selection, crossover and mutation.

6) According to the above update the group after the operation go to step 3).

4. Design Problem Solving

4.1. Design of Affinity Function

At a temperature $T = 705\text{ }^{\circ}\text{C}$, the claim to: carbon monoxide shift reaction equilibrium constant $K_{Pms} = 14.5039$.

At a temperature $T = 740\text{ }^{\circ}\text{C}$, the claim to: the conversion of methane equilibrium constants $K_{Pwgs} = 1.3211$.

In the example, enter: $P=9.84e5$, $m=3.6683$, $D=0.01133$, $R=3.8618$; Into the above (1), (2) have a, b of the binary nonlinear equations:

$$g_1(a,b) = \frac{94.3081(3a+4b-0.1659)^3}{(2a+2b+4.7073)^2(1-a-b)(3.8618-a-2b)} - 14.5039 = 0 \quad (4)$$

$$g_2(a,b) = \frac{b(3a+4b-0.1659)}{a(3.8618-a-2b)} - 1.3211 = 0 \quad (5)$$

Set affinity function:

$$f(a,b) = \frac{1}{1 + (g_1(a,b))^2 + (g_2(a,b))^2} \quad (6)$$

$$0 < f(a,b) \leq 1$$

Affinity function images shown in Figure 2, the original equations and into Qiuqin and the maximum value of the solution function.

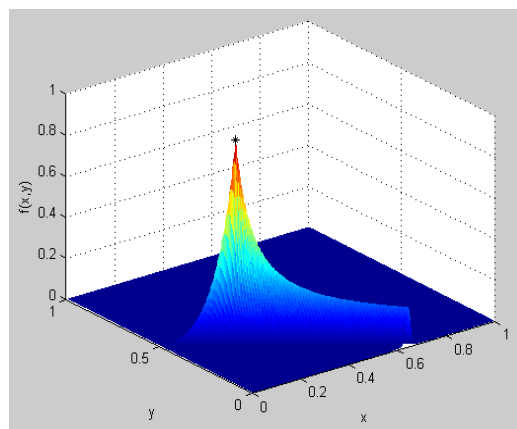


Figure 2. The fitness function

4.2. Update on the Concentration of Population

To ensure the diversity of antibodies to improve the global search capability, using a Euclidean distance based on antibody and antibody to calculate the similarity of fitness and concentration methods. Antibody x_i and x_j in mind the Euclidean distance $D(x_i, x_j)$ respectively, the fitness $f(x_i)$ and $f(x_j)$, given the appropriate constant $\delta > 0$, $\varepsilon > 0$, such as to satisfy the following formula:

$$\begin{aligned} D(x_i, x_j) &\leq \delta \\ |f(x_i) - f(x_j)| &\leq \varepsilon \end{aligned}$$

x_i, x_j antibody and antibody called similar to antibodies and antibody similar to the number of x_i as x_i the concentration of antibody, denoted by C_i ; antibodies were selected as likely $x_i, \rho(x_i)$, namely:

$$p(x_i) = \alpha C_i \left[1 - \frac{f(x_i)}{M(x)} \right] + \beta \frac{f(x_i)}{M(x)}$$

Where, α, β for the (0,1) between the adjustable parameters, $M(x)$ for all antibodies of the largest fitness value, C_i is the concentration of antibody x_i .

It can be seen from the above equation: When the antibody concentration is high, the antibody is selected to adapt to high probability to small; when the antibody concentration is not high, the antibody is selected to adapt to high probability for large. This not only retains the excellent individuals, but also reduce the choice of similar antibodies, to ensure the diversity of the individual.

4.3. Genetic Operation

Immune genetic algorithm can maintain the diversity of antibodies and eventually converge to the optimal solution to a major operation, that is, a choice in the algorithm, crossover and mutation operator exists, so that the fitness of the whole antibody population along the direction of better search.

1) Select the operator. Selection operator with the following:

$$P_s(x_i) = \alpha \frac{\rho(x_i)}{\sum_{i=1}^n \rho(x_i)} + (1 - \alpha) \frac{1}{N} e^{-\frac{C_i}{\beta}}$$

Where: $\rho(x_i)$ is the type of fitness function for the vector distance; C_i is the concentration of antibody x_i . α and β is the constant adjustment factor, N is the total number of antibodies within the population.

2) Two cross-cutting method.

Let $X^l_1 = [x^1_1, x^1_2, \dots, x^1_n]$, $X^l_2 = [x^2_1, x^2_2, \dots, x^2_n]$ is l on behalf of the two antibodies, in the first point and d, i -point arithmetic implementation of two cross-cutting to produce the next generation of antibodies are:

$$\begin{aligned} X^{l+1}_1 &= [x^1_1, \dots, x^i_1, \dots, x^j_1, x^1_{j+1}, \dots, x^1_n] \\ X^{l+1}_2 &= [x^2_1, \dots, x^i_2, \dots, x^j_2, x^2_{j+1}, \dots, x^2_n] \end{aligned}$$

Where, x'_k and $x''_k (i \leq k \leq j)$ Generated by a linear combination of the following:

$$\begin{aligned} x'_k &= \zeta x^1_k + (1 - \zeta) x^2_k \\ x''_k &= \zeta x^2_k + (1 - \zeta) x^1_k \end{aligned}$$

Where, $\zeta \in [0, 1]$, the scale factor.

3) Gaussian mutation method. Gaussian mutation, the first decoding of the antibody to

the corresponding network structure, in accordance with the following formula to change ownership of the network value:

$$x_i^m = x_i + \gamma \times e^{-f(x_i)} \times \mu(0,1)$$

Where, x_i^m is the variation of the antibody, x_i is a variation of the antibody before; $\mu(0,1)$ is mean 0, variance 1 normal random variable; $\gamma \in (-1, 1)$, the mutation rate of the individual; $f(x_i)$ is the fitness of antibody x_i , that is the fitness value of the objective function. Instructions on the type of variation and adaptation antibody is inversely proportional to the degree that the lower fitness (the smaller the fitness value of the objective function), the higher the mutation rate of the individual, and vice versa. Variation, the re-formation of a new antibody.

Take the initial population size $N = 20$ and other parameters, the claim to: $a = 0.2052$, $b = 0.3591$, the fitness $f(a, b) = 0.9998$, the total School to then come to the number of coefficients $nT = 5.8359$, and thus Considered as content of each component in Table 1.

Table 1. The content of each component

Components	CH4	H2O	H2	CO	CO2	N2
mol%	7.4661	50.3506	32.3195	3.5157	6.1536	0.1941

5. Conclusion

This paper presents a steam conversion of hydrocarbon mass balance of the nonlinear equations of the immune genetic algorithm method, and achieved good results. Immune genetic algorithm is a reference adaptive immune system recognize and eliminate foreign body penetrated the body of the function of antigen, the immune system, learning, memory, and the diversity of the introduction of genetic algorithms. Gai algorithm has the genetic algorithm based on the introduction Gaussian mutation and update strategy based on antibody concentration adjustment mechanism, can effectively maintain the diversity of antibodies, which exist in the genetic algorithm to avoid the premature convergence problem [3]. In solving practical problems, the objective function and constraints as the antigen input, then generate the initial antibody group, and through a series of genetic manipulation and the calculation of antibody affinity, antibody diversity in maintaining the circumstances, to identify the antigen for Antibody, that is, the solution of the problem. Immune genetic algorithm The basic features include: improved ability of global search algorithm, to avoid falling into the local optimal solution; with best individual memory; with fast global convergence.

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