CHAPTER 5

EXPERIMENT FOR FINDING APPROPIATE CONDITION

This chapter will conduct the experiments for finding appropriate condition for controlling the image printing defects in image printing process. The appropriate condition will be determined from factor affecting to image printing particularly emulsion thickness, printing pressure, and printing speed.

5.1 Finding Appropriate Condition Experiment

In manufacturing experiment, one-factor-at-a-time (OFAT) experiment is selected to perform the appropriate condition for controlling the image printing defects in image printing process. The objective was to minimize the ink thickness, as a function of three factors, emulsion thickness, printing pressure, and printing speed. This OFAT experiment will vary only one factor at a time while keeping others fixed. The advantages of OFAT experiment is that the can be used to estimated curvature in the factors. Additionally, other factors are set to be the best condition for each factor.

5.2 Experiment and Data Collection

The team performed the OFAT experiment for three factors and collected data as follows.

5.2.1 Printing speed

The OFAT experiments for printing speed are performed as follows.

Experiment No.	Factors							Output	
	A	B	C	D	E	F	G	Y1	Y2
1	80	10	0	8	28	2.0	10		
2	80	10	0	8	28	2.5	10		
3	80	10	0	8	28	3.0	10		
4	80	10	0	8	28	3.5	10		
5	80	10	0	8	28	4.0	10		
6	80	10	0	8	28	4.5	10		
7	80	10	0	8	28	5.0	10		

Table 5.1 The layout sheet of OFAT experiment for printing speed

Experiment No.	Factors							Output	
	A	B	C	D	E	F	G	Y1	Y2
1	80	10	0	8	28	2.0	10	10.8	10.7
2	80	10	0	8	28	2.5	10	10.8	11.0
3	80	10	0	8	28	3.0	10	10.8	10.7
4	80	10	0	8	28	3.5	10	11.0	10.8
5	80	10	0	8	28	4.0	10	11.2	11.0
6	80	10	0	8	28	4.5	10	Circuit indentation	
7	80	10	0	8	28	5.0	10	Circuit indentation	

Table 5.2 The data of OFAT experiment for printing speed

5.2.2 Printing pressure

The OFAT experiments for printing pressure are performed as follows.

Experiment No.	Factors							Output	
	A	B	C	D	E	F	G	Y1	Y2
8	80	10	0	8	4	2.5	10		
9	80	10	0	8	8	2.5	10		
10	80	10	0	8	12	2.5	10		
11	80	10	0	8	16	2.5	10		
12	80	10	0	8	20	2.5	10		
13	80	10	0	8	24	2.5	10		
14	80	10	0	8	28	2.5	10		
15	80	10	0	8	32	2.5	10		

Table 5.3 The layout sheet of OFAT experiment for printing pressure

Experiment No.	Factors							Output	
	A	B	C	D	E	F	G	Y1	Y2
8	80	10	0	8	4	2.5	10	Ink not through screen	
9	80	10	0	8	8	2.5	10	Ink not through screen	
10	80	10	0	8	12	2.5	10	10.8	10.8
11	80	10	0	8	16	2.5	10	12.3	12.3
12	80	10	0	8	20	2.5	10	12.5	12.5
13	80	10	0	8	24	2.5	10	12.5	12.5
14	80	10	0	8	28	2.5	10	10.8	10.8
15	80	10	0	8	32	2.5	10	10.8	10.8

Table 5.4 The data of OFAT experiment for printing pressure

5.2.3 Emulsion thickness

The OFAT experiments for emulsion thickness are performed as follows.

Experiment No.	Factors							Output	
	A	B	C	D	E	F	G	Y1	Y2
16	80	10	0	2	16	2.5	10		
17	80	10	0	4	16	2.5	10		
18	80	10	0	6	16	2.5	10		
19	80	10	0	8	16	2.5	10		
20	80	10	0	10	16	2.5	10		
21	80	10	0	12	16	2.5	10		

Table 5.3 The layout sheet of OFAT experiment for emulsion thickness

Experiment No.	Factors							Output	
	A	B	C	D	E	F	G	Y1	Y2
16	80	10	0	2	16	2.5	10	10.5	10.5
17	80	10	0	4	16	2.5	10	10.8	11.0
18	80	10	0	6	16	2.5	10	10.5	10.5
19	80	10	0	8	16	2.5	10	10.8	11.0
20	80	10	0	10	16	2.5	10	10.8	11.0
21	80	10	0	12	16	2.5	10	11.0	11.0

Table 5.6 The data of OFAT experiment for emulsion thickness

5.3 Data Analysis of Experiment

According to the experiment, some data could not been obtained as planned in the experiment as follows.

- ☆ The experiment no. 6 and 7 have occurred circuit indentation.
- ☆ The experiment no. 8 and 9 have occurred ink could not been passed through printing screen.

However, the analysed result of each factor in the experiment is shown as below.

5.4.1 Printing speed

This includes analysed result when printing speed is changed at one time while the other factors are kept fixed. The best result is chosen when printing speed is 4.0 m/s to minimise ink thickness as well as increase productivity. The result of this experiment is shown in figure 5.1.

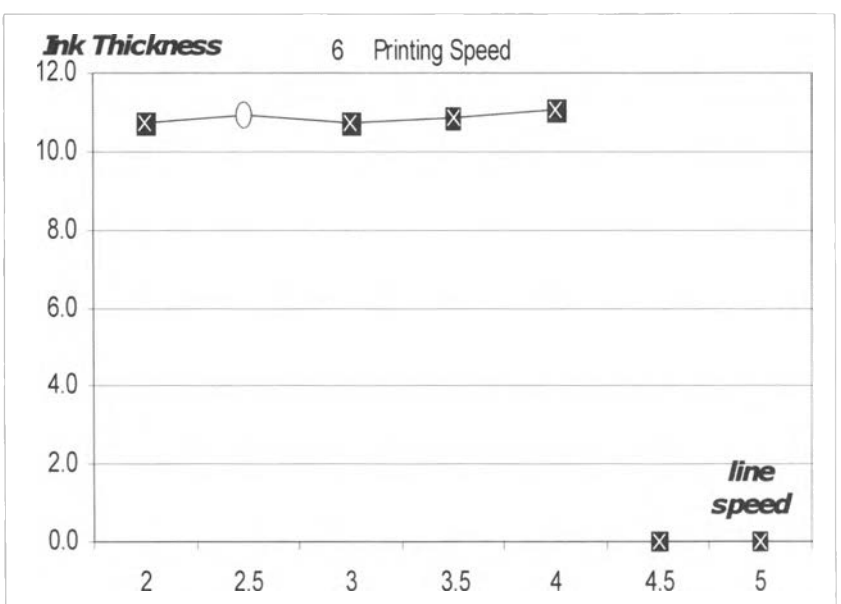

Figure 5.1 The result of this experiment when fixed printing speed

5.4.2 Printing pressure

This includes analysed result when printing pressure is changed at one time while the other factors are kept fixed. The best result is happened when printing pressure is 28 Kgf/cm^2. The result of this experiment is shown in figure 5.2.

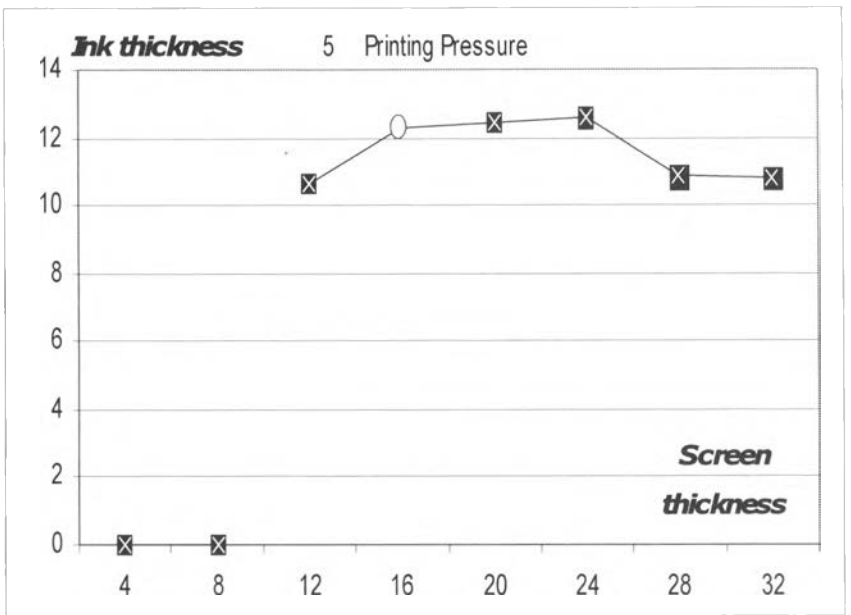

Figure 5.2 The result of this experiment when fixed printing pressure

5.4.3 Emulsion thickness

This includes analysed result when emulsion thickness is changed at one time while the other factors are kept fixed. The best result is happened when emulsion thickness is 2 microns. The result of this experiment is shown in figure 5.3.

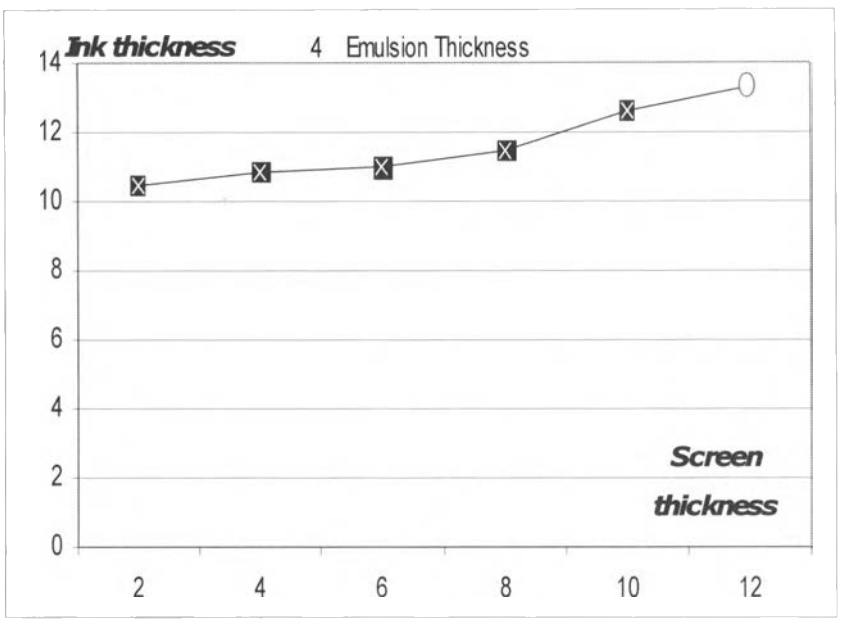

Figure 5.3 The result of this experiment when fixed emulsion thickness

According to the analysed results, the suitable condition for controlling the image printing defects in image printing process as a function of three factors can be concluded as below.

- ☆ The printing speed is 4 m/s.
- ☆ The printing pressure is 28 Kgf/cm^2.
- ☆ The emulsion thickness is 2 microns.

Where as,

- ☆ The squeegee hardness is 80 B.
- ☆ The squeegee angle is 10 degree.

☆ The squeegee cut angle is 0 degree.

☆ The table clearance is10 mm.

5.4 Confirmation Experiment

This experiment is performed to confirm the result of the experiment between "Before" and "After" improvement.

Before : Original condition of each factor

After : The best condition of each factor

The product is measured 10 times at point A in figure 5.4.

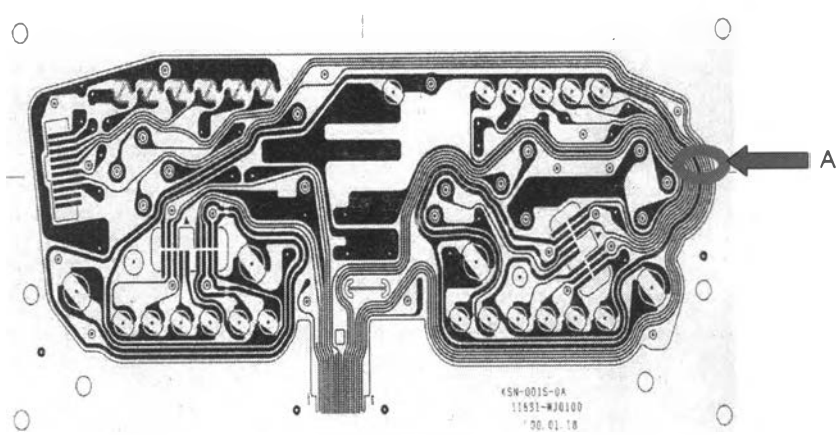

Figure 5.4 The ink thickness measuring area

The layout sheet of the confirmation experiment are shown in table 5.7

Experiment No.	Factors							Yavg.	Range	Stdv.
	A	B	C	D	E	F	G			
Before	70	20	0	12	16	2.5	8			
After	80	10	0	2	28	4	10			

Table 5.7 The layout sheet of the confirmation experiment

The ink thickness measuring data are shown as below.

No.	Before improvement	After improvement
1	11.5	10.9
2	11.2	10.9
3	11.0	10.6
4	10.8	10.8
5	11.6	11.0
6	11.2	10.6
7	11.3	11.0
8	11.3	10.5
9	11.1	10.9
10	11.3	11.2
Avg.	11.1	10.8

Table 5.8 The ink thickness measuring data

The method of hypotheses testing is used to test differences between two means and variances of the ink thickness before and after improvement process. This was produced using the MINITAB computer program.

Initially the Normal Probability Plot of the ink thickness before and after improvement process are tested and illustrated as follows.

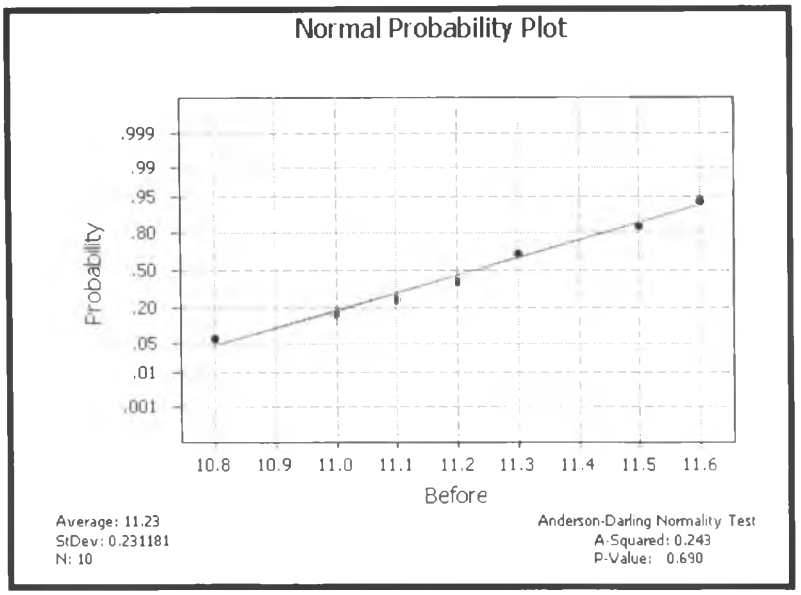

Figure 5.5 The Normal Probability Plot of the ink thickness before improvement process

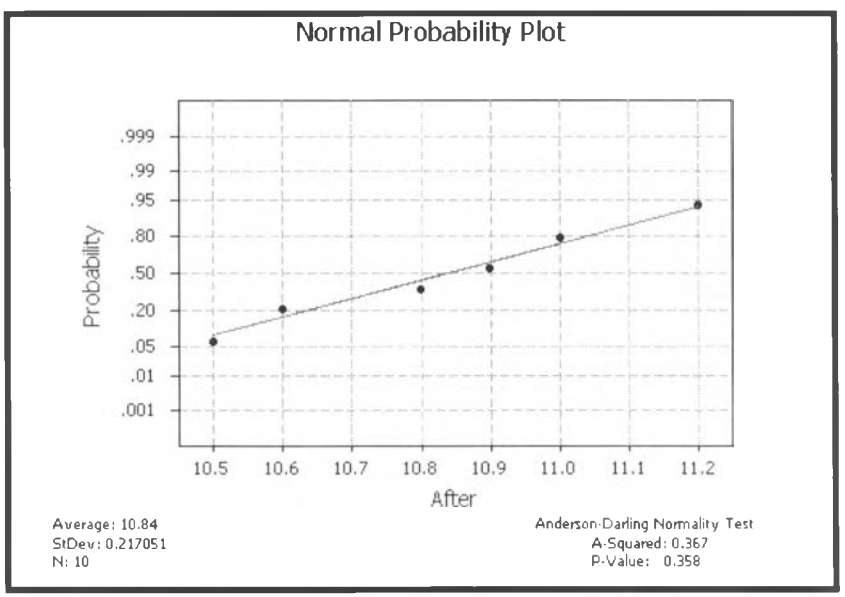

Figure 5.6 The Normal Probability Plot of the ink thickness after improvement process

Refer to figure 5.5 and 5.6, the plot data shows that the points fall reasonably close to the reference line, indicating that the data are normally distributed. Additionally, the p-value for the both tests are more than 0.05 then the data are considerably normal.

Next, the F- test is used to test the differences between two variances of the ink thickness before and after improvement process which of two opposing hypotheses.

- ☆ H_0 (the null hypothesis): $\sigma_A^2 = \sigma_B^2$
- ☆ H_1(the alternative hypothesis): $\sigma_A^2 \neq \sigma_B^2$

The p-value for the test is 0.085, which is more than level of significant, 0.05. H_0 can be accepted. Then there is no difference between the two variances.

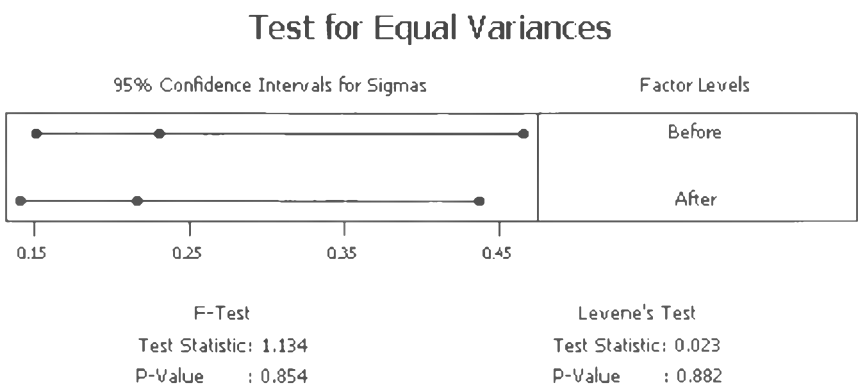

Figure 5.7 The test for equal variances

Subsequently, the two-sample t test is used to test the differences between two means of the ink thickness before and after improvement process which of two opposing hypotheses.

- ☆ H_0 (the null hypothesis): $\sigma_A^2 = \sigma_B^2$
- ☆ H_1(the alternative hypothesis): $\sigma_A^2 \neq \sigma_B^2$

The p-value for the test is 0.085, which is more than level of significant, 0.05. H_0 can be accepted. Then there is no difference between the two means. The test for means is shown in figure 5.8.0

	N	Mean	StDev	SE Mean
After	10	10.840	0.217	0.069
Before	10	11.230	0.231	0.073

Difference = mu After - mu Before

Estimate for difference: -0.390

95% upper bound for difference: -0.216

T-Test of difference = 0 (vs <): T-Value = -3.89 P-Value = 0.001 DF = 18

Both use Pooled StDev = 0.224

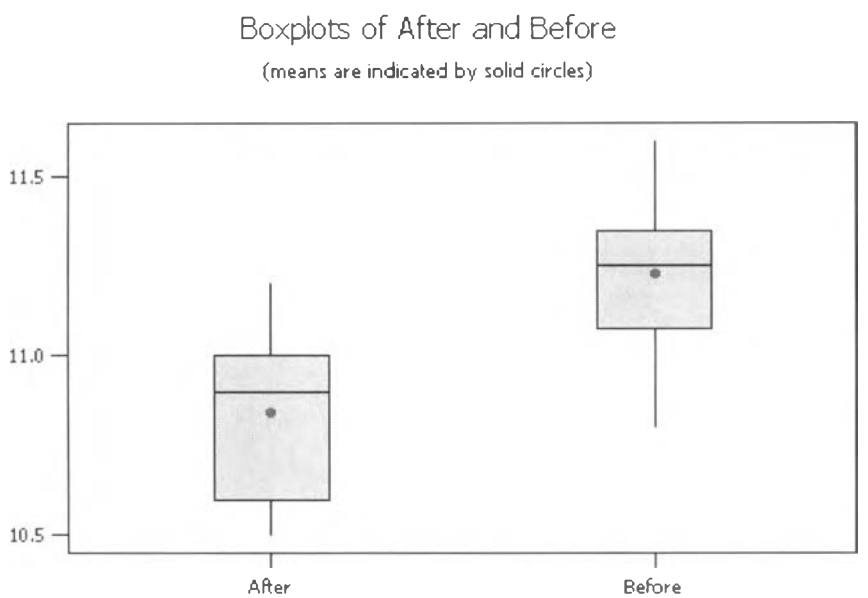

Figure 5.8 The test for means

The collected data from the confirmation experiment are shown in table 5.8

Experiment No.	Factors							Yavg.	Range	Stdv.
	A	B	C	D	E	F	G			
Before	70	20	0	12	16	2.5	8	11.1	0.8	0.2
After	80	10	0	2	28	4	10	10.8	0.7	0.2

Table 5.8 The collected data from the confirmation experiment

Refer to table 5.8, the average ink thickness after improvement is thinner than the average ink thickness before improvement 3 microns shown in figure 5.9.

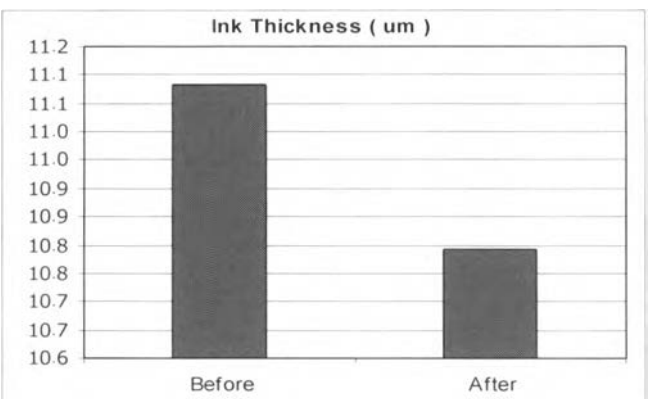

Figure 5.9 The ink thickness improvement

As a result, the printing speed was increased from 2.5 m/s to 4.0 m/s. This translates into an 60% increase process capability without effect to the whole quality of product and an annual saving of 72,244 baht.

Therefore, the suitable condition from the experiment can implement for controlling the image printing defects in image printing process.