Lean Path to Reduce the Cost of Silk Consumption of Ultra-fine Cigarettes— — a Multi-dimensional Study Based on Six Sigma

Yu Chen [1], Pingshu Shi [2, a, *], Yuchao Wang [1], Huali Zheng [1]

[1] Cooperative Production Office of China Tobacco Zhejiang Industrial Co., Ltd. Shangcheng District, Hangzhou City, Zhejiang Province Zhejiang Zhongyan 310008, No.77 Zhongshan South Road.

[2] Cooperative Production Office of Zhejiang Zhongyan Industrial Co., Ltd. Zhejiang Zhongyan 310008, No.77 Zhongshan South Road, Shangcheng District, Hangzhou City, Zhejiang Province

[a] ships@zjtobacco.com

Abstract. In this paper, the optimization framework of Six Sigma method is proposed and applied to solve the problem of single cut tobacco consumption of ultra-fine cigarette in Z Company. VSM was used to sort out the production process comprehensively, and FMEA was used to identify the key factors affecting the consumption of single piece of cut tobacco, and the regression and analysis of variance (ANOVA) in Six Sigma was used to predict the optimization variables. Combined with the design of experiment (DOE), the optimization effect was verified, which significantly reduced the cost per piece of cut tobacco, and improved the production efficiency and resource utilization. This paper not only provides a theoretical basis for cost control in lean production, but also provides a practical guidance for Z company to enhance its competitiveness in the international market and sustainable development.

Keywords: Cut tobacco consumption; Six Sigma; Lean production.

1. Research background

With the sustainable development of the global tobacco industry, the cost of tobacco materials has become a key factor restricting the profitability of enterprises. The price fluctuation of cut tobacco, filter rods and packaging materials directly affects the cost structure and resource allocation of enterprises. In the context of the continuous growth of international market demand, the rising cost of tobacco consumption has brought severe challenges to the profitability of Z Company, limiting its competitiveness in the international market.

2. Current situation investigation

At present, the circumference of the superfine cigarette of Z Company is 17.12mm, the length of the cigarette is 59mm, and the length of the filter rod is 25mm (after cutting). Z Company is facing the challenge of transporting cut tobacco from China due to the lack of local production lines. The high logistics cost and complex transportation links in the transportation process make the efficient use of cut tobacco a key factor in cost control. Although Z Company has taken a number of strict control measures, the consumption of a single piece of cut tobacco is still significantly higher than that of similar products in the world. Specifically, the single cut tobacco consumption of ultra-fine cigarette of Z company is 3. 38 kg, while the single cut tobacco consumption of international similar products is 3. 14 kg, there is a significant gap between the two. This gap not only aggravates the pressure of production cost, but also restricts the competitiveness of Z Company in the international market to a certain extent.

3. Research and Analysis

In order to optimize the consumption of a single piece of cut tobacco in the ultra-fine cigarette production process of Z Company, the enterprise adopted a systematic analysis method. Firstly, the production bottleneck was identified by the value stream analysis diagram, then the potential

influencing factors were evaluated by the failure mode and effect analysis (FMEA), and finally the optimal process parameter combination was screened by the Six Sigma data analysis to accurately control the cut tobacco consumption. Through value stream analysis (VSM), three key links affecting the consumption of ultra-fine cigarette cut tobacco were identified, and three key links of tobacco rod forming, cutting and conveying and filter rod supply were preliminarily identified as possible factors affecting the consumption of cut tobacco. In order to further clarify the specific role of these links on cut tobacco consumption, an in-depth study will be conducted in conjunction with failure mode and effect analysis (FMEA). The analysis results showed that the consumption of cut tobacco in the tobacco rod forming process was the highest, which became the key optimization object.

Through the FMEA analysis of the whole process of ultra-fine cigarette, it was determined that the key factors of single cut tobacco consumption focused on the tobacco rod cutting, filter rod cutting and tobacco rod forming process. As shown in Table 1:

Table 1 Summary of Key Variables

Serial number	Process link	Dependent variable (y1-y3)	Arguments (X1-X10)
1	Cigarette rod cutting	Cigarette length Y1	X1: Determination of number of transmission teeth X2: Limit block selection X3: cutterhead clearance adjustment X4: Guide rail cutting position adjustment X5: Spider Claw Pick Position Adjustment X6: Cut two guide adjustment
2	Filter rod cutting	Filter rod length Y2	X7: Filter rod cutting two-guide device X8: Filter rod transfer drum device X9: Size of filter rod bank
3	Cigarette rod forming	Cigarette circumference y3	X1 0: Cigarette weight

3.1 Analysis of dependent variable cigarette length Y1 on independent variables (X1-X6)

Based on Y1 (59mm) before improvement, Z Company ranked the hypothetical data of Y1 (production data omitted), and used multiple linear regression analysis to screen out significant variables. See Table 2 for details:

Table 2 Regression analysis results

Variable COEF STD t P & gt; |t| [0.025 0.975]						
Constant term 50.6723 0.124 407.080 0.000 50.407 50.938						
X1	3.1824	0.385	8.259	0.000	2.361	4.004
X2	-0.7350	0.406	-1.812	0.040	-1.599	0.129
X3	0.0095	0.033	0.290	0.776	-0.060	0.079
X4	0.0095	0.033	0.290	0.776	-0.060	0.079

X5	0.0095	0.033	0.290	0.776	-0.060	0.079
X6	0.0095	0.033	0.290	0.776	-0.060	0.079

3.1.1 Predicted cigarette length Y1

Through the multiple linear regression analysis, the interaction between the number of transmission teeth X1 and the choice of limit block X2 has a significant positive effect on the length of the cigarette after cutting, and the choice of limit block is close to significant, which deserves attention. The cutter head clearance adjustment X3, guide rail cutting position adjustment X4 and other factors have little influence, so it is recommended to carry out simple equipment adjustment. The linear regression model successfully predicted that the cigarette length after cutting was 57 mm, and the specification of 57 mm was recommended for the number of transmission teeth X1 and the stop block X2 to ensure the equipment matching.

3.2 Analysis of filter rod length Y2 for independent variables (X7-X9)

Based on the fact that the length of Y2 filter rod before improvement is divided into two parts (50mm), Company Z decided to sort the hypothetical data of Y2, and used the post multiple comparison analysis method to analyze, as shown in Table 3, to screen out the optimal parameters.

Table 3 Variance analysis of Y2 on independent variables

ANOVA table							
	Y2 Filter rod length measurement mm (after cutting) (mean ± SD)						p
	50.0(n=2)	51.0(n=2)	52.0(n=2)	53.0(n=2)	54.0(n=2)	60.0(n=2)	
Length of filter rod slot mm	100±0	102±0	104±0	106±0	108±0	120±0	0.021
Filter rod cutting center adjustment mm	0±0	1±0	2±0	3±0	4±0	6±0	0.034
Size adjustment of filter rod storehouse mm	100±0	102±0	104±0	106±0	108±0	120±0	0.012
* p<0.05 ** p<0.01							

3.2.1 Predicted value of filter rod length Y2

According to the results of ANOVA, the size adjustment of filter rod bank, the length of filter rod slot and the center adjustment of filter rod cutting significantly affected the length of filter rod. The effect of filter rod bank size adjustment is the largest, and the p value is 0.012. It is suggested that this parameter should be optimized first. The p values of the length of filter flute and the adjustment of the cutting center of filter rod were 0.021 and 0.034, respectively, which were slightly lower but still significant. The linear regression model predicted that the length of filter rod was 54 mm when the size of filter rod bank was adjusted to 108 mm, which was only the initial cut value after cutting. After comprehensive analysis, it is suggested that the size of the filter rod bank should be adjusted to 108mm first, then cut to 54mm to ensure the accuracy of the length of the filter rod, and then continue to cut to the length of 27 mm wrapped with cigarettes.

3.3 Analysis of cigarette circumference y3 for independent variable (X10)

Based on the cigarette circumference of y3 (φ17.12mm) before improvement, Company Z decided to sort the hypothetical data of y3, and used the post multiple comparison analysis method to analyze, as shown in Table 4, to screen out the optimal parameters.

3.3.1 Predicted value of cigarette circumference y3

Analysis of variance (ANOVA) was used to study the effects of y3 cigarette circumference measurement on filter rod length (after cutting), cigarette weight (single cigarette) and cigarette length. The results showed that there were significant differences ($p < 0.05$) in these three parameters among different y3 cigarette circumference measurement samples. According to the analysis, when the circumference of the cigarette is 16. 96 mm, the corresponding length of the filter rod (after cutting) is 27 mm, the weight of the cigarette is 430 mg, and the length of the cigarette is 57 mm. The results are in line with the predicted values.

3.4 Summary of optimal prediction parameters

Based on the correlation analysis of Y1, Y2 and y3 in the previous period, the predicted values are shown in Table 5:

Table 5 Predicted values of optimal parameters

Y1 Cigarette length (after being cut)	Y2 length of filter rod (after cutting four)	Y3 Cigarette circumference
57mm	27mm	φ16.96mm

4. Effect verification

4.1 Theoretical verification

Based on the systematic data analysis of the variables of Y1, Y2 and y3, the ideal predicted values were finally selected as follows: the cigarette circumference was 16. 96, the length of a single cigarette was 57 mm, and the length of a filter rod was 108 mm (before cutting). Company Z will perform the DOE verification. As shown in Figure 1:

4.1.1 Confirmation of the significance of the main and interaction effects of Y1, Y2 and y3

The regression lines of cigarette circumference, cigarette length and filter rod length (before cutting) were steep, so the main effect was indeed significant; from the interaction effect diagram, it could be seen that the effects of cigarette length and filter rod length (before cutting) were obviously not parallel, indicating that the interaction between the two was significant.

4.1.2 Y1, Y2, and y3 Response Optimizer Validation

After judging the validity of the model, based on the analysis of a large number of previous data, the response optimizer finally obtained the optimal parameter combination: the cigarette length Y1 is 57 mm, the filter rod length Y2 (before cutting) is 108 mm, and the cigarette circumference y3 is 16. 96 mm. These optimized parameters are consistent with the previous predictions, and the model is valid.

4.2 On-board verification

Based on the analysis of independent variables (X1-X10), Z Company made a simple equipment adjustment to the relevant non-significant factors, and carried out trial production according to the predicted three y values. Subsequently, the amount of cut tobacco used per hour was continuously

recorded, and the statistical results were subjected to normality test and two-sample T test, as shown in Table 6.

Table 6 Two-sample T test before and after improvement

Two-sample T test and confidence interval: the consumption of single cut tobacco before improvement is kg, and the consumption of single cut tobacco after improvement is kg
Double sample T before improvement (single cut tobacco consumption kg/piece) and after improvement (single cut tobacco consumption kg/piece)
N mean standard deviation mean standard error
Before improvement (single cut tobacco consumption kg/153.2573 0.0299 0.0077
After improvement (single cut tobacco consumption kg/153.1207 0.0103 0.0027
Difference = mu (before improvement (single cut tobacco consumption kg/piece))-mu (after improvement (single cut tobacco consumption kg/piece))
Estimate of difference: 0. 13667.
95% confidence interval of the difference: (0.11995, 0.15338)
T-test for difference = 0 (and ≠): T-value = 16.75 P-value = 0.000 degrees of freedom = 28
Both using pooled standard deviation = 0.0224

After the improvement, the mean value of cut tobacco consumption per piece (kg/piece) decreased from 3. 257 to 3. 121, and the standard deviation decreased significantly from 0. 02987 to 0. 01033, indicating that the fluctuation of consumption decreased and the process became more stable. The P value decreased from 0.247 to 0.012, which met the statistical significance requirement. The P value of the two-sample T test was 0. 000, which was significantly less than 0. 05, indicating that there was a significant difference in the mean value before and after the improvement, which verified the effectiveness of the improvement measures.

Sum up

Through the lean improvement technology, Z Company successfully optimized the production process, significantly reduced the use of ultra-fine cigarette single cut tobacco (3. 12 kg/piece), and saved about 320 thousand yuan of production costs per year. The improvement did not adversely affect the equipment, but improved the production efficiency and equipment stability, while ensuring the consistency and stability of product quality. The international market feedback is positive, and the product quality and stability have been highly evaluated, which has promoted the brand reputation of Z Company and gained a larger share in the fierce market competition.

References

[1] Jiang Xuexue. Application of Six Sigma Management in Cigarette Process Quality Management [J]. Chinese and Foreign Enterprise Culture, 2020, (05): 63-64.

[2] Shao Jianzhong, Wang Yi, Yang Yawei. Analysis of Cigarette Production Management Optimization Based on Value Stream Analysis [J]. China Equipment Engineering, 2024, (S2): 69-71.

[3] Wang Youyuan, Li Qiang, Xie Chengming. Application of Lean Six Sigma Management — — Taking Reducing Power Consumption of PASSIM Cigarette Machine as an Example [J]. Chinese Journal of Tobacco, 2013, 19 (05): 89-92.

[4] Jin Song, Guo Daquan. Application Research of Quality Management Module Based on Six Sigma Management [J]. Information Technology and Informatization, 2019, (12): 223-225.

[5] Chen Yongsheng. Application of Lean Six Sigma Management in Cigarette Factory [J]. Management Observation, 2015, (19): 68-69.

[6] Guan Saisai, Xu Hongyu, Wang Zizhong, et al. Optimization of threshing and redrying process based on DOE analysis [J]. Anhui Agricultural Sciences, 2024, 52 (20): 163-168.

[7] Xie yuan, Jiang Shifei, Wen Yadong, et al.Study on reducing the coefficient of variation of flavoring ratio of blended silk based on six Sigma principle [J].Light Industry Science and Technology, 2024,40 (01): 13-15.

[8] Chen Rui. On the Application of Six Sigma Concept in Quality Management [C]//Collection of Excellent Academic Papers of Shanghai Tobacco System in 2008. Shanghai Tobacco Group Beijing Cigarette Factory, 2009: 246-257.

[9] Hu Dongdong, Li Xiao. Using Six Sigma Method to Improve Cut Tobacco Crushing Resistance in New Product Development [J]. Chinese and Foreign Entrepreneurs, 2016, (14): 215 + 217.

[10] She Di, Yan Naihu, Shu Chang, et al.Application of multiple linear regression analysis in the relationship between physical index and draw resistance of cigarette [J].Light Industry Science and Technology, 2020,36 (03): 94-96 + 105.