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Evaluation and Improvement of Operation Quality in PA Diaphragm Production Line

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Abstract

According to the statistics of the quality parameters of the operation cycle of the new production line, the operation quality evaluation model is established through the system dynamics to express the influence law of qualified output and product quality on the operation quality. The reasonable quality value of continuous production line running for a long time is obtained by adjusting the rate variable. The simulation results show that the improvement of the inspection scheme can promote the improvement of the operation quality and achieve the output target while ensuring the product quality. The conclusion of this paper provides the balance scheme of production target and quality assurance for the annual operation of production line, and provides preventive suggestions for new projects under construction from the point of view of quality management, which is the basis for the formulation of production plan, equipment management plan and process test plan.

Keywords

PA Diaphragm Production Line; Quality of Operation; System Dynamics; Inspection Scheme.

1. Introduction

The quality evaluation of automatic production line is a comprehensive reflection of the construction process plan and implementation results, which includes the measurement of defect degree, boot rate, stability and so on. The inspection result is the reflection of the running quality level, and the product as the inspection benchmark can reflect the running quality through the quantitative product attribute detection. The automatic production line has more function of parameter feedback and adjustment, the product model and running speed are updated quickly, and the operation stability of the equipment is high. The evaluation index is used to measure the quality characteristics of each component of the production line and the output result of the product quality.

For the establishment and application of the quality evaluation system, the scholars at home and abroad have put forward various solutions. Abbaspour H et al. (2018) proposed SDM models for drilling and blasting operations as interactive systems for modeling and optimization under uncertain and uncertain conditions. Adane TF et al. (2019) select teable methods from pre-selected performance standards to achieve improved potential manufacturing system optimization. Stadnicka D et al. (2019) describes how the integration of Extension Value Flow Diagram (VSM) with System Dynamics Analytics (SDA) may increase the likelihood of waste identification and elimination. Qi Wenxiu et al. (2018) established a CPS - based quality management structure in a daily chemical production line, and through quantitative evaluation of production line quality management, the performance and maturity evaluation results were obtained. Chen Mengjun et al. (2021) used Delphi method and

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hierarchical analysis method to determine the weight of each evaluation factor and used the weighted evaluation model to build the farmland quality evaluation system of land improvement project area. Ye Shaoshuai (2020) proposed the "optimal / worst of standard object" and "expert" hypothesis based on engineering practice, and constructed a project quality evaluation framework based on TOPSIS. Ma Shumei et al. (2012)proposed Bayesian networks based on probability theory and graph theory as a method for the production line quality diagnostic model. Yue Shunli et al. (2020) build the quality system model of construction projects, and consider the optimal strategy of project quality guarantee from the overall perspective. Xing Yanming (2020) explores the standardized, quantitative, real - time and automatic passenger car project quality evaluation system. Kim Hongmin et al. (2016) changes through the supplier attention and policy simulation to get the product quality first increase and then stabilize.

The above research results show that the operation quality evaluation model and system are different in different kinds of projects, and the manufacturing projects need to select the indexes with high sensitivity to the quality target from the extensive subsystem performance. In operation quality management, the setting of test standards and methods should be considered synthetically, so as to express the positive correlation (favorable influence) and negative correlation (adverse effect) between indicators. According to the statistics of the quality parameters of the new production line, the operation quality evaluation model is established through the system dynamics to express the influence of qualified output and product quality on the operation quality. The reasonable quality value of continuous production line running for a long time is obtained by adjusting the rate variable.

2. Evaluation steps of PA diaphragm production line operation quality

The final product of the production line is polymer film, which is used in lithium battery. In the stage of component inspection and equipment installation in project implementation, local quality evaluation results can be obtained by measurement. When it is carried out to the commissioning stage, it is possible to obtain the short-term quality evaluation results of the project from the situation of product trial production and equipment operation, and as part of the basis for the preliminary acceptance of the project. Then, the one-year production line operation is the quality inspection period of the final acceptance of the project, and the quality evaluation results can fully reflect the project performance.

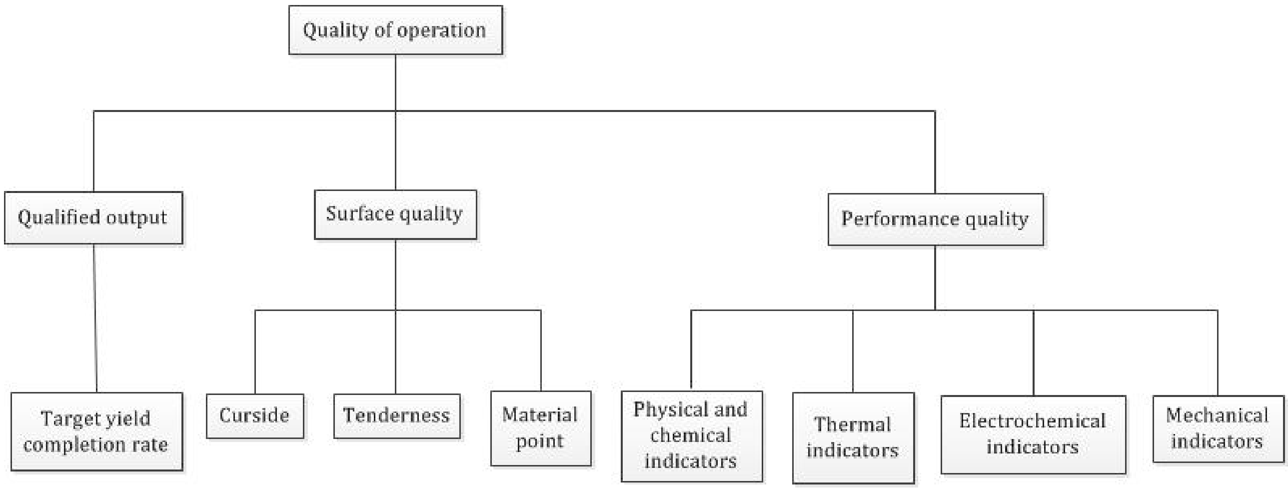

Figure 1. PA Diaphragm Production Line Quality Evaluation Framework

2.1 Establishment of a parametric framework

The PA diaphragm production line is 24 hours a day with continuous operation throughout the year. The normal temperature of each system must be maintained at about 150 ℃ for a long time. Changes in process requirements or quality inspection standards will lead to production interruption or waste

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production, while equipment failure will cause the whole line shutdown, and the cooling and heating process will take more than 24 hours respectively. Considering the construction and operation environment of the PA diaphragm production line, we will determine the initial quality parameters, which reflect the importance of the test results to the quality of the operating subsystem. In order to easily represent the relationship between the quality objectives and the parameters, the parameters are represented by the proportional value, and the evaluation framework established in this paper is shown in Figure 1.

2.2 Inspection design

As a statistical analysis technology, the inspection design helps to identify which parameters affect the operation quality, and identify the key parameters with the biggest impact on the operation quality, so as to provide convenience for the preparation of the operation quality plan. This technology is applied to product analysis and operation management, and the optimization analysis of quality management system, especially applicable to the solutions and methods of completed project operation quality problems with high research performance. The measured results of the inspection design at the final operation period are shown in Table 1, the parameters in the surface quality and performance quality indicate the proportion of the end of the quality standard, and the weight of the sub - parameters under the performance parameters is the same, and the inspection value indicates the weighted qualified rate at the end of the evaluation period.

Table 1. Actual Results of Final Inspection Design

code	Inspection Items	Data	Proportion of product area affected	Weight 1	Weight 2	Inspection value
S1	Curved edge	0.986	1.4%	0.217	0.411	0.965
S2	Reinforcement	0.995	0.5%	0.078		
S3	material point	0.954	4.6%	0.706		
F1	Thickness/porosity/aperture size/permeability/ tortuosity	0.952/0.969/ 0.978/0.965/ 0.958	3.7%	0.398	0.589	0.975
F2	Thermal closure temperature/ crack temperature/ thermal shrinkage	0.992/ 0.987/ 0.976	1.6%	0.172		
F3	Linear voltammetry/ ionic conductivity	0.98/ 0.982	1.9%	0.204		
F4	Puncture strength / tensile strengt	0.975/ 0.983	2.1%	0.226		
E(t)	Qualified/ target production	0.90				

2.3 Operational quality evaluation

Cobb-Douglas production function adopts marginal analysis method, which can be used to analyze the contribution rate and scale income of factor input to output. During the evaluation of production line operation quality, the product quality is not completely related to the operation quality. Therefore, this function is suitable for running quality evaluation. Product quality includes surface quality and performance quality, α as the elastic coefficient of surface quality, the relative variation rate of operation quality and surface quality ,β as the elastic coefficient of performance quality, the relative variation rate of operation quality and performance quality, and μ the coefficient of random factors. The function expression is:

$$Q=E_{(t)}S^{\alpha}F^{\beta}\mu \quad (1)$$

When $\alpha+\beta>1$, is defined as incremental quality type, it indicates that improving product quality is positively related to operation quality under current output completion rate;When $\alpha+\beta<1$, is defined as decreasing quality type, it means that improving product quality is negatively correlated with

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running quality under current output completion rate;When $\alpha+\beta=1$,is defined as invariant quality type, it means that only by increasing the output completion rate can the operation quality be improved, and the product quality has no effect on the operation quality completion rate.

3. Dynamic model of PA diaphragm production line running quality

System dynamics uses the causality of the system to qualitatively analyze the system structure and study the ways to improve the system structure and behavior. The system dynamics is applied to the operation quality evaluation of the PA diaphragm production line, using a qualitative and quantitative method to solve the contradiction between product quality and conditional shutdown.

The operating quality consists of qualified yield subterms, surface mass subterms, and performance mass sub - term, each of which is affected by many parameters that can form a positive / negative relationship. Therefore, the production line quality system is a system with a feedback function that meets the construction conditions of the system dynamic model.

3.1 Running Quality Flow Chart

Events affecting the operation quality of the production line include: when equipment failure causes failure to normal production, sufficient downtime is required to troubleshoot, when the boot rate will continue to decline, and the cumulative output will no longer increase; The boot rate is only a necessary condition, not a sufficient condition, for qualified output. It is assumed in the model that:

(1) The operating conditions of the production line during the evaluation period are not affected by external factors, that is, $\mu=1$;

(2) Maintain sufficient and reasonable frequency for quality inspection of products during the evaluation period.

To reflect the relationship between independent variables and dependent variables of running quality evaluation function, the system flow diagram is established by using Vensim as shown in figure 2.

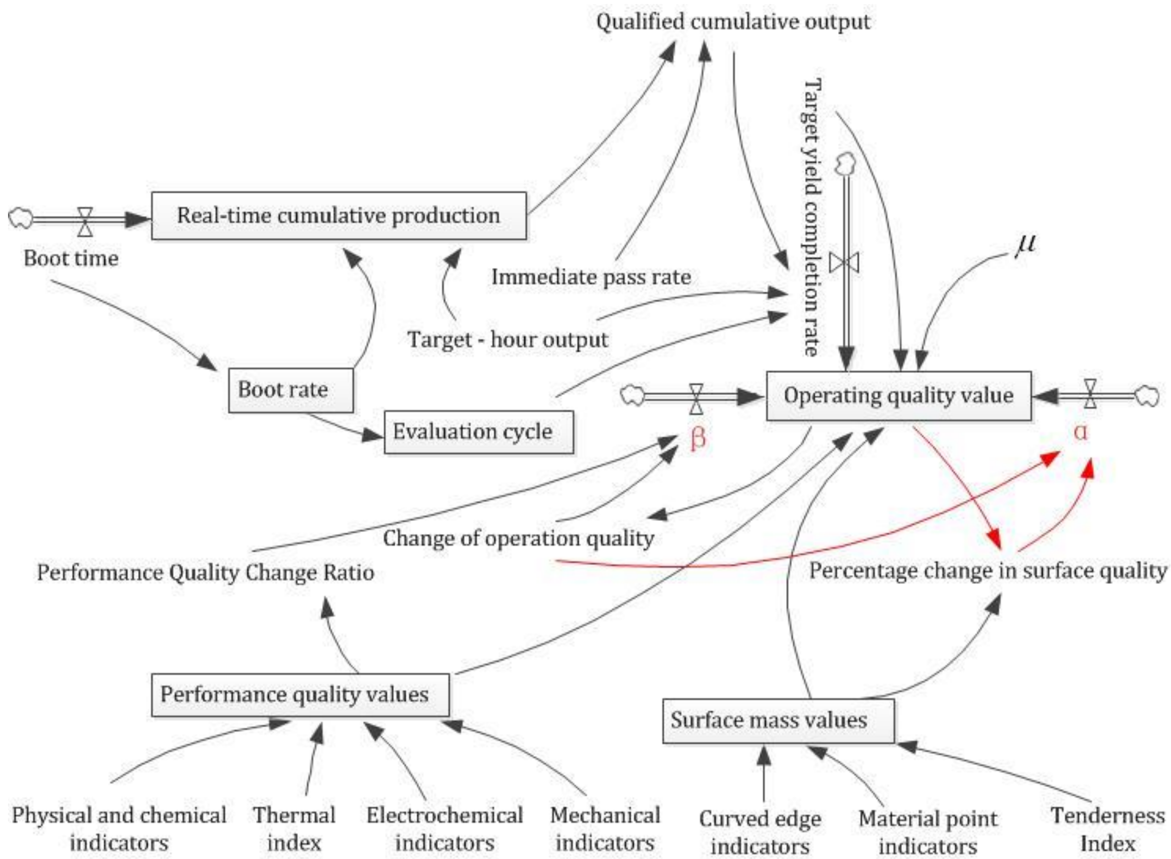

Figure 2. PA Production Line Running Quality Flow Chart

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3.2 Model variables and expressions

In the operation quality evaluation system, three state variables are used to express the relationship between operation quality and output. Elastic coefficient α, β as a rate variable, indicating the rate of change between the running quality and the corresponding product quality. During the operation of the production line, the single quality index of the product is tested every day, and the immediate qualified rate of each index can be obtained.

Table 2. Run Quality Model Variables And Expressions

Variable	Nature	Expressions
Operational quality values Q	State	E(t)SαFβμ
α	Rate	$\frac{\partial Q}{Q}/\frac{\partial S}{S}$
β	Rate	$\frac{\partial Q}{Q}/\frac{\partial F}{F}$
Percentage of changes in operational quality	Assistance	$\frac{\partial Q}{Q}$
Performance Quality Change Ratio	Assistance	$\frac{\partial F}{F}$
Percentage change in surface quality	Assistance	$\frac{\partial S}{S}$
Surface mass values Si	Assistance	S1*0.217+S2*0.078+S3*0.706
Performance quality values Fi	Assistance	F1*0.398+F2*0.172+F3*0.204+F4*0.226
Boot rate E(t)	Assistance	Boot time/assessment cycle
Boot time	Assistance	if then else(Surface mass values ∧ Performance quality values≥Inspection value, Boot time+1,Boot time+0)
Evaluation cycle	Constants	365×24
Curvededge/reinforcement /material point	Assistance	With lookup(S1,S2,S3) Δ
Physical and chemical / thermal / electrochemical / mechanical indicators	Assistance	With lookup(F1,F2,F3,F4)Δ
Immediate pass rate	Assistance	Si×0.411+ Fi×0.589
Qualified cumulative output	Assistance	Instant cumulative yield × instant pass rate
Real-time cumulative production	State	INTEG(Boot time × actual hourly output,0)
Target yield completion rate	Rate	$\frac{\text{Qualified cumulative output}}{\text{Target hour output} * \text{Evaluation cycle}}$
Target hour output	Constants	3600

Δ variables S1, S2, S3 F1, F2, F3, F4 entered from daily inspection records

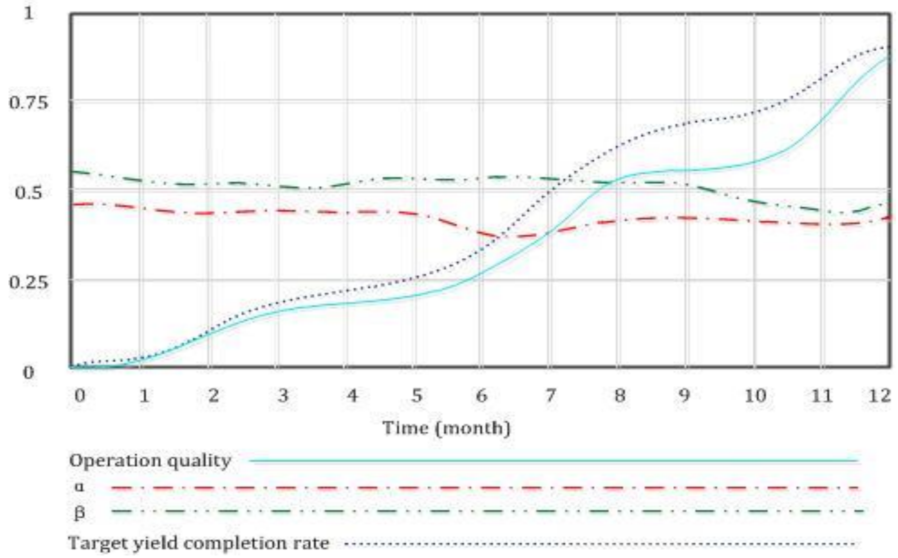

Figure 3. Actual Model Of Running Quality And Rate Variables

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4. Inspection and simulation of operation quality evaluation model of production line

4.1 Model testing

The qualified rate of all the indexes in the vensim is input into the production line for one year, and the numerical diagram of the production line operation quality is obtained. It can be observed that the joint action of the target output completion rate and the product quality leads to the constant change of the operation quality. Due to the failure to meet the qualified output target, the quality value at the end of the evaluation period is 0.88, and the α+β value is from 1 to 0.92 at the beginning of the period, which shows that the production management department does not pay enough attention to the output completion rate, resulting in 90% target output completion rate. Figure 3 accords with the actual operation record and verifies the validity of the evaluation model.

4.2 Improved simulation

According to Table 1, the performance quality is 17.7% higher than the weight 2 of the surface quality. Try to change the process of the same inspection frequency of each volume of products, and carry out the real-time parameter detection frequency according to the proportion represented by the weight value. To reflect the relative importance of each index. This will lead to the decrease of the qualified rate of S3, F1 with high weight and the decrease of the numerical S, F of surface and performance quality in the evaluation system. However, the increase of the frequency of key index inspection increases the probability of finding nonconforming products and reduces the risk of quality problems. Figure 4 shows that the β value increases greatly in the later period, the target yield completion rate increases faster than the previous value, and the quality value is more stable.

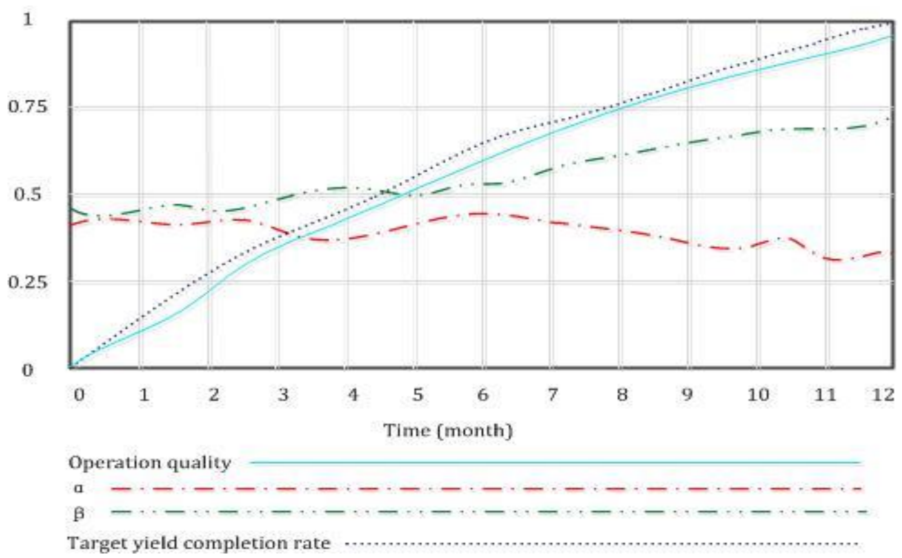

Figure 4. Simulation After Improvement Of Running Quality And Rate Variables

The production line running quality simulation shows that the production line in the first six months, α+β<1, indicating that the improvement of product quality at this stage will lead to the decrease of qualified output and thus reduce the running quality, If there are no major equipment or process problems, All efforts should be made to ensure the completion of the target output. 7th-9th month, α+β around 1, It shows that the improvement of product quality at this stage will not lead to the decline of qualified output, But it doesn't help the quality, Process improvement can be carried out without stopping to improve product quality; 10th-12th months, α+β>1,It shows that the quality of the product becomes the primary factor of the running quality at this stage. When the target yield completion rate is far beyond the production plan, Can be based on the process or equipment department needs to actively stop, Improve product or process quality. Meanwhile, The final running

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quality is 0.96, above the previous value of 9.1%, It is proved that the improvement of inspection scheme can promote the improvement of operation quality, Achieve output target while ensuring product quality.

4.3 Analysis and recommendations

The production line has the function of preset parameter adjustment, while reducing the production of non-conforming products, it also faces the loss of intermittent shutdown, including the power cost of rising and cooling and the long idling time. The equipment department needs to make quarterly and annual active downtime maintenance plan, the process department needs to arrange the test of changing parameters or raw materials in the normal production time, and the downtime usually accounts for about 10% of the annual downtime. Shutdown has both beneficial and adverse effects on output and quality, which requires that in the commissioning stage of carrying materials during the construction of the project, the process personnel should set more reasonable inspection standards, on the basis of ensuring the qualified rate of the products. Extend production line continuous operation as far as possible.

5. Conclusion

Cobb-Douglas function is introduced in the operation management of PA production line. The qualified output, surface quality and performance quality are regarded as independent variables to form a quality evaluation system with elastic coefficient adjustment. By looking for the influencing factors of independent variables, the relationship between the function and quantity of the expression factors of the system dynamics model is established. By assigning variables and constants in the Vensim, the simulation results are compared with the actual operation effect, and the output and quality improvement methods associated with the running time are obtained. The improvement of the inspection scheme can reduce the loss of working hours, achieve the output target while ensuring the quality of the product, and also benefit the more reasonable setting of the production plan, the equipment management plan and the process test plan. The conclusion of this paper provides the balance plan of production target and quality assurance for the annual operation of production line, and provides preventive suggestions for new projects under construction from the point of view of quality management, as the basis for making production plan, equipment management plan and process test plan.

In addition to the inspection scheme and process flow, the influence factors of production line quality are also important factors affecting the completion rate of qualified output. Combined with the consumption of maintenance and maintenance of machine parts and the modification period of raw materials, it is the direction of future research to further improve the operation quality of production line.

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