

The Research of Matrix Method of Stream Match to Retrofit HEN

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Abstract: According to the likeness between process system and dynamic linear system, base on the expression of state space for dynamic linear system, we establish the expression of state space for network of process system. Form the real project, we could know that it is a new way to express process system using the state space, that can be used in the optimization of the process system.

Keyword: process system, state space, optimization design

INTRODUCTION

Network of process system include mass exchanger network and heat exchanger network. Now day there is a lot thorough research in the matter exchanger network and heat exchanger network which used the pinch point technology and optimization techniques. Using some new method to describe the network of process system is very helpful to give the integration of the network of process system in a new way. This text compares the likeness of process system and dynamic linear system, introduce a method to using the state space to express network of process system, and give an examples.

1. THE MEANING OF STATE SPACE

The meaning of state space is a basic theory of line system. The description of state space gives us a possibility to research the structure of system in mathematical methods; and at the same time the concept of state space include a very important idea – all object can be describe as input variable, output variable and the relation between them. Figure 1 shows us a description of a state space with a single input and a single output. It is a linear system. The system is described with four matrixes. A (the matrix of system) B (the matrix of control) C (the matrix of observe) output) D (the matrix of input/output).

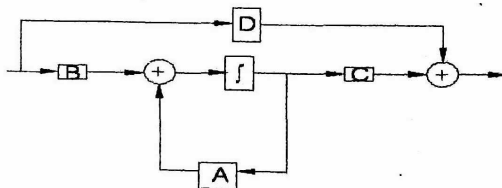


Figure 1: the dynamic linear system (express by I-S-O)

The stat and the action are according to the system structure and its beginning condition, all of them build up a equation about the input of the system, the output of the system and the state of the system(I-S-O),figure 1 can be describe as follow equation with mathematical methods.

$$z \delta = Az + Bu \quad (1)$$

$$w = Cz + Du \quad (2)$$

$$z(t_0) = z_0 \quad (3)$$

To describe as matrix

$$\begin{bmatrix} z \delta \\ w \end{bmatrix} = D \begin{bmatrix} z \\ u \end{bmatrix} \quad (4)$$

$$z(t_0) = z_0$$

$$D = \begin{bmatrix} AB \\ CD \end{bmatrix} \quad (5)$$

Form the matrix we can transform figure 1 to figure 2

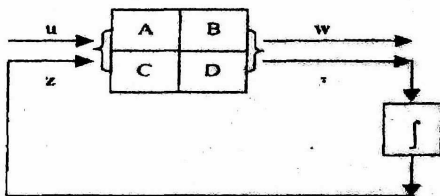


Figure 2: the dynamic linear system (express by matrix)

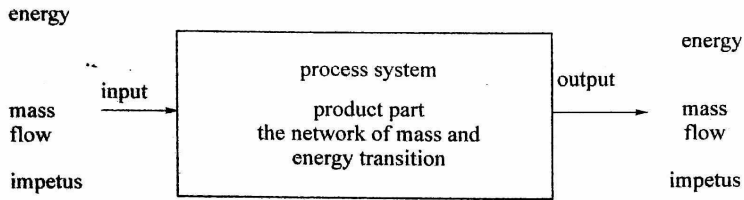


Figure 3: the model of process system

2. THE NETWORK OF PROCESS SYSTEM IN STATE SPACE DESCRIPTION

From the theory of system engineering, the process system can be turned to the system shown as Figure 3. It includes input and output; in this system, the input and the output can be energy, mass flow or impetus of the system; and the system includes produce part, energy exchanger network and mass exchanger network.

The analyses of the process system is that in the condition of knowing the configuration of the system network, to investigate the mathematical model of the network process, and form the configuration of the network and the input condition speculate on the characteristic of the network system and the output condition. And the optimization of the network system is in the condition of knowing the input and output condition and the restriction of the system to research the optimization of the network structure, and make the network satisfy with the request.

The analyses and integration of process system have the same characteristic of the dynamic system, it needs to find the connection of the input, output and the configuration of the network. In that way, the analyses of the process system is that under the condition of knowing the input condition and the configuration of the network to analyse the output of the system; the integration of system is that in the condition of knowing the input condition and the output condition to give the optimization structure of the system.

In the dynamic linear system, the input and output of the system are determined by two special arithmetic operators D and $\int$. We can also use the concept to the network of process system. The meaning of D is mix process or the distribute process. And the meaning of $\int$ is the integration process, for example, the mass integration or the energy integration. To a network of process system as Figure 4, we define DN (distribute network), it has the same meaning with

the arithmetic operators D , the distribute and max of the flow is accomplished at here. We define $(\cdot)$ as the process arithmetic operators, and complete the process colligation. In the DN, the matrix A controls the recycle of the flow; the matrix D distributes the flow; the matrix D controls the input and output of the system. The arithmetic operators of process mean the colligation of the system. To different process arithmetic operators, it means different colligation methods, and use the arithmetic operators to build up different mathematical models under different constraints.

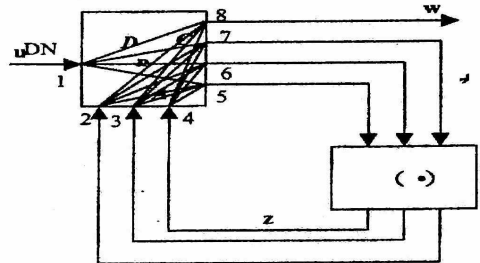


Figure 4: the network of the process system (expressed by state space)

3. THE ILLUSTRATION OF THE STATE SPACE

We make HEN as the illustration in using the concept of state space. For the better understanding of the application of state space, we choose the illustration that Linnhoff and Wood et al. has been investigated.

1 Three flow illustration

In this illustration, Linnhoff gives us some data (in Table 1). Wood makes the optimization of the HEN based on the data.

Table 1

Flow	Velocity of flow $F(\text{KW}/^{\circ}\text{C})$	Temperature of Input $T^{\text{in}} (^{\circ}\text{C})$	Temperature of Output $T^{\text{out}} (^{\circ}\text{C})$
Cold flow	3	100	380
Hot flow	1	520	240
Hot flow	4	344	204

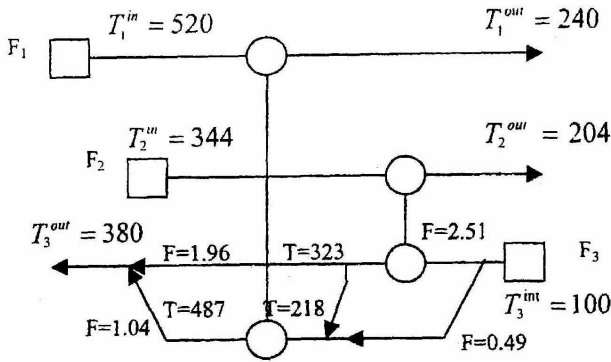


Figure 5 : heat exchanger network

Under the definition of the state space

$$u = [F_1 \quad T_1^{in} \quad F_2 \quad T_2^{in} \quad F_3 \quad T_3^{in}]^T \quad (6)$$

$$w = [F_1 \quad T_1^{out} \quad F_2 \quad T_2^{out} \quad F_3 \quad T_3^{out}]^T \quad (7)$$

$$z = [F_{H1} \quad T_{H1}^{out} \quad F_{H2} \quad T_{H2}^{out} \quad F_{C1} \quad T_{C1}^{out} \quad F_{C2} \quad T_{C2}^{out}]^T \quad (8)$$

$$z\delta = [F_{H1} \quad T_{H1}^{in} \quad F_{H2} \quad T_{H2}^{in} \quad F_{C1} \quad T_{C1}^{in} \quad F_{C2} \quad T_{C2}^{in}]^T \quad (9)$$

$$z = (.) z\delta \quad (10)$$

Figure 6 is the illustration with state space

In this illustration the arithmetic operators (.) must meet the follow equations.

$$F_{H1} c P_{H1} (T_{H1}^{in} - T_{H1}^{out}) = F_{C2} c P_{C2} (T_{C2}^{out} - T_{C2}^{in}) = U_{H1,C1} A_{H2,C2} \Delta \bar{T}_{H1,C1} \quad (11)$$

$$F_{H2} c P_{H2} (T_{H2}^{in} - T_{H2}^{out}) = F_{C1} c P_{C1} (T_{C1}^{out} - T_{C1}^{in}) = U_{H2,C1} A_{H2,C2} \Delta \bar{T}_{H2,C1} \quad (12)$$

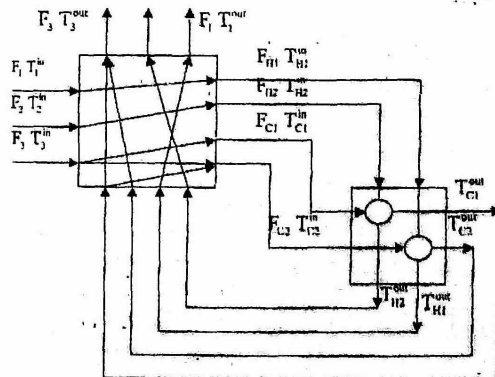


Figure 6 : the heat exchanger network (express by state space)

Arithmetic operators D in matrix

$$A = \begin{bmatrix} 0000 & 0 & 0 & 00 \\ 0000 & 0 & 0 & 00 \\ 0000 & 0 & 0 & 00 \\ 0000 & 0 & 0 & 00 \\ 0000 & 0 & 0 & 00 \\ 0000 & 0 & 0 & 00 \\ 0000 & \left(\frac{0.55}{2.51}\right) & 0 & 00 \\ 0000 & 0 & \left(\frac{0.55}{104}\right) & 00 \end{bmatrix}$$

$$B = \begin{bmatrix} 1000 & 0 & 0 \\ 0100 & 0 & 0 \\ 0010 & 0 & 0 \\ 0000 & 0 & 0 \\ 0000 & \left(\frac{2.51}{3.00}\right) & 0 \\ 0000 & 0 & 1 \\ 0000 & \left(\frac{0.49}{3.00}\right) & 0 \\ 0000 & 0 & \left(\frac{0.49}{1.04}\right) \end{bmatrix}$$

$$C = \begin{bmatrix} 10000 & 0 & 0 & 0 \\ 01000 & 0 & 0 & 0 \\ 00100 & 0 & 0 & 0 \\ 00010 & 0 & 0 & 0 \\ 00001 & 0 & 1 & 0 \\ 00000 & \left(\frac{1.96}{3.00}\right) & 0 & \left(\frac{1.04}{3.00}\right) \end{bmatrix}$$

$$D=0 \quad \dim(6*6)$$

Form the illustration we know that, the optimization of the HEN(heat exchanger network) can be expressed in state space, and can also build up the mathematical model. If the state space of the system has been known, the mathematical model can be built up base on this, though the mathematical model we can also make the optimization of the network. The object of the optimization can be the min cost of the energy, the min cost of the mass or the min cost of the investment, and it also can be the colligation of them.

REFERENCES

- [1] Hu Shou tao <<Principles of Automatic Control>> beijing national defence industry press
- [2] Linnhof, B., mason, D.R. and Wardle, I. Understanding heat exchanger networks. Cumpt. Chem. Engng 1979,295-302
- [3] Wood, R.M., Wilcox, R.J. Grossmann, I.E A note on the number of minimum units for heat exchanger synthesis Cumpt. Chem. Engng. 1985, 14: 1165-1184