Sigma Level Assessment System for Tobacco Production Process Based on PDM and MES

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Abstract. In order to solve the problems in cigarette production process sigma level assessment, such as poor timeliness, calculation process complexity and error results, we put forward information system integration with Product Data Management (PDM) and Manufacturing Execution System (MES) in cigarette enterprises, to build the data acquisition, data calculation and data analysis for a complete process to calculation the cigarette manufacturing sigma level assessment model, thus reached the purpose of assessment for sigma levels in the enterprise. The application results show that the integrated evaluation function based on PDM and MES, in order to improve the quality management level of enterprise and provides effective information technology support to strengthen and enhance the real-time quality control.

Introduction

Under the condition of market economy, the competition of cigarette industry enterprises is more and more fierce. This kind of competition is not only the competition of brand, the competition of technology and the competition of market, but also the competition of management. Scientifically implementing the Sigma management method, combined with practical application, can bring business performance to cigarette companies to improve product quality, reduce costs, and increase customer satisfaction [1-3]. In order to solve the long-standing problem of a lack of systematic, comprehensive, and scientific methods for evaluating enterprise process control capabilities in cigarette manufacturing enterprises, the State Tobacco Monopoly Bureau issued the "Guidelines for Sigma Level Measurement Guidelines for Cigarette Manufacturing Processes" in 2009, according to Sigma management. According to Sigma's management idea, a model for calculating the process manufacturing capability of steady-state process control based on parameterized control is proposed. In the application of the model, there are many problems, such as the complexity of the model, the large amount of data involved in the calculation and the error prone. Therefore, it is an effective way to realize the calculation of the model through the information system [4]. At present, Zhejiang tobacco industry company has successfully implemented the cigarette product R & D and quality management system (PDM) [5], ERP and MES systems, and achieved the integrated information integration platform for cigarette industry enterprises through SOA architecture and enterprise bus technology[6]. This provides a comprehensive information support platform for the refined management and manufacturing of enterprise product R&D, supply chain management and manufacturing. Therefore, based on the company's existing PDM and MES systems, according to cigarette manufacturing Sigma level measurement model, can achieve the entire enterprise cigarette production process Sigma level assessment.

Overall Thinking

At present, the company's cigarette product R&D and quality management system (PDM) manages various BOM and process parameter standard information related to finished cigarette products, and
will be published to the ERP and MES systems in real time for production execution. At the same time, the PDM system manages the relevant index standards, defect standards, and defect determination standards as well as specific inspection data in the quality inspection of completed finished cigarettes and the inspection of incoming materials for cigarettes. The MES system of two cigarette factories in Hangzhou and Ningbo integrates the functions of centralized control, data collection, self-produced filter rod inspection and so on, and manages the contents of the quality related inspection data in the cigarette production process. Through the integration of the above standards and data, the complex calculation of six Sigma evaluation can be realized in MES system. Therefore, through the PDM and MES system six Sigma level evaluation system to achieve the overall idea design as follows:

1) According to the different sources of assessment requests and users, it is divided into two levels: the company's technology center level and factory level. For technical center-level users, the PDM system issues evaluation requests to the MES system; for plant-level users, it provides them in the MES system. Business functions.

2) The PDM system delivers the weight template data of the process quality evaluation, the quality inspection data of the completed finished cigarette products, the inspection defect standard information and the inspection defect determination standard information to the MES system.

3) The MES system uses the process quality parameter standard and the process quality inspection data of the process quality assessment parameter in the process of the process quality evaluation.

4) The results of the process quality evaluation calculation are displayed in the MES system and stored in the system and transmitted back to the PDM system through the interface.

Figure 1. Schematic diagram of information exchange between PDM and MES systems.

The Realization of Technology

Mathematical Model Formula

Based on the tobacco industry standards and customer demand, the key processes and their weights are determined, and the key quality characteristics and their weights are determined, and the Sigma level assessment is carried out according to the evaluation model. The evaluation, analysis and improvement are carried out according to the evaluation results. According to customer needs, the use of quality functions to develop methods to determine the key processes affecting product quality, constitute the core process of cigarette production (covering tobacco, filter rod molding, rolling, packaging, finished product inspection and other processes). So the Sigma level test calculated the
pass rate of basic CTQ or the value of Defects Per Million opportunity per million chance defects, with the measurement of the five core process critical quality features CTQ (Critical to quality as the minimum cell). Then the sigma level is obtained through the transformation of Z table.

**Measurement Data (Standard Deviation).**

A. Bilateral standard:

\[ p = 1 - \Phi \left( \frac{\text{USL} - \mu}{\sigma} \right) + \Phi \left( \frac{\text{LSL} - \mu}{\sigma} \right) \]  

(1)

B. One-sided standard:

- Expect small value: \( p = 1 - \Phi \left( \frac{\text{USL} - \mu}{\sigma} \right) \)  

(2)

- Expect great value: \( p = \Phi \left( \frac{\text{LSL} - \mu}{\sigma} \right) \)  

(3)

In the formula, USL-CTQ upper specification limit, LSL-CTQ lower specification limit, \( \mu \)-overall mean, \( \sigma \)-overall standard deviation.

When the data is normally distributed, the calculations are performed according to equations (1) to (3). When the data is non-normally distributed, normal transformation of the data is required. This formula is mainly used to measure the pass rate of the process real-time production process CTQ.

**Measured Data (DPMO).** The counting data is divided into piece type and point type, and the failure rate \( p \) is calculated according to equations (4) and (5) respectively:

A. Piece-type data:

\[ p = \frac{\text{number of defective products}}{\text{number of product inspections}} \]  

(4)

B. Point data:

\[ p = \frac{\text{number of defects}}{\text{(number of product opportunities per product} \times \text{number of product inspections)}} \]  

(5)

This formula is mainly used for the analysis of discrete data, and it is used to measure the qualification rate of CTQ in the production process that includes defects and the number of defective products.

**Methods for Measuring SIGMA Levels of Products**

**Model for Measurement.** Calculate the quality level (qualification rate) of each CTQ, and calculate the qualification rate for each process or process using the geometric average method. Between processes or processes, according to the difference in the overall contribution of the process, give them the corresponding weight, calculate the geometric mean qualification rate, and then convert to the overall sigma level of the process. The calculation model of the SIGMA level is shown in Figure 2:
Calculation Method of SIGMA Level. Y1~Y11 indicate the qualification rate of each link, and the qualification rate of each link is calculated and synthesized according to the weight of the CTQ pass rate included in the link. (When stem cuts, skeins, sheets (tobaccos) are outsourced, Y4, Y5, and Y6 are set to 1). Y1 is calculated as follows:

\[ Y_1 = Y_{1-1} A_1 \times Y_{1-2} A_2 \times \ldots \times Y_{1-n} A_n \]  

In the formula: Y1-n represents the qualification rate of each CTQ within the Y1 link, An represents the weight of the CTQ, and A1+A2+A3+...+An=1. The calculation of Y1 value is based on the specific calculation formula in Appendix D as follows:

\[ Y_1 = \prod (Y_{1-1} \cdot Y_{1-2} \cdot \ldots \cdot Y_{1-n}) \]  

(7)

The Y2-Y11 calculation method refers to the Y1 formula above.

Y12 indicates the pass rate of the yarn making process, which is calculated and synthesized by the pass rate of each process of the yarn making process:

\[ Y_{12} = \sqrt[6]{Y_1 \times Y_2 \times \ldots \times Y_7} \]  

(8)

In the formula: C1, C2, C3, C4, C5, and C6 are weights determined according to the proportion of actual weight of the blended materials in the yarn making. C1+C2+C3+C4+C5+C6=1.

NY represents the standard qualification rate for a branded product. For the formula, see (9):

\[ NY = \sqrt[10]{Y_1 \times Y_2 \times \ldots \times Y_{10}} \]  

(9)

In the formula, D1 and D2 indicate the degree of influence of the tobacco manufacturing process and the cigarette molding process on the product, and D1+D2=1.
Methods for Measuring SIGMA Level at the Factory

When assessing the quality level of the factory production process, relevant quality information is obtained for grades with more than 80% of the total output of the factory, and the overall SIGMA level is calculated. The standard pass rates for n brands of cigarettes can be expressed as NY1, NY2, ..., NYn, respectively. The proportion Wn of each brand's output to the total output of all brands of synthetic SIGMA levels is weighted, W1+W2+...+Wn=1. The standard pass rate of the entire factory is NY = NY1 × W1 + NY2 × W2 + ... +NYn × Wn, and the SIGMA level of the cigarette manufacturing process of the entire factory can finally be obtained.

Realization of Sigma Level Measurement Technology

Process Quality Evaluation Weights Template. The weight template of process quality evaluation refers to the standard value of the weight index of a group of process evaluation parameters. This group of weight index values defines which production processes and which process parameters are involved in the overall evaluation calculation of the process quality in the production process. The process quality evaluation weight template is maintained by the technical center personnel in the PDM system and delivered to the MES system.

The rules for evaluating the template are as follows:
1) the weight template of process quality evaluation is not defined according to the brand number of finished product and is managed by version.
2) process quality evaluation weight template branch evaluation template and cigarette factory evaluation template two types, each type of evaluation template has its own version. The PDM and MES systems hold all historical versions of the two types of test templates.
3) each evaluation template defines step by step the evaluation weight of each process, production link, section, production procedure, and each evaluation parameter in the way of "tree type" structure. An example is shown in figure 3 below:

As shown in figure 3, the first level of the evaluation template is the process, including "making tobacco", "molding", "cigarette", "packaging", "finished product". The second stage is the production link, which is the refinement of the production link of the "making tobacco" process. The production links of tobacco making process include making cut tobacco, making expanded stem, making cut stem, making thin tobacco and blending tobacco, in which the weight value of making expanded stem,
cut tobacco, cut stem and thin tobacco is not set. In the actual calculation, the sum of the total weight is 1. According to the actual admixture amount of various admixture according to the mathematical average. Among them, molding, cigarette, packaging section of the production segment is not subdivided, using the node of the process. The third level of the evaluation template is the section, which defines the section to be evaluated and the weight of each section. The fourth level of the evaluation template is the production process, which defines the processes to be evaluated and the weights of each process. The fifth level of the evaluation template is the evaluation project, which is the leaf node of the entire evaluation template tree. The number of each evaluation item is the same as the number in the process quality parameter standard so as to facilitate the system to obtain the standard value and the detection value of the process parameter. The maintenance of process evaluation weights in the PDM system is shown in figure 4:

![Figure 4. The maintenance of process evaluation weights in the PDM system.](image)

The display interface of the Sigma evaluation weight template received in the MES system is shown in Figure 5. The tree structure on the left side of the diagram defines the entire evaluation template, and the minimum unit is the CTQ of each process point.

![Figure 5. The display interface of MES system Sigma level evaluation weight template.](image)

**Request for Evaluation of Process Quality.** The request quality data of the process quality evaluation refers to the request sent from the PDM system to the MES system for Sigma evaluation and calculation. The unified and unique code identification of the issued evaluation request facilitates the transmission and reception of the PDM and MES system indexes and evaluation results. The evaluation request must specify the time period, the version of the assessment template, the cigarette brand number (one or more), or a certain percentage of the total output (brands are sorted from highest
Calculation of Process Quality Assessment. According to the selected assessment time range, evaluation template version, test cigarette brand number or production ratio, build a process quality evaluation result tree. Using the structure of the process quality assessment weight template, an evaluation result tree for evaluation grades (finished products, cut tobacco, and leaf tobacco) is calculated one by one, for storing and displaying the data and results of the evaluation calculation process. According to the brand code to query the corresponding tobacco code, there is only one tobacco code for a brand name; if the tobacco material or the material of the tobacco material is evaluated, the derivation of this step is unnecessary.

1) Query the BOM version of the material used in the tobacco during the evaluation period, and the corresponding cut tobacco, expanded stem, and cut stem for the tobacco in each version. For example, the evaluation period is 1-3 months. In January-February, tobacco shreds use cut tobacco A and cut tobacco B. In March, cut tobacco A and cut tobacco C were used. In the evaluation result tree, cut tobacco A and cut tobacco B, cut tobacco C should be included. If the evaluation specifies a wire material, the derivation of this step is not required.

2) Query the filter stick code that corresponds to the brand number (a default filter stick code is used for a brand name). If you only evaluate the results of the spinning section, you do not need to query the filter stick code.

3) The process and evaluation items in the evaluation result tree are generated based on the evaluation template. The default process and evaluation items include all items. In the actual calculation, the invalid item should be removed according to the actual processing path, for example, the process that the cut tobacco A does not contain the cut rolled stem drying SH93 technology. In the actual calculation, this node is to be deleted (that is, the evaluation item is reversed based on the actual data acquisition result).

Based on the received assessment request, the MES system uses the evaluation template prepared for actual evaluation and calculation to obtain the final evaluation result. The specific information is shown in Fig. 6. In the results, information such as DPMO, standard deviation, qualification rate, and defect rate of the respective sections, processes, and indicators can be clearly seen in the results, facilitating the analysis and application of results by the business personnel.

Figure 6. The evaluation request maintenance interface in the PDM system.

Conclusion

Through the information integration of the existing PDM and MES systems in the enterprise, the function of Sigma level evaluation of the production process of each factory in the enterprise is
realized, and the data collection, model establishment and calculation of the evaluation data are completed, and the evaluation standards among different factories are unified. At the same time, it helps the relevant departments of quality management, such as technical center, factory and so on, not only to understand the Sigma level of process, workshop and products in time, but also to compare and analyze the process manufacturing capability of different factories. By tracking and analyzing the results of Sigma evaluation, we can further help the relevant departments of enterprises to strengthen the quality control of the production process, and help to improve the level of product quality management and lean production management in an all-round way.

References


