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Automatic Control and System of Three-layer PE Anticorrosion Forming Process for Steel Pipelines

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The traditional three-layer PE anticorrosion of steel pipeline is manual operation, which is limited by the complexity of the three-layer PE anticorrosion in the process and the low yield of finished products, and cannot meet the current manufacturing requirements. The rapid development of computer technology is beneficial to intelligentize the production process of three-layer PE anti-corrosion forming process. With some advanced soft-sensing technology and corresponding computer technology, each stage of pipeline PE anti-corrosion molding production is modeled, and based on its non-linear, large-delay and multi-disturbance system characteristics, an intelligent segmentation control scheme is proposed in this paper, especially with the traditional PID algorithm and feedforward feedback control algorithm. At the same time, a strong coupling optimization algorithm is proposed to optimize the control system proposed in this paper. Finally, based on the anti-corrosion data of an oil pipeline, this paper has been verified and analyzed. The experimental results show that the algorithm is superior.

1. Introduction

With the development of computer technology and intelligent manufacturing technology, many foreign production lines about three-layer steel pipeline PE anti-corrosion forming have realized automatic production (Souto et al., 2005; Ramezanzadeh and Attar, 2013). However, the intelligent production line of this technology is relatively immature in China, and many anti-corrosion production remain at the level of manual operation. With the further intellectualization of modern manufacturing industry, the traditional steel pipeline three-layer PE anticorrosion production process cannot meet the needs of the society and it is difficult to control its corresponding quality (Petrunin et al., 2009). The automatic and intelligent improvement of the whole production line has become an inevitable trend. The advantage of intelligent three-layer PE anticorrosion production of steel pipelines is mainly focused on its benefits to improve the standardization of the whole production and improve the efficiency of the whole production process and the stability of the production system (Alasil et al., 2008). Of course, the research on the intellectualization and automation of the whole steel pipeline anti-corrosion production process is beneficial to the improvement of the technical level of the steel pipeline anti-corrosion production line in China. At the same time, it can also bring huge economic benefits (Khun and Frankel, 2013). Foreign research on the corresponding automatic and intelligent production line mainly focuses on the following: Some scholars at Lanzhou University of Technology have proposed intelligent fuzzy multi-modal segmentation control strategy (Zhu, 2011; Yun et al., 2014; Wang et al., 2018), which provides a good control strategy to some extent, but it is too complex in modeling to implement the whole system. The DCS process control scheme proposed by China Institute of Water Resources and Hydropower Research has a strong advantage in modeling, with the segmentation modeling process, but there are some limitations in the process control (Yang, 2005). Therefore, it is necessary to further analyze and study the intellectualization and automation of steel three-layer PE anti-corrosion production process.

2. Intelligent Segmentation Control System

In this paper, the modeling analysis is carried out based on four stages in the process of steel three-layer PE anti-corrosion production, which are the transmission process, the interrupted heating process, the copolymer

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primer and the coating process of polyethylene winding. For the above four stages, the mathematical model is established by using the modeling method aiming at the essential principle. Based on the above mathematical model, the whole production line of steel three-layer PE anti-corrosion is designed intelligently based on the traditional PID control and the cooperation of the feedback control before and after. Finally, in order to further improve the efficiency and reliability of the system, an algorithm based on strong decoupling is proposed to optimize the design of such a system with large disturbance and non-linearity. According to the process of steel three-layer PE anti-corrosion production, the four stages are accurately modeled one by one. Based on the mathematical model of modeling, the system polarity is optimized as below specifically:

2.1 Modeling analysis

In the anti-corrosion processing of steel three-layer PE pipelines, the main parts to be modeled are the side extrusion hot-wound coating process, the plastic extrusion process, and the melting zone process, and the corresponding schematic diagram of the side extrusion hot-wound coating process are shown in Figure 1:

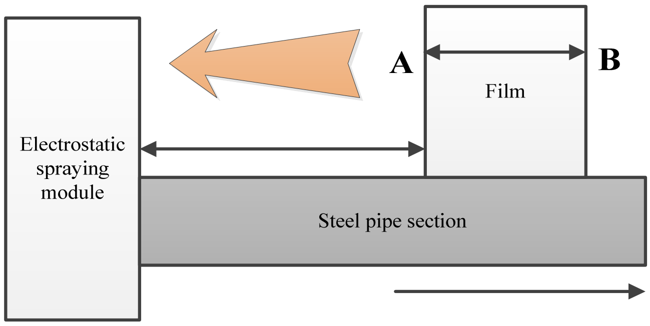

Figure 1: Schematic diagram of the corresponding side extrusion hot-wrap coating process

After the whole steel pipe enters the transmission equipment, the most important step is the side extrusion hot-wound coating process. Based on the whole working process, the relationship between the main parameters of the polyethylene layer extrusion equipment and the axial speed of the steel pipe is shown in Formula 1: The corresponding Q2 is the extrusion amount of the extruder, and t3 is the corresponding thickness:

(1)

The plastic extrusion process plays an important role in the whole three-layer PE anti-corrosion molding process, and mainly restricts the efficiency of the whole production line. The corresponding schematic diagram is shown in Figure 2: The corresponding mathematical model is shown in Formula 2, which is a function group:

$$\begin{aligned} v &= g_1(x,y,z) \\ y &= g_2(x,y,z) \\ r &= g_3(x,y,z) \\ p &= g_4(x,y,z) \end{aligned} \quad (2)$$

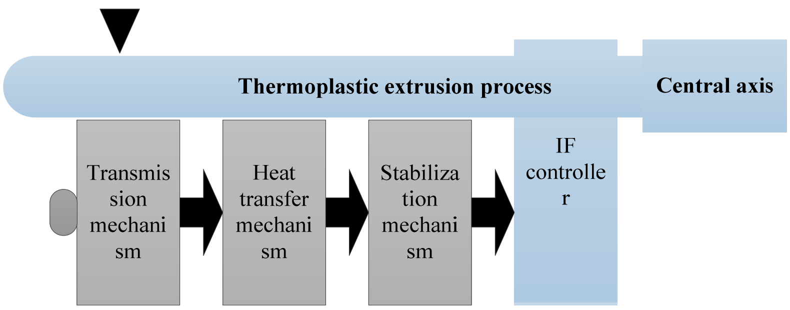

Figure 2: Extrusion equipment schematic

In the melting section, it is mainly the melting capability, which mainly affects the productivity of the entire melting output. The extrusion parameters of a plastic machine are generally determined based on the productivity of the melt output. Based on the micromotion equation of viscous fluid mechanics and its theoretical assumptions, for example, assuming its motion is stable and the entire flow rate doesn't vary by time; and assuming that a trough model with equal depth and width can be infinitely stretched in the third dimension, and its motion is not affected by the flow rate, the flow direction of the melt is ignored while the trough model is simplified, being equivalent to the parallel plate model. The corresponding mathematical model formula is shown in Formula 3:

$$\frac{\partial p}{\partial x} = \eta \frac{\partial^2 v_x}{\partial y^2} \tag{3}$$

2.2 Intelligent segmentation control algorithm

In the control algorithm, the main body part is the transmission control strategy, and the main physical model is as shown in Figure 3. When the constant speed transmission process is stable, the pipeline will reach a stress equilibrium state, but the relevant glue therein will bring a certain friction force. At the same time, in this process, the steel pipe will also take itself as the axis for rotational movement. On the basis of this, the transmission process control section of the corresponding constant speed segment may have its corresponding control relation frame diagram as shown in Figure 4 based on the PID control algorithm, and its corresponding simplified process diagram is shown in Figure 5:

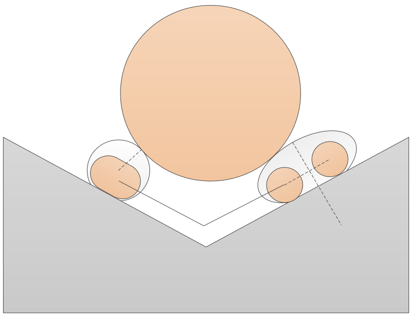

Figure 3: Transmission control strategy its main physical model

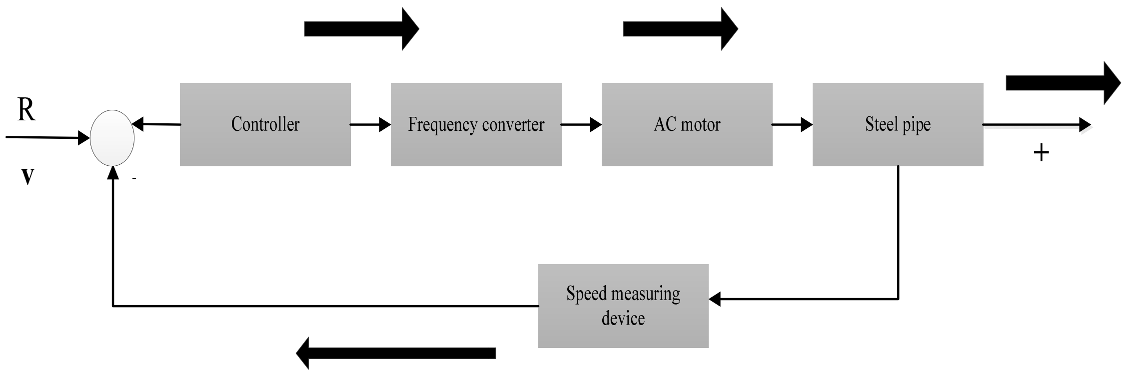

Figure 4: Constant speed section drive process control section

In the heat control stage, the before and after feedback is the design basis, and the expect temperature of the steel pipe is realized mainly by the heating device with intermediate frequency. A closed loop is formed during the heating process, in which the speed and ambient temperature need to rise. Data for speed and power and temperature during heating are listed in their corresponding tables as shown in Table 1:

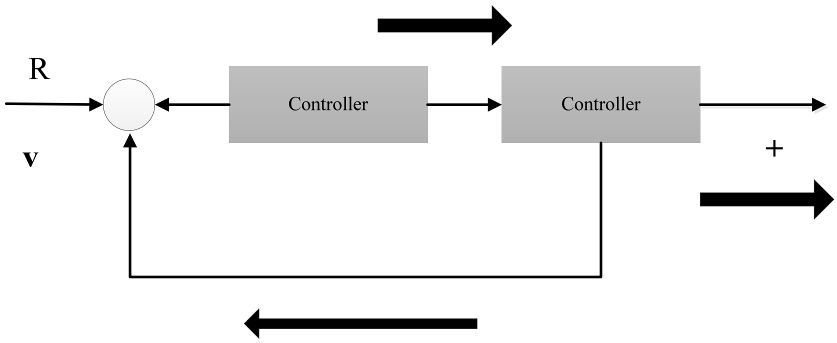

Figure 5: Simplified diagram of the control process of the constant speed section

Table1: List the speed and power and temperature data during heating

v0/a/w	300	390	480
0.02	152.4311	189.1731	228.1642
0.03	124.5399	176.8937	186.8912
0.031	106.7322	152.3467	158.2313
0.042	97.3145	137.2154	145.3121

From the above analysis, it is found that under the condition of steady speed, the disturbance of ambient temperature to the controlled variable is small, and the influence of the power of intermediate frequency heating device on the controlled variable is moderate.
Based on the above analysis and discussion, the control system framework diagram of the three-layer PE anti-corrosion forming heating process of the steel pipe as shown in Figure 6 can be obtained:

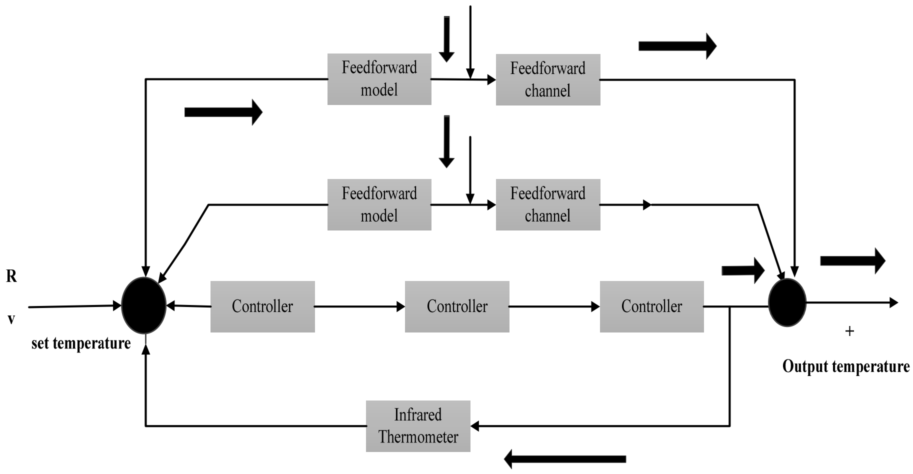

Figure 6: Framework diagram of control system for three-layer PE anti-corrosion molding heating process of steel pipeline

Based on the above analysis and discussion about the main control process, the intelligent hierarchical control method adopted in this paper can divide the risk of the whole control system one by one, and avoid the low reliability of the whole system resulting from too much concentration in the past. At the same time, based on the hierarchical control system put forward in this paper, it's advantageous to make the further optimization of the system, and based on the control system proposed in this paper, it also has some economic advantages in transforming the results. The structural block diagram of the corresponding hierarchical control system is shown in Figure 7:

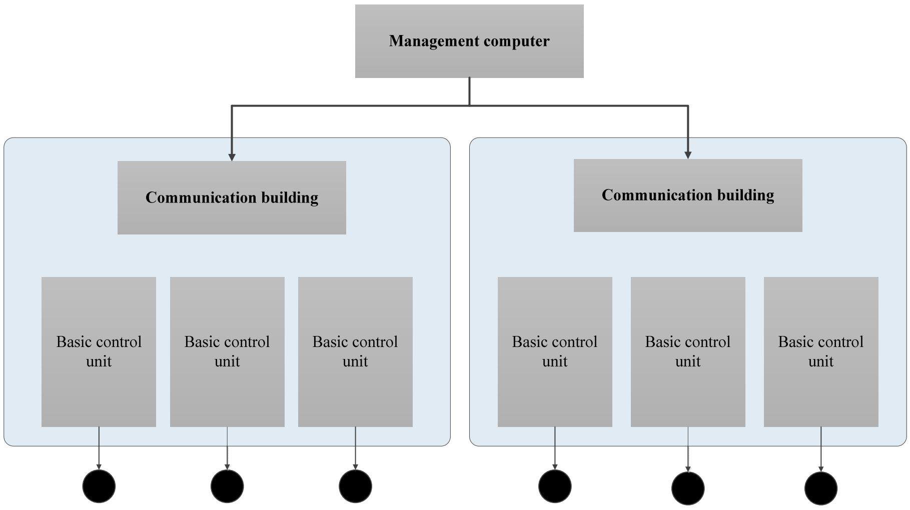

Figure 7: Block diagram of the hierarchical control system

2.3 System optimization

In the system optimization, a strong decouple optimization method is mainly adopted in this paper, in which three layers of PE are coupled with temperature and velocity when corrosion prevention is carried out, and the upper and lower limit of the region time of glue application are manually fitted with the least square method, with the corresponding fitting formula is shown in Formula 4:

$$\begin{bmatrix} m & \sum_{i=1}^{m}\theta_i & \sum_{i=1}^{m}\theta_i^{2} \\ \sum_{i=1}^{m}\theta_i & \sum_{i=1}^{m}\theta_i^{2} & \sum\theta_i^{3} \\ \sum_{i=1}^{m}\theta_i^{2} & \sum\theta_i^{3} & \sum\theta_i^{4} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{m} t_i \\ \sum_{i=1}^{m}\theta_i t_i \\ \sum_{i=1}^{m}\theta_i^{2} t_i \end{bmatrix} \tag{4}$$

Based on this, the corresponding decoupling device can be connected in series, and the corresponding device diagram is shown in Figure 8:

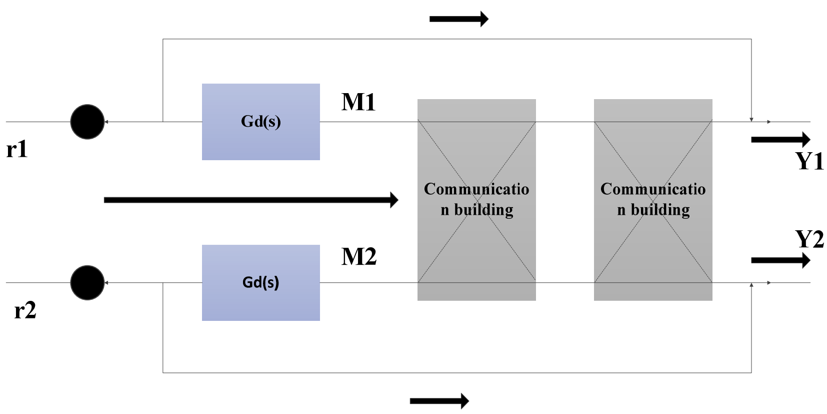

Figure 8: Decoupling device

3. Experimental results and analysis

The data on the three-layer PE anticorrosion production process of steel pipeline based on a petroleum survey system, this paper tests Siemens S-7 PLC and the measured steel pipe speed and intermediate frequency power are shown in Table 2:

Table 2: Steel pipe speed and intermediate frequency power meter

Power/speed	50	55	65	77	81
	0.018	0.0193	0.021	0.023	0.03

Based on the above-mentioned curve diagram and table data, it is found that the forming and processing system of steel three-layer PE anti-corrosion pipeline proposed in this paper has strong advantages.
From Figure 6, the geographical position of the model car can be seen, and the text on the right shows how the model car is running, such as speed, temperature and humidity.

4. Conclusion

In this paper, an intelligent segmentation control scheme has been proposed, especially with the traditional PID algorithm and feedforward feedback control algorithm. At the same time, a strong coupling optimization algorithm is proposed to optimize the control system proposed in this paper. Finally, based on the anti-corrosion data of an oil pipeline, this paper has been verified and analyzed. The experimental results show that the algorithm is superior.

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