Study on Improving the Processing Efficiency of Mixing Production Line

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Abstract: In order to improve the processing efficiency of the mixing production line and enhance product competitiveness, lean Six Sigma method is adopted to solve the faults that affect the output efficiency of the mixing production line according to the DMAIC path, which can assist workers to increase the average daily output of product processing from 1.3 to 2.6 units. Lean Six Sigma method can deeply analyze the production faults of the hybrid production line and effectively solve the problem of product production efficiency.

Keywords: Lean Six Sigma; Methodology; Daily Output; Efficiency

1. Introduction

Production line efficiency is the most important thing in production, and it is the cornerstone that determines the development potential of enterprises.Is the basic condition of customer satisfaction.With the continuous growth of product orders, whether the average daily production capacity of the current machine block preassembly process can meet its market demand for the current production capacity of the internal enterprise;Externally, other competitive enterprises in the same industry can continue to improve, which has a greater impact on the orders of enterprises;According to the requirements of internal and external customers, it is urgent to increase the daily production capacity of product processing.Lean Six Sigma methodology is a methodology system that integrates lean method and six Sigma method.The core of Lean is to eliminate waste, Six Sigma focuses on reducing volatility and variation, the combination of the two, so that the enterprise application improvement is fast and good[1~3].

2. Definition Phase (D)

2.1 Project Selection

A series of product orders continue to grow, the sales target in 2021 is 3,000 units, internal customer requirements: processing A pre-assembly process can meet the average daily production requirements of market orders;External customer requirements: the competitive enterprises in the same industry can continue to improve, which has a greater impact on the orders of enterprises;Under the strong requirements of internal and external customers, it is urgent to improve the processing capacity of product A.

2.2 Problem Statement

Since 2021, the output demand of product A has increased to 3000 units. According to the current processing task arrangement of product A and taking into account the normal output of series B, the current processing rhythm of product A's body cannot meet the demand.As shown in Table 1.

Table 1. Statistics of Average Production Volume from January 2021 to July 2021

Month	Average Daily Output	Goal
Jan.	1.3	2.5
Feb	1.5	2.5
Mar	1.2	2.5
Apr	1	2.5
May	1.4	2.5
Jun	1.5	2.5
Jul	1.3	2.5

According to statistics, from January 2021 to July 2021, the average daily output of the preassembled A product body is 1.3 units, and its average daily output cannot meet the market demand.

3. Y Defect Definition and Analysis Phase (A)

3.1 Y and Defect Definition

The average daily production Y is defined as follows:

$$\text{Average daily output (Y)} = \frac{\text{Effective working hours per shift}}{\text{Max (h1、h2、h3……)}}$$

Note: 1, the effective working time of each shift is 8h/ day;
2, h1, h2, h3...Is the operation time of the process.
According to the analysis of the value flow chart (VSM) of the production of product A in 2021, factors affecting the average daily volume of product A are classified into eight categories and Y is defined, as shown in Table 2 below:

3.2 X impact Analysis

3.2.1 Analyze X6 (operator skill) and Y
Where X6 is the skill of the operator and Y is the average daily output;HO (null hypothesis) is that operator skills and average daily output have no significant effect, Ha(alternative hypothesis) is that operator skills and average daily output have a significant effect.Two-sample T test was used.

Table 2. Factors Affecting the Average Daily Volume of Product A

order number	bug	Evaluation criteria	measuring method	Importance to the customers
Y1	Long transit time between processes	Transfer time	stopwatch	6
Y2	Long anterior and posterior terminal face and pore processing time of OP 110	process time	The machine tool has its own timer	7
Y3	OP 110 opening surface and push processing time is long	process time	The machine tool has its own timer	7
Y4	OP 110 was long	Detection time	stopwatch	6
Y5	The OP 120 cylinder hole has a long processing time	process time	The machine tool has its own timer	7
Y6	OP 120 long long processing time	process time	The machine tool has its own timer	7
Y7	Long pore processing time for the OP 120 cylinder pore face	process time	The machine tool has its own timer	7
Y8	OP 120 has a long detection time	Detection time	stopwatch	6

Table 3. Y Data collection table

Serial number	variable(Y)	Measure the content	Evaluation item / type	acquisition time	place	Person in charge
Y2	Long anterior and posterior terminal face and pore processing time of OP 110	process time	Roughness, machining size / count type	For 30 consecutive days	BTA beltline	Gong junzhen
Y5	The OP 120 cylinder hole has a long processing time	process time	Cylinder hole aperture, processing interval time / metering type	For 30 consecutive days	BTA beltline	Xu Shixiang, Liu Fei
Y6	OP 120 long long processing time	process time	Roughness, processing interval time / measurement type	For 30 consecutive days	BTA beltline	Gong Junzhen and Xu Shixiang

Y7	Long pore processing time for the OP 120 cylinder pore face	process time	Processing interval time / counting type	For 30 consecutive days	BTA beltline	Gong Junzhen and Xu Shixiang

Table 4. X Data Collection Table

Serial number	variable(x)	type	measuring method	acquisition time	place	Person in charge	analytic procedure
X5	Blade material and shape	Count type	Cylinder hole aperture	For 30 consecutive days	BTA beltline	Li Baobao, Sun Kai	chi-square test
X4	Tool structure	Count type	Measure roughness	For 30 consecutive days	BTA beltline	Li Baobao, Sun Kai	Double sample T
X6	Operator skills	Count type	process time	For 30 consecutive days	BTA beltline	Li Baobao, Sun Kai	Double sample T
X7	The knife technique	Count type	process time	For 30 consecutive days	BTA beltline	Li Baobao, Sun Kai	Single factor variance
X8	Tool parameters	Count type	Measure roughness	For 30 consecutive days	BTA beltline	Li Baobao, Sun Kai	Double sample T

Table 5. Analysis Table of X6 and Y

variable	name	type	diagnostic tool
Y	Average daily output	Measurement type	Double sample T
X6	Operator skills	Count type	

Based on $P=0.214 > 0.05$, the H0 hypothesis is valid, that is, operator skills have no significant effect on the average daily output.However, due to the large spread of new employees, it is necessary to conduct operational skills training for new employees.

Through analysis, it can be concluded that the new employees are not very skilled in the process;In order to improve this situation, new employees and operators should be trained in the basic knowledge of the process and explained in the field application, repeated practice, and special examination of P17 process knowledge, and the score of more than 90 will be qualified.

Through the implementation of the measures, all new staff operators can master the process, in the P17 process knowledge special examination are above 92 points, all passed.As shown in Table 3-10.

Figure 1. Process Training for Employees

Table 6. Analysis Table of X7 and Y5

variable	name	type	diagnostic tool
Y5	Cylinder hole aperture	Measurement type	Single factor variance
X7	The knife technique	Count type	

3.2.2 Analyze X7(tool adjustment technique) and Y5

Where X7 is the tool adjustment method, Y5 is the OP120 cylinder hole processing time (cylinder hole aperture);HO (original hypothesis) is that the OP120 cylinder hole processing time (cylinder hole aperture) is not related to the tool adjustment method, Ha(alternative hypothesis) is that the OP120 cylinder hole processing time (cylinder hole aperture) is related to the tool adjustment method.The hypothesis testing method of single factor analysis of variance (three tool adjustment techniques were selected, and one piece was measured for every five pieces) was adopted.

P=0 < 0.05, the original hypothesis is not valid, that is, the processing time of the OP120 cylinder hole is related to the tool adjustment method.

Through the analysis, it is concluded that P17 is a dry cylinder liner, which has high requirements for tool adjustment and no uniform adjustment mode, and the quality of the cylinder holes processed is inconsistent.In order to solve this problem, the cylinder hole tool adjustment adopts a unified standard, and the tool adjustment personnel are trained, so that the cylinder hole quality processed in the shortest time is qualified, the tool adjustment time is reduced, and the overall processing time is shortened by about 20min.

Figure 2. Training for Knife Cutters

Table 7. Analyzed the X4 and Y6

variable	name	tape	diagnostic tool
Y6	harshness	Measurement type	Double sample T
X4	Tool structure	Count type	

Table 8. Analysis of the Relationship Between Props Structure and Roughness

Tool structure	set number	harshness	Tool structure	set number	harshness
1	5	0.17	2	5	0.32
	5	0.27		5	0.33
	5	0.22		5	0.32
	5	0.24		5	0.33
	5	0.24		5	0.35
	5	0.26		5	0.38
	5	0.26		5	0.37
	5	0.26		5	0.35
	5	0.18		5	0.36
	5	0.28		5	0.37

3.2.3 Analyze X4 (tool structure) and Y6

Where X4 is the tool structure, Y6 is OP120 tappet hole processing time (roughness);HO (original hypothesis) is OP120 tappet hole machining time (roughness) has no relationship with tool structure, Ha(alternative hypothesis) is OP120 tappet hole machining time (roughness) has relationship with tool structure;The hypothesis testing method of two-sample T test was adopted.The analysis results are shown in the table 8 below:

Two-sample T test and confidence interval: surface roughness at structure 1, surface roughness at structure 2.

P=0.000 < 0.05, the Ha hypothesis is valid, that is, the tool structure has a significant effect on the machining time of OP120 tappet holes.

The analysis shows that OP120 tent-hole reamer has low tool life, poor material, frequent manual tool adjustment and tool change.

In order to solve this problem, the tool structure was modified from guide bar type to integral carbide type to reduce the number of manual tool adjustment and tool change, and the processing time of the optimized tashet hole was reduced by 16min.

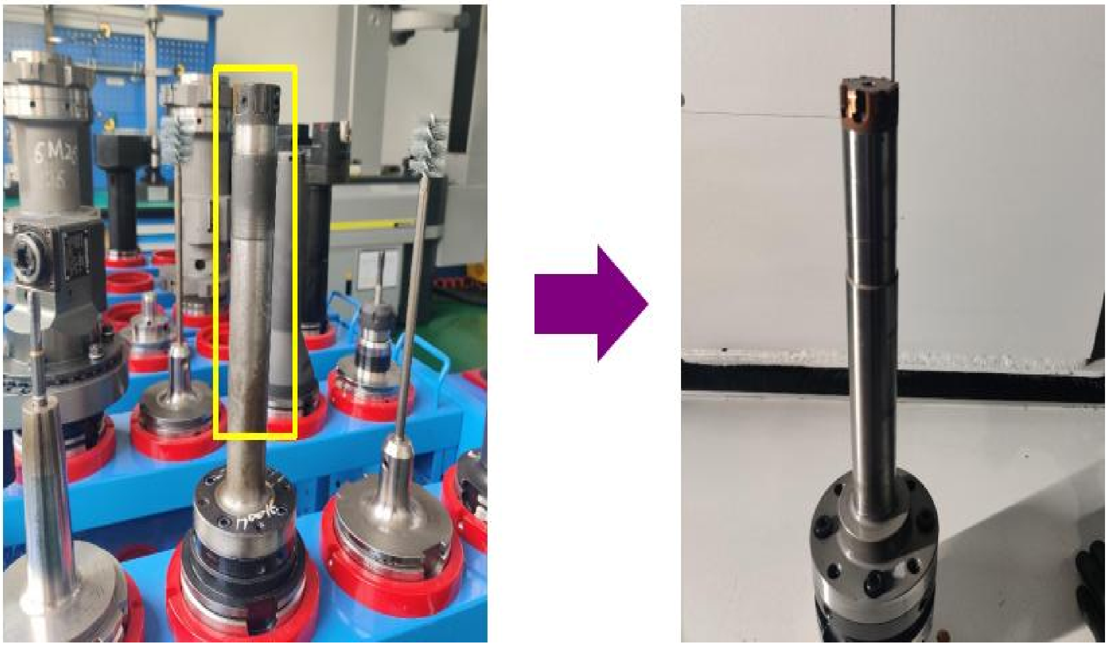

Figure 3. The Tool is Changed from Guide Type to Hard Type

3.2.4 Analyze X8 (tool parameters) and Y

Where X8 is the tool parameter, Y is the average daily output (roughness);HO (null hypothesis) is the average daily output (roughness) and tool parameters have no relationship, Ha(alternative hypothesis) is the average daily output (roughness) and tool parameters have a relationship.The hypothesis testing method of two-sample T test was adopted.The analysis results are shown in the figure below:

Two-sample T test and confidence interval: surface roughness when S=1200, surface roughness _1 when S=1700

If P=0.000 < 0.05, the Ha hypothesis is valid, that is, the tool parameters have a significant effect on the average daily output.

Table 9. analyzed X8 and Y

variable	name	tape	diagnostic tool
Y	harshness	Measurement type	Double sample T
X8	Tool parameters	Count type	

Table 10. Analysis Table of the Relationship Between Tool Parameters and Roughness

Tool parameters	set number	harshness	Tool parameters	set number	harshness
S=1200 F=850	3	0.18	S=1700 F=900	3	0.31
	3	0.26		3	0.34
	3	0.21		3	0.35
	3	0.25		3	0.32
	3	0.25		3	0.34
	3	0.27		3	0.39
	3	0.27		3	0.36
	3	0.27		3	0.34
	3	0.19		3	0.35
	3	0.29		3	0.35

Table 11. X Table of Data Analysis Results

X Data analysis results				
variable（X）	factor	Test the analysis results	conclusion	Improve the plan
X4	Tool structure	P<0.05	Significant impact	Improved
X5	Blade material and shape	P<0.05	The influence of the blade manufacturer is not significant, and the blade material and shape are significant	Stage I for further analysis
X6	Operator skills	P＞0.05	The effect was not significant	Improved
X7	The knife technique	P<0.05	Significant impact	Improved
X8	Tool parameters	P<0.05	Significant impact	Stage I for further analysis

Table 12. Key Core Factor Improvement Schedule

serial number	procedure	variable（X‘s）	Output results	Factor properties	plan
X5/Y5	OP 120 finishing cylinder holes, straight ings, back and pores	1. Blade material; 2. Shape of blade；	Cylinder hole aperture	Countermeasures factor	Through the DOE test
X8/Y6	OP 120 finishing cylinder holes, straight ings, back and pores	Tool parameters (1. spindle speed; 2. Feed speed)	Quite column hole roughness	Countermeasures factor	Through the DOE test

The remaining factors need to be improved after further analysis in the next stage.

4. Improvement Phase (I)

4.1 Vital Few X's Features

Develop a preliminary improvement plan for the selected key core factors:

4.2 DOE experiment and factor are the best

4.2.1 Full factor experimental design for X5

According to the two control factors of X5-1 blade material and X5-2 blade shape, a two-factor, two-level full factor experiment was carried out (repeated once), which was marked in detail as follows.As shown in Table 11-18.

Table 13. Blade Two-Factor Two-Level Experiment Table

serial number	name	-1 Lev	1 Lev	remarks
X5-1	Blade material	CBN	kentaniu m	Low level with CBN material blade; High level with carbide blades
X5-2	Blade shape	delta	rhombus	Low level with a triangular blade; High-level application with a diamond-shaped razor blade

Table 14. Cylinder Bore Size Data Sheet For October

Standard order	Running order	Point type	granule	Blade material	Blade shape	Cylinder hole aperture
3	1	1	1	1	-1	131.008
7	2	1	1	1	-1	131.009
2	3	1	1	-1	1	131.011
5	4	1	1	-1	-1	131.024
6	5	1	1	-1	1	131.01
1	6	1	1	-1	-1	131.024
8	7	1	1	1	1	131.017
4	8	1	1	1	1	131.019

Table 15. Table of the Blade Experiment Analysis Results

factor	Blade material	Blade shape
The best level	kentanium	trigon

Data collection:Using minitab to generate high and low level test sequence of standard sequence, running sequence, point type, block, blade material and blade shape, explore the influence of parameters such as cylinder aperture X5-1 blade material and X5-2 blade shape in OP120 process, carry out field measurement of workpiece, and conduct general full factor experiment with line number of 2.Collect and measure cylinder bore diameter data in October.General full factor experimental analysis results: P values are less than 0.05, the model is effective.
Factor regression: cylinder hole aperture and blade material, blade shape
Main effect diagram and interaction diagram of general full factor experimental analysis:
Response optimization: cylinder bore size
Through data acquisition and data analysis, the OP120 process cylinder hole aperture X5-1 blade material and X5-2 blade shape can be obtained, as shown in the chart:
4.2.2 Conduct full factor experimental design for X8
According to cast iron cutting experience, three horizontal tests of spindle speed S (r/min) and feed speed F (mm/min) are best selected, as shown in Table 17 below.
Data acquisition: minitab was used to generate the test sequence of standard sequence, running sequence, point type and block, explore the influence of tool parameters on the roughness of tappt holes in OP120 process, carry out on-site measurement of the workpiece, and collect and measure the roughness data of tappt holes in November.
Screening design model: roughness and spindle speed, feed speed
The non-significant factors of AA were removed
The optimal level is obtained by the response optimizer Target 1.6
Through data collection and model design, it can be concluded that the optimal selection of spindle speed S (r/min) and feed speed F (mm/min) for cast iron cutting experience can be obtained, as shown in Table 19:

Table 16. Casting Iron Cutting Three-Level Experiment Table

serial number	name	-1 Level	0 Level	1 Level	remark
X8-1	main shaft speed	620	820	1200	
X8-2	feed rate	500	650	800	

Table 17. November Column Shaft Roughness Data Table

Standard order	Running order	Point type	granule	speed of mainshaft	feed rate	harshness
5	1	1	1	820	650	0.7
2	2	1	1	620	650	1
1	3	1	1	620	500	1.5
3	4	1	1	620	800	1.5
8	5	1	1	1200	650	0.8
6	6	1	1	820	800	1.5
4	7	1	1	820	500	1.2
9	8	1	1	1200	800	1.6
7	9	1	1	1200	500	0.8

Table 18. Cast-Iron Cutting Analysis Results Table

factor	speed of mainshaft	feed rate
The best level	1200	800

Table 19. Summary Table of the Phased Improvement Plan

num	Process steps	key factor	M	A	I

ber			plan	reality	plan	reality	plan	reality
X1	Check the measurement	Measurement method	★	★				
X2	Check the measurement	inspection record	★	★				
X3	process-cycle	Program layout	★	★				
X4	process-cycle	Tool structure			★	★		
X5	process-cycle	Blade material and shape			★	☆	★	★
X6	process-cycle	Operator skills			★	★		
X7	process-cycle	The knife technique			★	★		
X8	process-cycle	Tool parameters			★	☆	★	★
X9	process-cycle	Workpiece incoming condition	★	★				
X10	Transfer between processes	Workpiece transfer	★	★				

4.3 Conclusion of Improvement Stage

Analyze the problem according to different factors and summarize the improvement plan of the stage:

After the Phase I improvement, the average daily production of WP17 was increased from 2.3 to 2.6 units.

5. Conclusion

1) By carrying out this Six Sigma project, we have doubled the average daily output of WP17 machine from 1.3 to 2.6, and monitored the average daily output of WP17 in December to fully meet the market demand.At the same time, an efficient and cooperative team has been formed to ensure that the body processing meets the market demand and improves the processing quality and efficiency.

2) On the basis of this project, to challenge the WP17 body line size zero defect as the goal, continue to carry out Six Sigma project in terms of processing size consistency, combined with online measurement tools (Q-DAS) and machine MES and other tools to comprehensively improve product consistency.

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